Formation and Renewal of Human Resources as Components of the Evolution of the Domestic Innovations

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Abstract : In modern economy, accumulation and modernization of human capital is of great importance to sustain the national innovation system. Although human capital is recognized as important to both optimize human capital to match labour market needs and to create a competitive knowledge based economy, challenges still persist. This research investigates how human capital is accumulated and modernized in innovation driven environments such as those within scientific institution, technopolis, technology park, or business incubators. The research proceeds through a systematic approach based on the methods of scientific abstraction, system analysis, and modeling to evaluate the coupling between human capital development and investment-based driven innovation. The results emphasize that scientific institutions are fundamental sources of scientific knowledge and technological development, for the constitution of technopolises. They then become hubs to integrate innovations into production and promote technology parks offering the needed infrastructure for commercialization. Startups are further fomented by business incubators, as well as upgraded worker competency. The study puts strong emphasis on the need of government policies for stimulating the investment in education, training, and research to modernize the human capital effectively. The main thesis argues that for a viable national innovation ecosystem, there is an inevitable need for boosting collaboration between scientific institutions, businesses, and public authorities.

Keywords: human capital, innovation system, scientific institutions, startups, economic growth.

Introduction

The development of human capital has gradually turned into a key factor of the economic growth and national competitiveness in modern conditions. The insufficiently explored problem of effective accumulation and modernization of human capital calls for finding mechanisms of its development most effective. We consider human capital to be an asset for which the investment of resources is an ongoing issue in economic research. Although it is recognized as quite important, the process of knowledge formation, skills or competencies and the most important factors of renewal and effective application of this knowledge, skills and competencies are still an object of debates [1]. Starting from the rapid pace of scientific and technological progress, digitalization, demographic changes, and increased global competition, human capital management manifests the need for an organised approach.

If this resource is not modernized enough, this will lead to growing difference between the needs of the labor market and labor qualifications, which will entail lower productivity and slower economic growth. Insofar as state policies can create favourable climate for accumulation of human capital and modernization, this is of undue importance. Raising education, vocational training and research standards, as well as improving the social infrastructure of the country, are basic to raising the level of workforce competencies and its adaptability to the changes taking place in the labor market [2]. For this reason, the evaluation of human capital accumulation and modernization mechanisms is crucial in developing a national innovation system that efficiently relates to and exploits the social and physical environment of a country. That entails much more than reviewing development in school and job training programs and plans to develop a human resource development framework conducive to flexibility.

Literature review

There has been a considerable number of scholars who have studied innovation ecosystems, human capital development, as well as investment mechanisms of Special Economic Zones (SEZs).

Chernyavska [3] considers the method of technopolises as a significant steamer of technological progress, and as a motivation for its realization. Nevertheless, human capital accumulation is not the explicit focus of her study on the impact of human capital accumulation on the long-term sustainability of such innovation clusters. Further studies should explore how workforce competencies influence the effectiveness of technopolises.

Link and Scot [4] focus on research, science, and technology parks as tools for technology transfer. Their work provides valuable insights into innovation diffusion but does not fully address the role of business incubators in strengthening human capital within SEZs. Expanding the study to include the interaction between technology parks and startup ecosystems would enhance its relevance.

Musterd and Murie [5] discuss competitive cities, highlighting urban innovation clusters. While their work contributes to understanding regional innovation policies, it does not consider how SEZs integrate into national innovation systems through human capital modernization. Future research should focus on analyzing the impact of localized knowledge hubs on overall economic development, considering their role in technology transfer, the formation of competitive advantages, and the promotion of innovation processes.

Prodius et al. [6] explore the relation between corporate strategies and entrepreneurial paradigms and global business integration. Their findings imply that the way investment strategies should be aligned with the innovation policies has not been addressed as the SEZs are viewed as a platform for the development of human capital.

Reichert [7] considers the changing role of universities in regional innovation systems, with an emphasis on providing human capital for innovation through education. The author, however, does not integrate students R&D component in his reasoning.

The study by Lu et al. [8] examines the impact of SEZs on human capital investment by taking use of China's vast number and diverse range of SEZs. According to the results of study, SEZs considerably raise the local high school enrollment rate; however, the effect differs depending on the kind of zone: export-led zones discourage education, whereas technology-oriented zones promote it. Thus, the authors focus mainly on purely education scale implications, rather than human capital development.

Zianko and Nechyporenko [9] assess the current status of technology parks in Ukraine, identifying challenges in infrastructure and investment attraction. However, they do not provide a detailed examination of workforce skill gaps and training mechanisms. Addressing this would provide a clearer picture of how technology parks contribute to national Ukrainian innovation system development.

Thus, while existing studies cover various aspects of SEZs, technology parks, and innovation policies, a comprehensive assessment of how human capital accumulation and modernization fuel SEZ growth remains underexplored. Future research should focus on integrating human capital policies into innovation infrastructure development to ensure sustainable economic transformation.

The aim of the article is to study the processes of human capital accumulation and modernization as key stages in the national innovation system development and to justify mechanisms for their effective management within the Ukrainian context.

Method

The study employs a systematic approach to analyze human capital accumulation and modernization within the national innovation system. The research integrates three key methods: scientific abstraction – used to generalize theoretical concepts, focusing on essential factors that link human capital development to innovation; system analysis – for examining scientific institutions, technopolises, technology parks, and business incubators as interconnected elements, identifying their roles in fostering an innovation-driven economy; modeling – to model simulation of investment impacts on human capital development, assessing policy outcomes and optimizing strategies for sustainable economic growth. By combining these methods, the study provides insights into enhancing synergy between education, business, and government institutions to strengthen the national innovation system.

Result and Discussion

It is generally known that the effectiveness of any company's operations directly depends on the level of competence of its employees at all management levels, highlighting the importance of human capital. Its development and optimization are usually the responsibility of the Human Resources (HR) Department, which handles recruitment, training, workforce planning, as well as the analysis and evaluation of labor efficiency. The concept of human capital is based on the understanding that the workforce is heterogeneous in terms of knowledge, skills, and experience. However, employers can improve the quality of this capital by investing in education, professional training, and the development of employee competencies, as well as talent management. Such investments hold significant economic value not only for individual enterprises but also for the national economy as a whole. In this context, the process of human capital modernization should be viewed as a set of measures, strategies, and tools aimed at its effective renewal and enhancement, within a systemic and even eco-system paradigm. It is important to note that the nature of these processes can vary significantly depending on the country- and industry-specific context and the overall innovation policy of the country.

