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THE ROLE OF UNIVERSITIES IN THE NATIONAL INNOVATION SYSTEM

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Abstract. The intensification of innovations required system approach, including at the macro level, which resulted in creation of national innovation systems (NIS). Such systems are designed to support and ensure innovation processes, including creation of favorable conditions for interaction of their different actors (various kinds of business; universities; scientific institutions; state). Each of the actors performs its own role in NIS, which contributes to the total innovation productivity. *Methodology*. Universities playing a specific role in NIS are an integral subject of innovative activity. Despite considerable attention to this problematics, this role is disclosed in a fragmented manner. Therefore, the research is focused on clarification of theoretical and methodological background to study of the role of universities in NIS, justification of the evolution of universities and definition of their functions in the NIS structure, specification of the key aspects of the disclosure of this role implementation. *Results*. This paper highlights the increasing importance of education in innovation processes and changed requirements to it, which causes respective changes in curricula, organizational models and approaches to external cooperation with science and business. In this context, the paper discloses the key aspects of interaction between universities and entrepreneurial sector, as well as evolution of universities by a number of features (dominant functions of science; universities as knowledge providers; universities as providers of high-skilled employees; universities as mobilizers of entrepreneurs). The major contradictions of the concept of entrepreneurial university are highlighted. *Practical implications*. The paper describes the key functions of universities in NIS, including education, R&D, development and promotion of innovations. It is suggested considering the role of universities in NIS within the framework of six key aspects: integrators of ecosystem for innovations; providers of innovations for economy; platform for cooperation; concentrators of resources needed for innovations; mechanism for knowledge transfer and source of skills; pillars of the advanced science and providers of new knowledge. In this context, the emphasis is laid on the need to develop resource and infrastructural potential of universities as well as innovation capabilities. *Value/originality*. When summarzing the functions of universities, it is suggested taking into consideration the impact of university activities on the local economic development (regional, urban economy), and considering their role in interaction with international environment. A number of practical recommendations to improve the efficiency of educational and innovative activities in NIS are identified. This will be a basis for future researches.

Key words: national innovation system, universities, innovative entrepreneurship, ecosystem.

JEL Classification: I20, I23, O30

1. Introduction

An innovative model of economy based on the rapid development and implementation of innovations is a today's dominant paradigm of economic development. This model is characterized by the predominance of the innovation-based competition and launch of the large-scale innovation processes, being continuously reproduced and routinized. In this context, the modern economy needed a system approach to intensify the innovative activities, which was evident in creation and improvement of the innovative systems. The development of the concept of such systems started from the definition of national innovation system (NIS). This macro-level system is the key one in terms of ensuring the innovative activities within national boundaries, and it combines regional, sectoral, technological and partially corporate innovative systems.

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Undoubtedly, a human intelligence is the primary basis for creation of innovations. Therefore, a human and his/her intellectual activities are the key focus of support in the context of NIS. In recent years, there has been marked a strong global trend in the world, which consists in creation of favorable ecosystems (eco-environments) for development and productive intellectual (creative) human activities. This trend sets new areas for improvement of NIS. Naturally, the role of the education sector has moved to the forefront in the NIS's functional structure and economy of economy. This raises the theoretical problem and a number of scientific-practical problems related to explanation and the full implementation of functions (taking into account their extension and update) in NIS.

The basis of education sector, being traditionally responsible for development of human potential, consists of universities, which combine scientific researches, creation and development of innovations. Global experience demonstrates that universities play a varied and often pivotal role in NIS, as well as in creation and development of human potential, R&D and development of innovations. Universities more and more penetrate into the innovative sector, generating entrepreneurial projects and supporting the small innovative business, which often grows from the academic environment. Today, there is a need to bridge the gaps between the established education system and technological changes. It requires extension of educational functions and, therefore, a new understanding of universities and all aspects of their activities within NIS.