In this context, it should be also noted that the activities of public authorities are focused on enhancing the competitiveness of regional labor markets, which is an important stage in the development of the national innovation system (Table 1).

Table 1. Stages of Human Capital Accumulation and Modernization in the Development of the National Innovation System

Stage	Stage Name	Managing Entity	Goal	Tasks
1	Development of Strategic Forecasts for the Regional Labor Market Structure	Public authorities	Identifying labor market needs	Forecasting labor market demand and supply
				Allocating budget-funded places in educational institutions
2	Development of Training and Professional Preparation Recommendations	Enterprises, educational institutions	Enhancing the efficiency of education-business interaction	Improving educational standards
				Strengthening cooperation
3	Formation of General Human Capital	Educational institutions, healthcare institutions, family centers	Developing general knowledge, skills, and competencies	Accumulating educational potential
				Preparing specialists according to modern requirements
4	Modernization of General and Specialized Human Capital	Employment services, enterprises, educational institutions, family centers	Professional growth and implementation of knowledge and skills	Modernizing human capital
				Retraining personnel
				Creating and maintaining jobs
				Supporting the population's standard of living

Source: developed by the author based on [10]

One of the primary stages of human capital management is the development of strategic forecasts regarding the structure of the labor market at the regional level, which includes determining the demand for qualified specialists, the level of whose qualifications depends on the education they have received. Public authorities responsible for implementing state policies in specific areas should ensure access to reliable data on the forecasted demand and supply in the labor market. In this context, local government administrations are responsible for distributing authority among relevant sectoral departments to collect and analyze information about the number of job openings in enterprises within specific sectors of economic activities. It is also important to obtain data on the number of newly hired and dismissed employees (including their specialties), as well as information on their wages and working conditions, which relevant institutions should provide upon requests from public authorities for accurate calculation of forecasted indicators. In recent decades, integrated reporting of companies also became a source for understanding state-of-the-art in human capital development [11]. At the same time, authorities responsible for managing education make decisions about the allocation of budget places in educational institutions based on labor market forecasts provided by relevant public

authorities, as well as develop vectors for cooperation with educational institutions and supporting them [12]. These indicators reflect the needs of the population in the regions for education and training of specialists that meet the requirements of specific sectors of economic activity. A stimulating tool in this process is the education quality assurance system, which contributes to the formation of highly qualified professionals ready to work in their acquired specialties.

At the next stage of the development of the national innovation system, educational institutions should develop proposals and recommendations regarding training and the level of professional preparation of specialists, which contribute to increasing their competitiveness in the labor market, as well as their ability to attract potential consumers of goods and service recipients. This helps strengthen the responsibility of specialists for fulfilling their duties, producing goods, and providing services within their scope of authority. The best realization of these processes is possible within triple helix [13]. It is clear that the level of professional competence directly affects the effectiveness of specialists in performing their tasks, which, in turn, shapes the demand for labor. One of the important aspects is also considering the stimulation of personnel work and career growth opportunities, which largely depend on the effective interaction between businesses, institutions, organizations, and educational institutions. To achieve this goal, educational institutions should implement tasks related to developing educational standards for professional development programs, retraining, specialization, and internships, taking into account the needs of enterprises, in particular, within the cooperation through corporate universities. This will promote deeper interaction with educational institutions, which, in turn, will enhance the effectiveness of this cooperation. As noted by Tereshchenko [10], the goal of every organization in a given sector (including educational institutions) is not only to generate profit (for the private sector) or achieve budget balance (for the public sector), but also to attract qualified personnel – the most valuable asset in the knowledge economy. The quality of this personnel's work will determine not only the prospects in the goods and services market but also in the labor market.

By utilizing the results obtained at previous stages of development, educational institutions contribute to creating conditions for training specialists who meet the requirements of both job responsibilities and other types of activities, thus shaping elements of human capital possessing both hard and soft skills, adherent to life-long learning and continuous self-development, able to cope with challenges of VUCA and BANI world [14]. In today's conditions, most enterprises, institutions, and organizations require employees to be able to apply their acquired knowledge and practical skills at the level of ready specialists. This raises questions about the effectiveness of employing newly graduated individuals who need additional support in orienting themselves towards further professional development. To achieve these objectives, both educational institutions and healthcare institutions, collaborating with educational establishments, need to be involved already at the earliest, preschool, stages of education, particularly to assess the general health of future specialists and citizens, based on which medical assessments, including mental health assessments, are provided for further education. This approach implies the individualization of the learning process since its very beginning, customizing it according to personal specific features of every individual, which further contributes to enhancing labor productivity and the effectiveness of participants' future professional activities. It is also advisable to involve informal institutions, family centers, which help parents understand the peculiarities of raising children as individuals, considering their natural abilities and tendencies towards professional development in certain fields. This requires significant investments in the development of the education system and professional growth of individuals at the nanolevel, shaping individual development as a personality and stimulating the accumulation of human capital at the level of specific companies. Ultimately, a sufficient level of human capital accumulation within individual institutions contributes to enhancing the competitiveness of the sector at the mesolevel and, consequently, the modernization of human capital at the national level. Unfortunately, this nano-level and earlier stages of person' development, as a rule, as not included in triple helix paradigm. To some extent, there are attempts to solve this issue within penta helix, but due to misbalancing stakeholders' interests such initiatives rarely become effective and stable in the long term.

The final stage of the modernization of general human capital within the framework of the national innovation system involves the implementation of measures to accumulate specialized human capital. This is the result of investments in acquiring specialized knowledge, developing skills, and forming competencies necessary for performing important tasks in accordance with educational level and job responsibilities under specific working conditions. Such an approach stimulates professional growth among specialists, fostering the development of their inherent and acquired abilities in professional activities within the context of the national innovation system. The modernization of general human capital serves as the foundation for accumulating specialized human capital, which in turn contributes to further development and utilization of accumulated knowledge, skills, and competencies by personnel. This process is crucial for the functioning and development of innovation infrastructure, as the level of investment in human capital reflects

the results of company modernization and the availability of necessary resources, which in turn contributes to the creation of new jobs and the preservation of existing ones. As a result, personnel have the opportunity to work in comfortable conditions that promote health, while utilizing available resources to perform tasks aimed at enhancing the efficiency of managerial activities within public-administrative relations. Continued professional development of specialists through retraining, specialization programs, and talent management allows them to increase their professionalism, which, in turn, contributes to increased labor productivity. In this context, employment services should integrate their authority with educational institutions that prepare personnel, with the goal of optimizing employment procedures and filling vacant positions through competitive selection and the appointment of successful candidates. This is facilitated, in particular, by digital platforms of talent marketplaces. Today, experts emphasize that the future of talent will be built on open talent ecosystems that operate on platforms and markets [15]. As part of this process, healthcare institutions should provide recommendations for assessing the overall health (including mental health) of candidates and create conditions for the effective performance of job duties, focusing on an individualized approach and the enhancement of professional competence. To ensure the sustainable development of society, it is important to involve informal institutions and family centers, which contribute to the development of individuals as personalities. These institutions help to shape an understanding of the role of individuals in positions as an important factor for the sustainable development of the state and society within the framework of the national innovation system.

Thus, as experience shows, the accumulation and modernization of human capital are important stages in the development of the national innovation system, which contribute to enhancing the innovation and investment capacity of regions. This level depends on the quality of research conducted on the external and internal environment of innovation entities by scientific institutions (Figure 1).

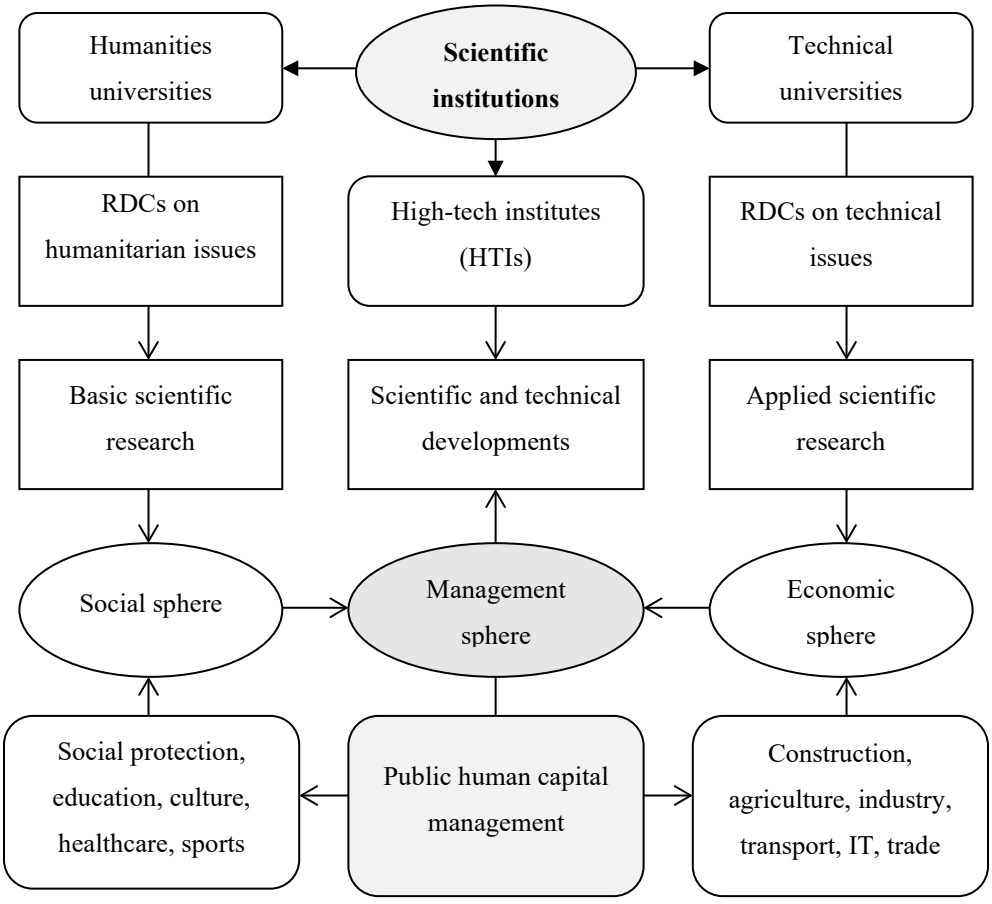

Figure 1. Managing Human Capital Accumulation and Modernization in Research Institutions

Source: developed by the author

As shown in Figure 1, scientific institutions include both humanities and technical universities, based on which research and development centers (RDCs) specializing in humanitarian and technical issues are operated. The RDCs focused on humanities conduct fundamental research, are studying the development of social sectors such as social protection, education, culture, healthcare, and sports. In contrast, the RDCs focused on technical issues conduct applied research related to materials and technologies necessary for construction, agricultural and industrial activities, as well as the production of vehicles and communication devices. Another category of scientific institutions is high-tech institutes (HTIs), which engage in scientific and technical development based on the results of fundamental and applied research conducted by RDCs. HTIs can act as intermediaries between public authorities and RDCs, receiving information for further development of new goods and services. The management sphere that arises as a result of public administration of human capital is crucial for the development of innovation and investment in the system of scientific institutions. Thus, the chains in the eco-system of national innovation potential are shaped.

The scientific institution' goal is to acquire new scientific knowledge, ensure scientific and technological progress, and contribute to the socio-economic and spiritual development of society. This requires high-quality training of scientific personnel, which contributes to the systematic accumulation and generalization of scientific results, the realization of creative potential, and the social protection of the scientific community. Moreover, one should bear in mind that, as Traitler et al. [16] rightly claim, innovation partnerships and the Sharing-is-Winning model reflect a paradigm change in the direction of speeding the co-development of sustainable innovation, with alignment of the whole value chain with consumer-centric innovations serving as one of its key components. It consists of three layers of typical cooperative development: universities, research institutions, and centres; start-ups and individual innovators; and a limited number of essential strategic suppliers. Reinventing R&D in an open innovation ecosystem and raising success rates in a competitive economy need considerable advances, both perceived and actual.

In Ukraine, scientific institutions operate at both the level of academic institutes (institutes of the National Academy of Sciences of Ukraine, universities, research parks) and private and corporate RDCs specializing in innovative developments in the IT sector. In recent decades, the number of research institutions has decreased due to economic difficulties and insufficient funding (Table 2).