It is a critical task for science and practice to carry out theoretical study of the role of universities in NIS. It is necessary in terms of government support provided to activities of universities, creation of the new effective scientific, educational and innovative structures based on universities as well as further full integration of academic science and innovative business. It corresponds to the understanding of knowledge economy with its specific structure and new prioritization of resource growth, where the intelligence and competences come to the forefront.

2. Literature review and investigated parts of general matters defining

The relevance of the role of universities in the NIS, being considered in this paper, is evidenced from the scientific researches. First of all, it should be said about the stiffer innovation-based competition and race between education and technology (Goldin, Katz, 2010). Against this background, education plays a critical role in the global knowledge economy and innovative systems (Marginson, 2010; Weber, 2011). By its relevance, education becomes the key factor for development of knowledge economy in the global landscape (Polyakov, Bilozubenko, Korneyev, Shevchenko, 2019). It becomes a basis for new practical approaches to NIS management (Khanin, Shevchenko, Bilozubenko, Korneyev, 2019). At the same time, the emphasis should be laid on the innovative education and its impact on the development and innovative capacity of the enterprises of High-Tech Industries (Huang, 2018). Bearing that in mind, the education sector should be considered as an integral part of the structure of innovative macro- (NIS) and meso-level (regional, sectoral, technological) systems that corresponds to the gradual evolution of the modern concept of system approach to innovations. S. Radosevic and M. Petraite (2006) emphasize the importance of the broad and varied role of education in NIS, particularly in the countries where such NIS is being developed.

This approach correlates with the current widespread "Triple helix" model, M. Rangaa and H. Etzkowitz (2011) represent the triple helix as the conceptual and analytical construction that describes the specific features of interaction between universities, industry and government in the innovative system (later they identified that the fourth helix is the civil society, and further the fifth one is the natural environment). The role of the higher education in NIS is considered in more details in the concept of "Knowledge triangle", which represents a system approach to relationships between research (generation of knowledge), education (dissemination of knowledge) and innovations (transformation and use of knowledge) (M. Unger и W. Polt, 2017). The knowledge triangle characterizes the relationship of such entities as scientific institutions, educational institutions (universities) and private companies, which creates a new perspective on the functional structure of NIS and the processes that take place therein (Lassnigg, Hartl, Unger, Schwarzenbacher, 2017). "Triple helix" and "Knowledge triangle" models draw attention to the role of different entities that, in fact, provides the functionality of NIS. Universities, the role of which is apparent along with large companies, small and medium-sized business, government and scientific institutions represent one of the most critical entities. In accordance with a modern concept, the roles of every entity should be harmonized.

In recent years, the attention to the role of universities in economy has increased (Deiaco, Hughes, Mckelvey, 2012; Valero, Van Reenen, 2016). The innovative and entrepreneurial potential of universities is being taken into consideration more and more (Kochetkov, Larionova, Vukovic, 2017). Therefore, more and more attention is paid to the role of universities in NIS that is represented in the papers of S. Datta, M. Saad, D. Sarpong (2019); T. Bedford, Y. Kinnaird, R. Migueis, E. Paolucci, B. Wijlands, A. Vos (2018); J. Katz, R. Spence (2008); A. Singh, P.-K. Wong, Y.-P. Ho (2015). This is evident by the concepts of academic entrepreneurship (M. De Silva, 2014), entrepreneurial university (Etzkowitz, Germain-Alamartine, Keel, Kumar, Nelson Smith, Albats, 2019), research university (Altbach, 2013), and innovative university (Christensen, Eyring, 2011).

The performed analysis has covered far from all researches that prove the critical role of universities in NIS. However, despite a significant attention to this problematics, the practice requires clarification of its role for improvement of institutions, organization structures and government policy in the sphere of innovations. So far there are no holistic approaches to conceptualization of the role of universities at the level of cities, regions and sectors, which block the improvement of methods and techniques for managing the university activities in NIS in conditions of knowledge economy.