Table 2. R&D Expenditure on Innovations from 2010 to 2023

Year	R&D Expenditure, mil UAH	Basic Scientific Research		Applied Scientific Research		Scientific and Technical (Experimental) Developments		Share of R&D Expenditure in GDP, %
		mil UAH	%	mil UAH	%	mil UAH	%	
2010	8107.1	2175.0	26.8	1589.4	19.6	4342.7	53.6	0.75
2011	8513.4	2200.8	25.9	1813.9	21.3	4498.7	52.8	0.65
2012	9419.9	2615.3	27.8	2023.2	21.5	4781.4	50.7	0.67
2013	10248.5	2698.2	26.3	2061.4	20.1	5488.9	53.6	0.70
2014	9487.5	2452.0	25.9	1882.7	19.8	5152.8	54.3	0.60
2015	11003.6	2460.2	22.4	1960.6	17.8	6582.8	59.8	0.55
2016	11530.7	2225.7	19.3	2561.2	22.2	6743.8	58.5	0.48
2017	13379.3	2924.5	21.9	3163.2	23.6	7291.6	54.5	0.45
2018	16773.7	3756.5	22.4	3568.3	21.3	9448.9	56.3	0.47
2019	17254.6	3740.4	21.7	3635.7	21.1	9878.5	57.2	0.43
2020	17022.4	4259.0	25.0	3971.4	23.3	8792.1	51.7	0.41
2021	20973.8	5163.7	24.6	4821.3	23.0	10988.8	52.4	0.38
2022	17117.8	4081.3	23.8	4827.6	28.2	8208.9	48.0	0.33
2023	21348.1	4424.4	20.7	6348.4	29.7	10575.3	49.6	0.33

Source: developed by the author based on [17]

Considering the economic instability in Ukraine, expenditure on R&D exhibits similar instability, caused by crisis phenomena that lead to a significant reduction in the corresponding expenses. While the volume of R&D expenditure significantly increased from 2010 to 2013 (from 8107.1 to 10248.5 mil UAH), in 2014, the figure decreased to 9487.5 mil UAH, after which it began to recover and reached 17254.6 mil UAH by the end of 2019.

However, the COVID-19 pandemic affected the economic situation, leading to a reduction in expenditure in 2020 to 17022.4 mil UAH. Considering the economic challenges related to the pandemic and the implementation of innovative online working methods in enterprises, research institutions were forced to increase expenditure on R&D, which amounted to 20973.8 mil UAH in 2021. However, in 2022, due to the full-scale war, R&D volumes significantly decreased, reducing the expenditure to 17,117.8 mil UAH. At the same time, the martial law prompted research institutions to allocate funds for conducting R&D, particularly in the field of medical and military technology for the subsequent production of products for medical and military needs, which led to a sharp increase in R&D expenditure to 21348.1 mil UAH by the end of 2023.

Regarding the activities of RDCs, technical research in Ukraine prevails over humanities research. The trends in the share of funding for fundamental scientific research from the total R&D expenditure during the analyzed period show moderate fluctuations, particularly from 2010 to 2014, when this share was 26.8 % and 25.9 %, respectively. However, after the temporary occupation of the Autonomous Republic of Crimea, Sevastopol, and parts of the Donetsk and Luhansk regions, this share decreased to 22.4 % by the end of 2015, despite a slight increase in spending to 2460.2 mil UAH compared to 2014 (2452.0 mil UAH). By the end of 2023, considering the full-scale war and the temporary occupation of some territories, the share of funding for fundamental research was 20.7 %, and the expenditure reached 4424.4 mil UAH, exceeding the 2015 level.

In contrast, the share of funding for applied scientific research showed a positive trend. The increase in this share to 29.7 % by the end of 2023, compared to 19.6 % in 2010, reflects a significant rise in spending on applied research, which amounted to 6348.4 mil UAH, compared to 1589.4 mil UAH in 2010.

Given the existing economic challenges and the development of the national innovation system, the situation in Ukraine highlights two important aspects. First, the country's high potential in overcoming the negative consequences of crisis situations through the quality execution of applied scientific research in technological sectors. Second, there is a noticeable weakness in the strategic human capital management, which is essential for conducting fundamental scientific research and planning strategic indicators, including issues related to the strategic planning of public-societal relations at national and international levels. Trends in changes in the share of funding for scientific and technical (experimental) developments carried out by Ukrainian HTIs are also important for understanding the effectiveness of human capital management. Between 2010 and 2021, moderate fluctuations in this indicator were observed (from 53.6 to 52.4 %), while the amount of expenditure increased from 4342.7 to 10988.8 mil UAH. However, in 2022, the share decreased to 48.0 %, and by the end of 2023, it slightly increased to 49.6 %, despite a noticeable increase in expenditure (to 10575.3 mil UAH) compared to 2022 (8208.9 mil UAH). This indicates the low effectiveness of human capital management in research institutions, which requires modernization and improvement to foster the national innovation system development.

Finally, the fluctuations in the share of R&D expenditure in the gross domestic product (GDP) during the analyzed period indicate the presence of negative trends. While in 2010 this share was 0.75 %, by the end of 2023, it decreased to 0.33 %, despite a significant increase in R&D expenditure volumes. As of early 2023, Ukraine has 158 scientific institutions and 43 enterprises of the research and production base within the National Academy of Sciences of Ukraine [18], the largest self-governing scientific institution. However, their activities are often limited due to unstable funding. Many universities have their own research divisions, but their infrastructure and resources significantly lag behind current international standards. Since the early 2000s, private RDCs have started to appear in Ukraine, mainly in the fields of information technology (IT), biotechnology, and engineering. Nevertheless, their number is rather limited due to high investment risks and shortage of financial resources for extension. The accumulation and modernization of the human capital is the crucial stage in the development of Ukraine's national innovation system in terms of overcoming existing constraints, obtaining a high level of the scientific and technological progress.

Research sector is not receiving the basic financing needed and even less basic incentives for investments in science neither by government funding nor by private investments. It causes highly qualified scientists to emigrate abroad and weakens the holding power of the country's science. Access to advanced technologies and the commercialization of scientific products are prevented by weak collaboration between science and business, lack of triple helix mechanisms and often purely declarative public-private partnership. Moreover, other challenges include the outdated material and technical infrastructure as well as bureaucratic barriers that hinder innovations implementation and deteriorate the

country's international competitiveness. These factors emphasize the need for an active development of human capital as successful stimulus for the improvements in the efficiency of the research and development.

A comprehensive approach should be taken to address these issues and improve the funding of scientific institutions, that is, the diversification of funding sources and increasing of the human capital management efficiency. First of all, there is the need to review the priorities in terms of public funding, namely to increase spending on scientific research, particularly in strategically important ones. Because of limited budgetary resources, the setting up of specialised funds to support long term scientific initiatives would be best. Secondly, the private sector should be encouraged to participate in the fund raising of science by the institution of tax incentives for the companies incurring the R&D expenditure; and the development of other public private partnership (PPP) arrangements. Here, best practices of other countries should be studied and benchmarked. In the Netherlands, a unique 'triple helix' paradigm allows the corporate sector, government, and academics to collaborate on novel ideas. For years, the Netherlands has been a European leader in innovation. The key is a highly efficient collaboration strategy known as the Dutch 'triple helix' concept. This plan provides a framework for forming relationships between the commercial sector, government, and academics. Each stakeholder plays an important role: knowledge institutions feed research and competence, the government provides favorable regulations, and corporations contribute commercial viability. Companies profit from getting access to world-class knowledge clusters, such as science and innovation parks, which contain R&D facilities, a large pool of people, and other industry leaders. Businesses assist to evaluate scientific information and foster entrepreneurship on university campuses, which benefits research institutes. Triple helix partnerships also allow the Dutch government to achieve larger policy objectives related to sustainability and economic growth. By carefully integrating these stakeholders, the Netherlands provides an open, collaborative environment in which businesses from many industries may develop creative solutions to global concerns. And it's not restricted to Dutch companies countless international enterprises integrate smoothly in the Netherlands and use the triple helix [19].

Science parks and innovation hubs will help in commercialization of research and attract the private investors. However, in compensation for the insufficient public funding, combined with the attraction of new resources and the exchange of experience with leading world scientific centers, active integration into the international grant programs, including the Horizon Europe [20], is needed.

Grant funding programs for young researchers and startups are crucial to retain talented scientists as to prevent "brain drain". This will create competitive working conditions, raise salary standards, and provide modern technical equipment for laboratories. Improving management processes in scientific institutions through the implementation of modern management models, such as Agile or Lean, will allow for more efficient use of available resources, reduce bureaucratic procedures, and quickly adapt to changes in the financial environment. This, in turn, will promote the creation of innovative science parks and enhance the effectiveness of human capital management within the context of developing the national innovation system.

The implementation of the proposed measures will allow Ukraine's science parks to unlock their potential as centers of innovation development, particularly in the form of technopolises, oriented towards the business community, where scientific developments are commercialized through startups and other business companies, contributing to the development of human capital.

The source of Göller Bölgesi Teknokent [21] interprets technopolises as associations of companies that use advanced or cutting-edge technologies or are focused on new technologies, typically within a single complex, utilizing the capabilities of scientific institutions or their surroundings. They work on transforming technological innovations into commercial products, methods, or services, which, in turn, contributes to the development of the region. In other words, a technopolis is a scientific-industrial complex created for the production of innovative products or the development of new science-intensive technologies through close cooperation with scientific institutions, where science, technology, and entrepreneurship are integrated, and there is interaction between academia, entrepreneurs, and government bodies at various levels. The most important feature of technopolises is their organization as a collection of science parks, where academic, economic, and social components are integrated.

In turn, technology parks (technoparks) are important innovation institutions that possess scientific, production, and human resource potential for the development and implementation of innovative products. As key elements of research and innovation ecosystems, they can combine the characteristics of both technopolises and scientific institutions, contributing to the accumulation and modernization of human capital within the framework of the national innovation system development (Figure 2).

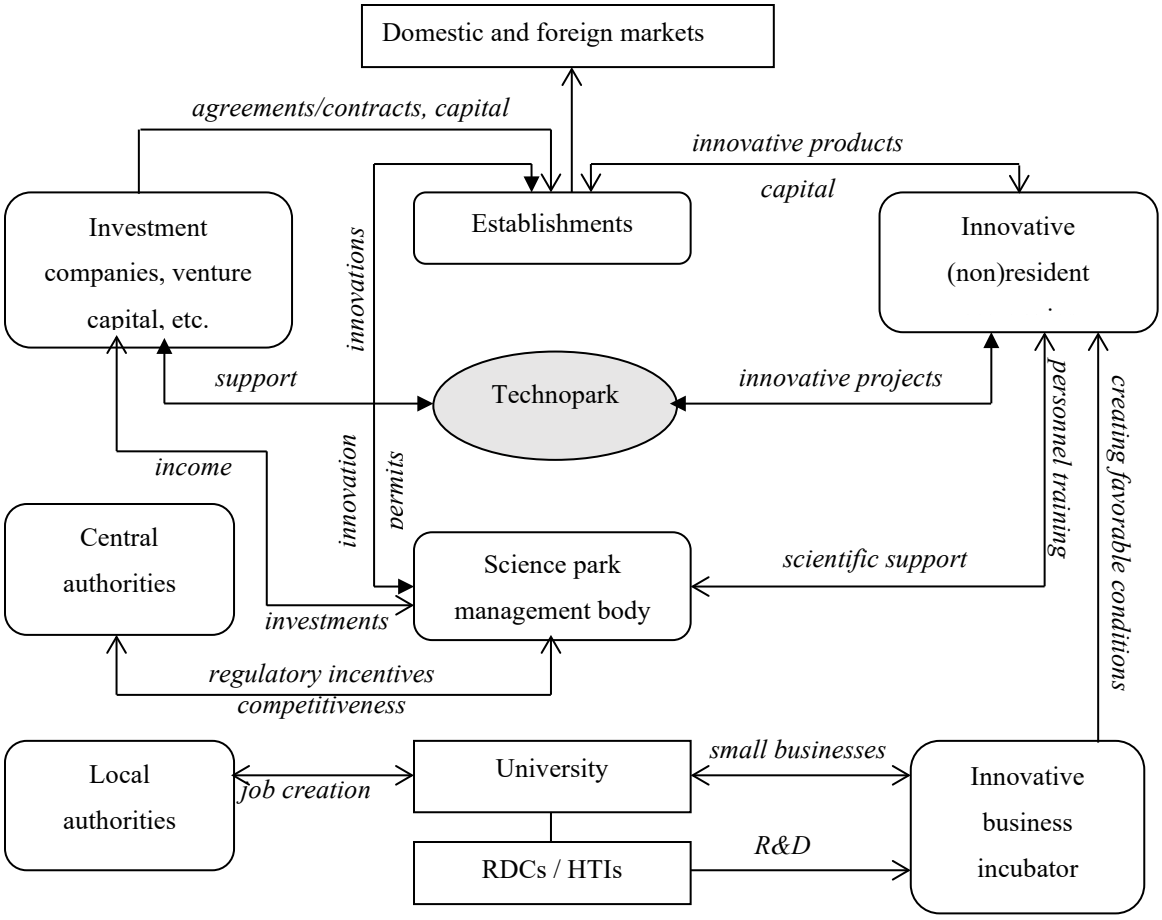

Figure 2. The Accumulation and Modernization of Human Capital in the System of Innovation Institutions
Source: developed by the author