3. Theoretical and empirical base

The research objective covers the following tasks: 1) clarification of the theoretical and methodological background to study of the role of universities in NIS; 2) justification of the evolution of universities and definition of their functions in the NIS structure; 3) specification of the role of universities in the innovative development of cities, regions and sectors.

The theoretical and methodological background to study of the role of universities in NIS, apart from traditional economic theories of mainstream and institutionalism, is based on the concepts of innovative systems and knowledge economy as well as a number of special models which define modern approaches to organization of NIS. The concept of innovative systems is quite well developed today and encompasses, apart from NIS, the regional, sectoral, technological and corporate systems. The concept is not just used as a theory, but it also became a real analytical and practical tool for organisation and support of innovative activities. The concept of knowledge economy clarifies a new specifics of the economic structure, intellectualization processes, new priorities in the economic growth resources. This concept is primarily focused on the human capital, which prioritizes not only science and innovative business, but also education. These sectors functionaly integrate within NIS, where the processes of knowledge generation, dissemination and usage take place. When highlighting the models which define modern approaches to organization of NIS, let us focus on four major ones: Triple Helix Model, Quadruple Helix Model (the role of the society is considered as the final user of innovations), Knowledge Triangle, Smart Specialisation (combination of industrial, education and innovation policy; creation of platforms for interaction between business, government structures and knowledge institutions) (Rangaa, Etzkowitz, 2013; Unger, Polt, 2017; Carayannis, Grigoroudis, 2016). These models are based on the understanding of the more important role of university in NIS, need to harness their full potential in knowledge economy, which implies change of the function and components, possible hybridization (for example, like in case of entrepreneurial universities). Taking into account the expansion of the ecosystem paradigm in support of innovations, probably, the new institutional, social and information formats of university activities are needed.

The empirical framework for the research is represented by the statistics of Human Development Index, materials of the world's leading universities, and international ratings of the most innovative universities (for example, Reuters Top 100, Reuters Europe), global rankings of universities (QS World University Rankings, World University Rankings, etc.). The data of the world's leading universities corroborates their huge innovative potential (Table 1).

The strategy of the world's leading universities proves an increase of their activities at the research and innovative arena. These universities fund and conduct original researches, create efficient technologies and stimulate local and global economy, acting as the players of the global knowledge market. The trend towards creation of special ecosystems for innovations based on universities is also corroborated (for example, White City Incubator in Imperial College London or Pennovation Works, created by University of Pennsylvania).

Table 1
Data on the world's TOP 10 universities

	R&D Expense, million USD	Academic personnel (faculty), persons	Number of patent applications
Massachusetts Institute of Technology	952.017	2977	425
Stanford University	1.110	4478	150
Harvard University	1123	4512	274
California Institute of Technology	400.312	1022	229
Oxford University	758.621	6436	188
University of Cambridge	687.619	5755	258
Swiss Federal Institute of Technology Zurich	329.26	2621	90
Imperial College London	472.91	3825	125
The University of Chicago	433.328	2538	135
London's Global University	602.338	6146	95

Compiled by the author based on the data of QS Quacquarelli Symonds Limited; National Science Foundation (the USA); Higher Education Statistics Agency; JŪSTIA Patents; Massachusetts Institute of Technology; Stanford University; Harvard's Office of Technology Development; California Institute of Technology (Caltech); Oxford University; University of Cambridge; Swiss Federal Institute of Technology Zurich; Imperial College London; University of Chicago; London's Global University.

4. General explanations

Scientific researches and education of specialists is a beginning of any innovation process. Therefore, science and education are the productive forces of the innovation-based economy. An increase in the level of science and education has become a critical prerequisite for the fourth evolution from the agrarian economy to the industrial one and further to the postindustrial one (knowledge economy). There is a growing demand for science and education due to the increasing needs for new knowledge and specialists. Tectonic changes in the labor sphere naturally heighten the importance of education. A convergence of education with the sphere of innovations fundamentally changes the requirements to quality of education, which should become individualized, multidisciplinary, and comprehensive as well as focused on talents and unconventionality. A human should be educated in a fundamentally new way, encompassing the values, beliefs, worldview, creativity and other qualities. It is a great challenge for the existing education systems, which, as before, should play the leading role in facilitating the adaptation of workforce to technological transformations. It should also be noted that education is a critical prerequisite for the development of scientific potential and a part of the mechanism of the strategical management of scientific and technological development of the country. Education is particularly important for huge innovations. It enables making the creative destruction to be large-scale, to grow new institutions, to achieve cultural changes. Rapid technological, structural and social economic changes as well as high rates and range of emerging innovations necessitate continuous improvement of education system in the innovation economy. Therefore, natural conservatism and challenges facing the education require new approaches (curricula, models, units) to make it more flexible and relevant. The need to integrate with science as well as close relationship with business necessitates considering the education in the context of the whole NIS.

In modern NIS, the availability of three elements – science, education and business – is not enough; their close integration, harmonious development and balance are necessary. This trinity starts at the level of universities, which remain the most developed knowledge institution. Universities are the basic level where the processes of knowledge generation, accumulation, dissemination and use take place, and conditions for synergies of all components are created.

Modern universities take a new form. Within the framework of the interactive model that prevails today, in complex, they create the required environment (institutions, infrastructure, relationship) for innovative entrepreneurship and various social factors (human capital, culture) that makes them a basis for formation of innovation ecosystems. Thereby the universities are represented in different sectors (science, education and partially business) of knowledge economy and subsystems of NIS (subsystems of knowledge generation, dissemination and use). Universities are also represented as spatial and network centers where the resources, activities and knowledge are concentrated and communities are established, which make them a basis for building NIS. Moreover, universities act as location where innovations are being initiated and developed, encompassing the whole cycle including organization of R&D. At the same time, universities provide the innovation process with all required resources: human, financial, information, material and technical. In terms of resources, universities are: 1) place of concentration and reallocation of resources; 2) place of creation and involvement innovation sphere of new human and intellectual resources. All this makes the development of universities a focal point of the government innovation policy.

One of the major problems of education is to meet the requirements of the innovation economy and labor market in the context of rapid technological changes. In this respect, the considerable attention is paid to cooperation between universities and business (industry), which have common values and interests, and complementary assets. Universities and business have a variety of areas of cooperation, including R&D, staff training, obtaining of scientific and technical information and services from scientists.

The cooperation of universities and business encompasses multiple types of activities, which are provided by different models of interaction and integration. University-industry relations are being developed quite actively and in a variety of ways; the key mechanisms are: technological platforms, business incubators, research consortiums, etc. The initiatives in the sphere of innovation-driven production lead to emergence of a plethora of new areas of cooperation between universities and industry-specific business. Of course, there are a number of problems related to establishment of relationships and partnership. Sometimes it is difficult to harmonize the objectives and interests of research and entrepreneurial structures. However, a common vector towards integration of science and industry has no other alternative; business is interested in expanding opportunities for cooperation with scientists and gifted students as well as in assimilation of the advanced research findings. Sinergy requires overcoming the administrative barriers, improving the legal framework, planning and organizational bases.

In recent years, universities have significantly evolved, which also contributed to the development of the academic entrepreneurship (Table 2). In the course of evolution, a new type of university emerged. It plays the initiating, generating, organizing, streamlining and developing role in NIS, being more economically active, including in the global arena.