As for information on Linked In [22] technopark contributes to the development of scientific and technological activities through significant investments in research, development, experimental work, and other efforts aimed at creating conditions for achieving success in science and technology. Investments can be attracted from investment companies, venture capital, and other funds, focusing on the development prospects of both national and international companies that generate new ideas for the development of innovative projects. This process contributes to the accumulation and modernization of human capital.

Such collaboration promotes long-term financial returns through the release of innovative products to domestic and international markets, which, in turn, stimulates the further development of priority sectors of the economy. Investment support for the science park through management bodies allows for the conduction of R&D within RDCs and HTIs. In BDC [23] is noted, that as a result of R&D activities, business incubators gain access to knowledge about production processes (know-how) in small enterprises, where personnel undergo training and skill enhancement at universities, particularly in generating new ideas for innovative projects. In this context, a business incubator creates a favorable environment for small innovative companies (startups), providing them with the necessary material and technical resources, as well as personnel, to achieve the company's innovation goals.

As stated by BDC [23], a business incubator as an innovation institute supports startups by providing services such as renting office space, leasing scientific and technical equipment, offering consulting on economic and legal matters, intellectual property protection, business plan and document preparation, as well as securing funding and conducting expertise. Young companies need access to networks, investors, mentors, and coworking spaces, which help them move beyond the initial phase of development and realize ideas for creating a Minimum Viable Product (MVP) and developing a real plan for launching this product on the market. If a startup is only in the process of developing an MVP or launching its own product, it may lose the opportunity to apply to a business incubator, as this process is more suited for companies that are in the stage of product promotion. The acceleration of this process is made possible by

providing young companies with access to logistical and technical resources, as well as shared office space. The duration of the incubation program can vary from a few months to several years, depending on the individual development pace of each company. Some business incubators operate as non-profit organizations, while others provide startup capital and support in exchange for equity in the companies. As interpreted in the Pharmaceutical Encyclopedia [24], the innovative activities of business incubators, aimed at supporting startups, are an important stage in the accumulation and modernization of human capital, as they allow companies to make their mark in the market and succeed in promoting innovative products.

Based of Sharjah Research [22]on LinkedIn, the management bodies of science parks provide scientific support for innovative projects developed by companies, which contributes to the training of highly qualified specialists. This, in turn, expands employment opportunities, allowing individuals to obtain interesting and well-paid jobs regardless of their place of residence. In this regard, central government authorities should continuously improve the regulatory framework governing innovation activities, particularly in terms of stimulating the work of scientific institutions that establish science parks. The activities of such parks promote the intensification of scientific cooperation at the local level, which positively impacts the development of the social sphere. This occurs through the implementation of infrastructure projects in regions with a high concentration of innovation-driven enterprises. The creation and support of such enterprises contribute to the accumulation and modernization of human capital by providing new jobs and attracting a significant number of specialists to high-tech sectors of the economy.

However, according to the definition of the Pharmaceutical Encyclopedia [25], the effective accumulation and modernization of human capital within the national innovation system require close cooperation between businesses and higher education institutions. This can be achieved through the formation of venture capital based on scientific institutions, involving high-tech companies, particularly in the IT sector, which facilitates the creation of joint innovation clusters and the utilization of economies of scale. Science parks are usually located outside city centers, as they require substantial land resources, ensuring the optimal use of infrastructure and available resource potential.

As stated by IASP [26], a technopark is an institution that concentrates human capital and is managed by specialized professionals whose primary goal is to enhance community well-being by fostering an innovation culture and strengthening the competitiveness of innovation-driven enterprises and scientific institutions. To achieve these objectives, a science park plays a key role in stimulating and managing the flow of knowledge and technology between scientific institutions, companies, and markets. It facilitates the creation and growth of innovative enterprises through incubation mechanisms and spin-offs (the separation of subsidiaries from parent companies) while also providing a wide range of value-added services. Additionally, technoparks provide the necessary infrastructure, including modern office spaces and high-tech equipment, which contribute to the effective accumulation and modernization of human capital.

The role of technoparks in the process of the national innovation system development extends beyond creating a favorable environment for small innovative companies; they also facilitate technology transfer and the commercialization of scientific developments [27]. The integration of office spaces, residential areas, and commercial infrastructure fosters the formation of an innovation cluster, enabling companies to benefit from economies of scale and cost optimization. Technoparks may fill up the gaps in the environment and infrastructure centered around technology.

Interreg Europe [28] emphasized that modern technoparks are not just usual business centers but rather the innovation hubs, which facilitate the development of human capital. By offering equal access to state of the art research equipment, technological resources, they enable small enterprises to launch innovative projects that were inaccessible to them, which can only be carried out by big corporates having enough funds to initiate these projects. This democratized technology culture gives room for any small business to effectively compete with the industry leaders, and thereby increasing the technological potential of the country.

The monitoring of the Info City Website [29] revealed that technoparks have a key role in moving research towards business activities associated with Innovation commercialization. As such, they function as platforms for the introduction of science-business collaboration and creation of new technology startups, as well as attracting investments into high-tech sectors of the economy. For that reason, the activities of these (public) institutions strengthen the competitiveness of the national innovation system, and enhance the development of a knowledge economy. Their mission goes far beyond merely providing office space and is focused on stimulating R&D. Investments in innovative projects not only provide opportunities for future breakthroughs capable of transforming industries, but also contribute to the development of the country's intellectual potential. The collaboration of

entrepreneurs, scientists, and investors, often in close proximity to scientific institutions, creates a unique environment for generating new ideas and their subsequent implementation.