Today, it is believed that, despite maintaining the primary mission of education and development of the existing knowledge, universities should also be involved in the sphere of entrepreneurship. The entrepreneurial university combines the role of educational and scientific entities, expands their scopes by means of using knowledge turned into the entrepreneurial resources. Apart from transferring the knowledge and technologies to the entrepreneurial sectors, universities independently or in cooperation with business are engaged in development and promotion of innovations. Of course, the model of entrepreneurial university triggers certain changes, for example, it requires the higher level of autonomy and financial independence. Today, we have various national models that differ by management and funding systems (creation of entrepreneurial structures within university management and funding systems or strengthening of cooperation with private firms). The world continues to search for more harmonious models of such entrepreneurial organization. However, the transformation of university into entrepreneurial structure does not facilitate scientific productivity. Research and entrepreneurial activities are combined in favor of the latter that generates new threats. There is a conflict between scientific and commercial values; the capability of performing the primary functions by the university decreases due to focus on the market. Therefore, the issue of the relevance of building the entrepreneurial universities is still open. Nevertheless, we have to accept the necessity to use entrepreneurial management in certain cases and to develop internal business structures. All kinds of entrepreneurial activities being developed today can be embedded in the updated model of classic university as auxiliary functions, and generation of scientific knowledge and education of students continues to be the primary functions. Especially since the financial independence, which enables development with less government support, enhances self-sufficiency and scientific self-administration, and autonomy in the development strategy. Generally speaking, there is a need for such new approaches to organization of classic university activities that would include it into the entrepreneurial sector and, at the same time, would not be a reason for any defects of the existing entrepreneurial activities. Thus, it can be internal and external autonomous units that connect university with real economy, venture capital and startups.

The most important part explaining the role of universities in NIS is to designate their functions. At the primary level, universities combine the functions of science and education. Following their mission, universities perform a complex of functions in NIS, which are represented below:

1. Selection and education of high-skilled specialists within the framework of a certain professional structure. Within the framework of this function, universities transform new knowledge into relevant competencies and skills. There is created a special human capital, being not only empowered with knowledge and skills, but also with a holistic worldview, values and beliefs, which also creates the innovation capability. Innovation-based competition and technological changes necessitate development of new curricula and education models being closely linked to practice.

2. Accumulation of financial, social, intellectual, material and technical resources, which form the innovation capability. Universities have a specific management system and operate within the framework of a certain scientific-technical and educational policy, enabling not only concentration, but also use of resources, being focused on priority areas. Universities also develop the resources needed for R&D and innovations, and make a part of resources available for business.

3. Universities initiate R&D, conduct it and provide with resources, and create the required infrastructure. Thereby they generate new knowledge, which is further transferred either to business or to other organizations or it becomes a basis for their own innovative developments. Generation, accumulation and transfer of new knowledge are an integral part of university activities, by means of which they implement the process of education. University knowledge has its distinctive features by structure and use, and contains a great

Table 2
Evolution of the modern concept of university

Feature	University 1.0	University 2.0	University 3.0
Dominant functions of science	Educational, cultural	Cognitive, educational, practical	Cognitive, practical
Universities as knowledge providers	Providing with knowledge directly with firms, assistance in search, focus on theories	Generation of knowledge together with business, development of innovations, focus on technologies	Bringing together theory and practice, formation of epistemological communities
Universities as providers of high-skilled employees	Formation of professional identity, providing with basic knowledge and skills	Education of personnel capable of working on innovation projects	Providing access to the increasing amount of knowledge and to epistemological communities
Universities as mobilizers of entrepreneurs	By means of education, provision of assistance, transfer of technology	By means of cooperation, service rendering	By means of mutual dependence, cooperation, integration

deal of fundamental knowledge. The development of innovations requires inventions at the crossroads of different disciplines. Therefore, universities expand their scientific specialization and evolve into scientific centers. Being the owners of intellectual property, universities actively deal with commercialization of knowledge on the local, national and global markets.

4. Universities are becoming the basis for organization of innovation processes due to government orders, their own projects and cooperation with private companies. Owing to this and having their own knowledge resources, universities develop their innovation potential and capacity. With respect to development of innovations, universities become the platform for cooperation of different companies, venture entrepreneurs, and creative communities. At the same time, universities as an intermediate structure have certain advantages. In particular, they rapidly connect and coordinate science and business.

In the modern competitive environment, universities should also develop new partnership relations with companies, funds and other scientific institutions. Universities can act: a) as partners and providers of knowledge and certain external resources for the company's innovation processes; b) as intermediaries in cooperation and open innovation processes, thereby forming the respective ecosystem.