In addition, as noted in the research work of Musterd and Murie [5], innovative projects in technoparks are inherently long-term, as a significant portion of investment capital is provided in the form of venture capital. This financing is aimed at supporting startups, business incubators, and clusters, which helps create high-tech enterprises. Investors, by funding these projects, may either receive substantial profits or incur financial losses. However, the risks in the technopark sector are usually lower compared to other areas of venture capital investment, such as industrial park development. Despite the importance of the latter for industrial growth, technoparks offer significant financial advantages by ensuring the accelerated accumulation of knowledge, the development of competencies, and the modernization of human capital, which is an integral part of the national innovation system.

As noted by Link and Scot [4], in SEZs, the responsibility of resources investment, mostly in infrastructure projects located in the areas of Special Economic Zone is left to private individuals with the support from a government as individual incentives mostly directed to non nationals. In this regard, participants in innovative projects of a technopark are not only subject to state economic incentives but get the opportunity to realize additional investment possibilities, which are provided by the government support programs. The mechanistic channels of performing this role in increasing human capital is important for the advancement of the national innovation system.

Human capital acts as a prime driver for the initiation and continued growth of SEZs as it is responsible for innovation–driven activities. However, for this resource to be able to effectively mobilize, there is need for a multifaceted approach with strategies like attracting investments, making this resource competitive, and blending this resource into the global economic situation. Such can be carried out through systematic planning, recruitment of highly qualified specialists, provision of an environment that will make technology to perform well.

The key for establishing and running a SEZ successfully is to define strategic focus which can be in sectors such as information technology, biotechnology, renewable energy, or advanced manufacturing. The first is about defining priority of investment areas, including fiscal incentives to supporting enterprises in conducting research and development as well as supporting startups by creating business incubators. These measures promote commercialisation of innovations and contribute to the long-term survival of SEZ.

The establishment of such a positive milieu which encourages professional growth is necessary to attract and develop human capacity to suit the needs of organizational growth that is making specialized education, vocational training centers, internship programs and exposure through experience accessible to young professionals, thanks to presence of RDC, HTI, laboratories and technoparks within SEZs that offer a basis for innovation activity. A good example would be the Astana Hub SEZ in Kazakhstan, which encourages IT start ups through developed technological infrastructure that includes educational programmes and networking opportunities with investors [30].

An accumulation of human capital in SEZs is for a critical part of broader technological process, thus enabling an improvement in nations' integration into the global technological area. Therefore, their competitive standing in the global markets strengthens as a result.

Introducing targeted policies for human capital accumulation is an important part of the development of stimulating innovative activity in national innovation system development. Some of such policies are tax incentives, direct subsidies for innovation driven projects, streamlined business registration procedures and reducing of administrative barriers. One example is Dubai Internet City SEZ in the UAE where companies receive corporate tax exemptions on a full ownership of their assets. Such incentives offer explanations to explaining why these IT firms were attracted into the SEZ and continue to play a role in developing the SEZ as a center for technological development [31].

To integrate SEZs into global markets, at this time it is important to develop a framework for the export of high-tech products, attract FDI and facilitate, globally, international collaboration. It is crucial to this process to achieve an efficient transfer of knowledge and technologies and thus achieve an improvement of the national innovation system. However, in this context, success of SEZs has depended on developing modern logistics infrastructure, strategic transport hubs and international trade corridors. These elements help to speed the adaptation of human capital to world technological standards and increase the commercialization of research driven innovations. The KAUST Innovation Hub SEZ in Shenzhen [32] is a notable example of SEZs contributing to economic growth by having been positioned strategically, within global value chains, with advanced port infrastructure and by being able to attract multinational corporations (MNCs) with high end technological capabilities in the region.

These stages contribute to the effective accumulation and modernization of human capital, which is a critical component of the national innovation system development, while also helping to create conditions for its integration into global economic processes (Figure 3).

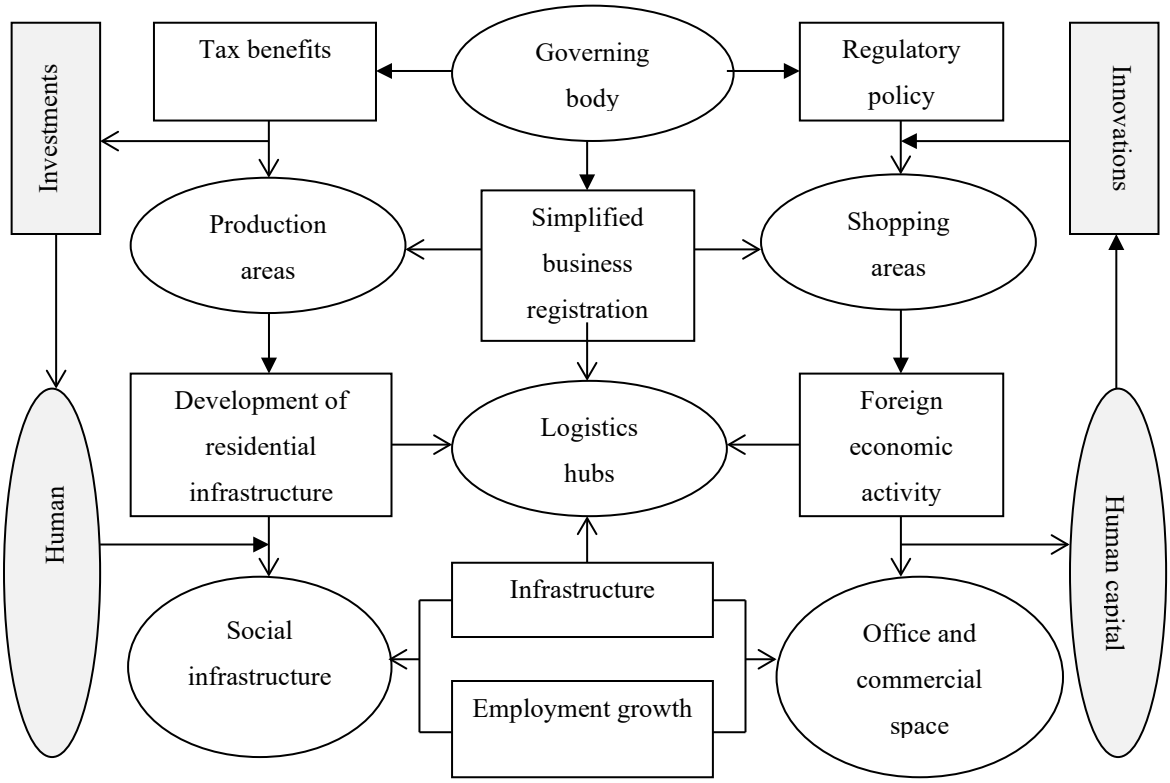

Figure 3. The Structure of SEZs in the Process of Accumulation and Modernization of Human Capital
Source: developed by the author

One of the key components of the process of accumulation and modernization of human capital is tax incentives, which reduce the financial burden on businesses, promoting investments in production, innovation, and business expansion.