5. Universities form communities for intensive knowledge sharing. From the very beginning, universities have gathered the leading scientists who deal with fundamental and applied researches in different fields, as well as gifted and motivated students who rapidly develop their skills. In this context, the whole communities ("social cluster") are established based on the university according to the fields of knowledge, R&D areas and technologies. Such a social environment easily produces creative communities, teams and startups. In many aspects, it is well-organized teams together with their ideas and knowledge, who attract business. Universities create favorable conditions for emergence of scientific communities, as they instill common views, values, priorities, and coordinate interests and culture. In addition, formal and informal mechanisms for cooperation emerge in universities, for example, consortiums and research (innovation) networks.

6. Modern universities have one more distinctive feature: support of entrepreneurship. Along with acceleration of inventions and fierce competition, universities view entrepreneurship as a part of academic experience, inspiration, creation of innovative thinking and culture. Therefore, the creative communities are strongly supported on the way towards establishment of startups and small companies, which implement the most daring projects, particularly, in social sphere. Special centers and incubators are established to support innovation business. Universities, first of all, support their own small enterprises. Often, startup creation becomes a part of academic career of scientists and students. By supporting small innovative enterprises, universities provide various kinds of support: financial, advisory, educational, organizational, etc.

Taking into consideration the support functions of innovative entrepreneurship, it should be noted that universities create the ecosystem required for innovations with a focus on human development. At the same time, universities represent and facilitate development of the innovation ecosystems of regional and national level.

The role of universities in NIS should be considered in six key aspects, as follows:

Each of these aspects, where the functions of universities become apparent, generates certain effects: resource, communicative, organizational, intellectual, etc. These effects are usable. They should also be used for formation or launch of NIS in different countries as well as a factor of processes in the system.

In order to enable universities to play the role of a driving force of innovation and economy, the development of their resource and infrastructural potential as well as innovation capacity is required. It affects the quality of the university-based ecosystem as a physical space to generate innovations. The potential of universities considerably depends on the government policy, which should also use them as an engine for development of innovative activities and should strengthen its support. Concerning the infrastructural potential as a part of university ecosystem, it should become more unleashed and should focus on development of digital components. The model of the open innovations becomes an integral element of management systems at universities.

Summarizing the above-stated, the role of universities in NIS can be considered within the framework of region and city (local economy). In this context, universities function as a core for formation of innovative clusters, which, in their nature, are increasingly based on science and education. Universities are the place where new knowledge is generated and transformed into intellectual assets and innovative products, which create economic productivity of the sectors in local economy (Figure 2).

In the context of globalization, universities become active actors in the world arena of knowledge. They build and connect to global research (innovative) networks, offer their inventions and R&D services, become providers of educational services; all this demonstrates their role in providing interaction of certain country's NIS with international space. Here universities act as attractors of researches and young talents as well as a subject of communication and cooperation.

The consideration of the role of universities in NIS enables highlighting the following practical recommendations to enhance efficiency of their educational and innovative activities:

– to develop programs and infrastructures of online education with engagement of not only the academic staff, but also experts in different fields;