The development of industrial zones and the enhancement of product competitiveness are directly influenced by the efficiency of SEZs. However, reduced tax revenues may pose financial challenges, necessitating the implementation of compensatory measures. Attracting external investors and efficiently managing resources as regards budgeting are among these measures. SEZ governing bodies are responsible for, among other things, the formulation of the tax policies and the regulatory conditions for business operations in frames of a stable business operation within the broader national innovative system.

It helps create a conducive environment for human capital accumulation, modernization by means of streamlined business registration processes, regulatory reforms, and liberalization of foreign economic activities, contributing to capital mobility, attract investments, the establishment of new enterprises, and the strength of SEZs and national economic competitiveness. However, quality control and safety of products, which are enforced through customs policies, trade regulations and other administrative measures, are necessary for deregulation.

The development of SEZs is, in fact, linked to the national innovation system through their infrastructure role in the national development. Particularly transportation networks, communication systems, energy supply, significantly reduce logistics costs, improve market accessibility for SEZs and integrate them into the global production teams. Infrastructure development increases the attractiveness of investment, improves the efficiency of logistics hubs, stimulates the work of the production zones. However, underdevelopment of infrastructure can impede the human capital modernization in SEZs, which should be assisted both with public and private sector funds.

The development of social infrastructure is a major factor of modernization of human capital, referring to residential complexes, educational institutions and healthcare facilities. Such advancement of this infrastructure encourages the attraction of the human capital through the provision of attractive living and working conditions for specialists involved in the activity of innovation. Employment growth brings economic development, but it also places a greater burden on the social sector, thus there should be enough financial support from the state or private investors.

The accumulation and the modernization of human capital in SEZs is very important in the field of national innovation system. Targeted investments help in job creation, implementation of targeted educational programs and upgrading skills of the workforce leading to improving labour productivity and eventual sustainable economic growth. Technology progress is stimulated by innovations, knowledge adaptation is facilitated, and career potential of the work force is improved. SEZ, in fact, is a closed system of capitalization and upgrading of human capital, in which investments give rise to the material support to education and professional training, innovations improve the quality and efficiency of human resources, allowing for stable growth of the economy.

Considering the above, it is worth noting that scientific institutions are the foundational elements for the development of innovations, as they create knowledge and technologies that serve as the basis for implementing innovations in production processes. They directly influence the development of technopolises by providing them with scientific research and developments, which are crucial for the commercialization of new technologies. Within the SEZs, scientific institutions help to create innovation clusters, where scientific achievements can be effectively utilized for business development [33]. To improve the situation in Ukraine, it is necessary to increase funding for scientific institutions, enhance the infrastructure for research, and strengthen collaboration with industry to ensure the practical application of research developments.

Technopolises serve an important role in helping bring science to practice and industrial application, and growing the business. They provide as innovation centers for the application of research findings and technological development. Technopolises within SEZs are strategic platforms where the process of innovation becomes integrated into the economic processes, requiring a highly skilled workforce to launch the current frontiers [3]. For the coordinated development of technopolises in Ukraine, all of the above must be done. These measures will not only raise the level of technological progress but also increase the desire for qualified specialists who would constantly modernize the human capital.

Technoparks as an integral part of SEZs' innovation ecosystem offer greatly required infrastructure for development of small and medium sized innovative enterprises. The important role they play as key facilitators of the commercialization of scientific discovery is that they offer startups opportunities for investment and business growth [9]. For technoparks in Ukraine to be maximally effective, it is necessary to connect them with scientific institutes and technopolises well, so that the advanced research development can be efficiently used. Furthermore, state support needs to be made stronger by targeted funding, tax incentives, and infrastructure development to allow for a dynamical and sustainable environment for an innovative space.

Business incubators are incubating entities that facilitate development of startup by providing the commercialization of innovative ideas. Prodius et al. [6] offer a variety of resources, such as financial assistance, expertise consultations, and structure models. In order to make business incubators more effective in SEZ of Ukraine, it is necessary to create a strong linkage with technoparks and technopolises. This integration will help the startups to use and benefit from the newest scientific advancement, the recent technology and work with the highly qualified persons. Improving the expertise in incubator personnel through specialized training programs in business strategy and technological innovation will also help to improve the efficiency and sustainability of the whole innovation ecosystem.

Conclusions

For the realization of innovation institutions in SEZs, effective accumulation and modernization of human capital in Ukraine is of primary importance. The operation and support of the core of the national innovation tissue (scientific institutions) necessitates really huge improvements in this process. The key focus here is to increase investment in R&D, secure sustainable funding for scientists organizations and modernise research infrastructure that would make scientific research more efficient and applied. Finally, furthering these collaborations between scientific institutions, businesses and government agencies is necessary to facilitate the engineering implementation of the research results in industry and entrepreneurship.

It is also important to create an integrated ecosystem of innovation or technopolis, or technopark or business incubator that works together to accelerate the technological progress and knowledge, but also to spread them. A PPP framework

and triple/penta helix paradigm that works can stimulate investment in innovative solutions to a transition from research to the commercialization.

Yet another important reason for modernization is the synchronization of the education system with the changing demands of innovation driven labor market. The development of targeted training programs for researchers, engineers, business leaders, and entrepreneurs is vital for cultivating a workforce capable of sustaining technological and economic growth.

In summary, the long-term competitiveness and resilience of Ukraine's national innovation system depend on the strategic accumulation and modernization of human capital within SEZs. By reinforcing cooperation between key innovation actors and creating a favorable environment for R&D, Ukraine can establish a sustainable and dynamic innovation-driven economy.

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