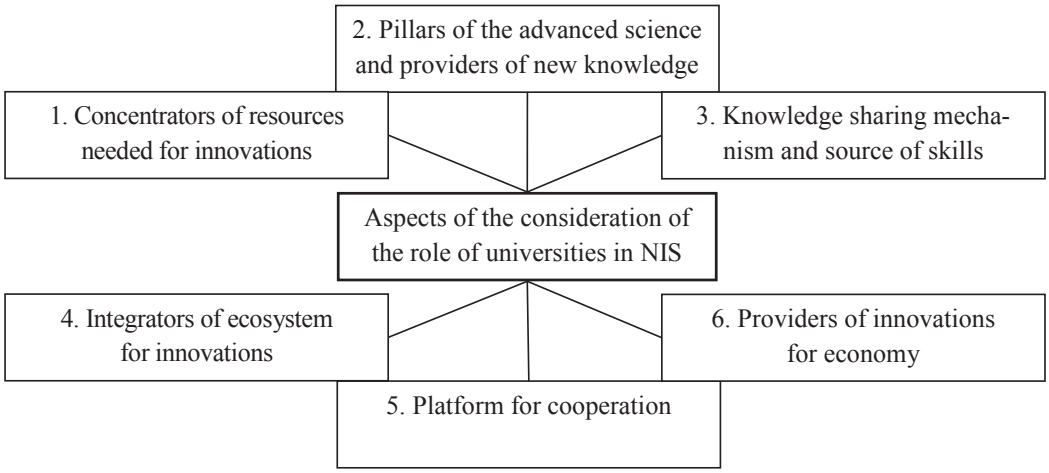

Figure 1. Key aspects of the consideration of the role of universities in NIS

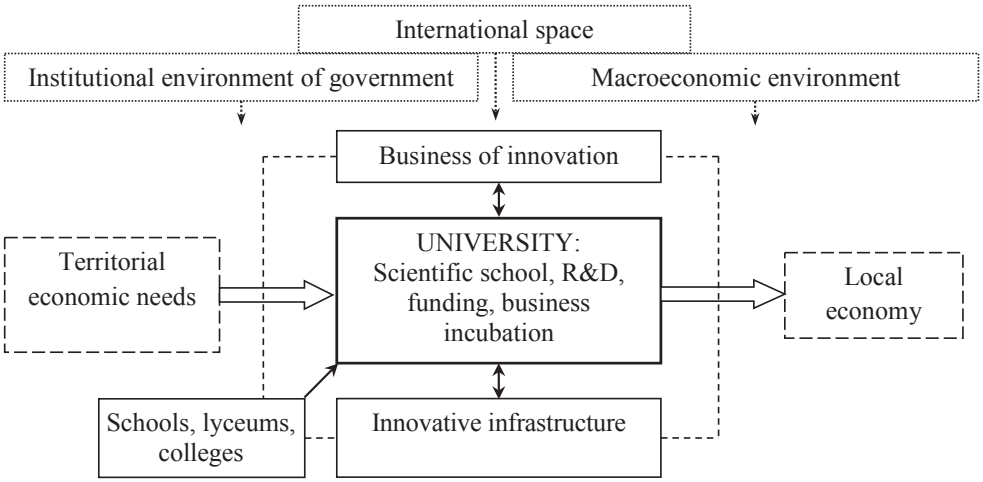

Figure 2. Scheme of the impact of university activities on local economic development

– based on universities, to establish the units which ensure interaction with business and unite students, postgraduate students and academic staff in their work on innovations;
– to provide new educational opportunities for students by means of the individual study programs, mentorship, etc.; shift towards developing a talent, human intellectual potential and creativity, a holistic understanding of the world and new worldview that address the present-day challenges;
– to diversify organizational forms, curricula and models of study, being adapted for the requirements of various innovative technologies;
– to create multidisciplinary curricula, being closely linked to addressing practical problems.

5. Conclusion

Consequently, the science and education become more and more important, making them the productive forces of the knowledge economy that determines their relevance in NIS. The modern educational system faces new challenges in the context of economic and technological changes, which require the review of the traditional approaches and search for the new ways to develop education in close connection with NIS. Universities evolve and their role in NIS is gradually expanding and diversifying. In this context, multiple and multifaceted functions of universities in NIS have been highlighted. These functions build the effects, which are produced by universities, and it is critical in terms of formation and efficient functioning of NIS. The major emphasize should be laid on the innovative potential or capability of universities that should meet the demands of economy. Universities become a driver in the innovative development of cities, regions and sectors. When considering the role of universities, the trends and problems of strengthening the relations between entrepreneurship and academic environment could not be ignored. It is expected to be studied in the nearest future.

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