Conference sub–theme 3.4. Transferring technology and knowledge to SMEs: the role of government and Higher Education Institutions, financial instruments creating a culture of knowledge-based SMEs.

Dominant Role of Universities in the Triple Helix Model

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Keywords: helical instability, threshold conditions, spiral interaction.

The foundational priority of a modern progressive society is the knowledge-based economy, which is defined as depending on the implementation degree of technical and technological innovations in industry. Modern society’s progress becomes impossible without intelligent management of innovation development and its modeling. Therefore, the need to develop appropriate models of innovative development increased, including the narrow meaning of the word “model” – as physics-mathematical or another analogue of the process of innovative development.

Over the last fifteen years the innovative development model based on the study of complicated interaction between three basic components – universities, business and government [1] – has become very popular. The creators of the model consider the linkage of the three components as the linkage of the spiral structure of the DNA molecule. The model was called "Triple Helix" and this name was so successful that it actually was adopted down in the literature and accepted by the scientific society. Nowadays, this model is also accepted by Russian Innovation as the Triple Helix Model [2-4].

The specific application of the "Triple Helix" model in the quantitative estimates was not obvious because of the complexity of the simulated relations. Science becomes science when its instruments can measure and express quantitatively the values that define the patterns of development of the phenomenon under research. If the physical sphere for measurement of physical quantities usually do not cause fundamental issues, the measurements in complex socio-economic spheres are characterized by considerable difficulties.

In the Triple Helix model, each helix individually represents an independent process and it has a unique quality specific value – measuring the parameters. Moreover, for each Triple Helix process there are sufficiently developed theories explaining the dynamics of development. For the *U*–component (university) the bibliometric and scientometric principles and corresponding measuring indicators are applicable: the number of publications in reviewed magazines and citation indexes, the number of applications for patents and the number of the patents obtained. In our case we will define the *U*–component wider than the authors [1] and include academic science. Under the *B*–component (business) we primarily understand the technological business (industry) [1], focused on the introduction of high technology products into production, coming from the *U*–component. For the *B*–component it is technological models and an evolutionary approach, and corresponding measurement indicators. In order to study the *G*–component (government) it is important to analyze the political activity of the state and its influence on the *U*– and *B*– components development.

The effectiveness of the *U*–component, expressed in the number of publications and citations of them, at the intersection of science and technological innovation determines the amount of patents. The number of patents given is based on the know-how of high-tech enterprises and an assessment of their effectiveness economic indicators provides information about the development of *B*–components. These data are the basic statistics and effectively taken into account by methods of descriptive statistics: monitoring, recording and summary statistics, and the subsequent grouping of primary data on the grouping attributes and further analysis to identify patterns. Accordingly, the selected part of the analysis, for example at the regional level, necessarily requires the collection, accounting and the accumulation of these statistics, which will effectively explore the development of the *U*– and *B*–components separately. However, a statistical analysis of the interaction of *U*– and *B*–components of the Triple Helix difficult by the disparities in grouping features in the statistics of the *U*–components and the statistics of the *B*–components.

An analysis of the interaction of *G*–components with the rest of the Triple Helix process is possible on the basis of influence on their development adopted by the national and regional solutions (special economic zones, technical parks and incubators, laws) and direct government funding of academic science, academic innovation and educational programs and support for small manufacturing businesses. This analysis is also, ultimately, reduced to a statistical analysis due to the *G*-influenced growth in the number of publications, citation indexes, the number of patents, the number of high-tech enterprises, the amount of new products produced and other economic indicators. Here, too, are various issues, such as the link between innovative results of operations and costs has clearly not been established; it is only known that this relation is nonlinear. Therefore, direct comparison of the *U*–components with the costs of research and development does not assess the level of investment for development of an integrated Triple Helix system.

The process of analyzing the Triple Helix, discussed above, relies on mathematical tools, including differential equations for the economic models, methods of statistical observation and grouping, regression analysis, special methods of scientometrics and bibliometrics. These tools are suitable for the respective components separately, weak approach to analyze the border areas where there are interaction components. The researcher of the Triple Helix model meets problems which underline the complexity of the studied sphere. In similar cases when it is evidently difficult to come to a solution to the task, an analogy method is sometimes used.

For example, the phenomenon of helical (spiral) instability (HI) of electron-hole plasma, known as oscillistor effect, is characterized not only by the likeness of the helical shape, but also by a qualitative analog of the "three helixes" - TH. Spiral instability is an occurrence and strengthening of spiral waves of density of semiconductor electron-hole plasma $n_1(r, z, \varphi)$, which have a very specific mathematical form:

$$n_1(r,z,\varphi) = f(r,z)\exp(\mathrm{i}m\varphi + \mathrm{i}k_z z - \mathrm{i}\omega t), \quad (1)$$

where r, z, φ are cylindrical coordinates; i - imaginary unit; k_z is a component of the wave number along the length of the sample; m is an angular (azimuthal) number; ω - circular frequency; $f(r,z)= f_1(r)Z_0(z)$, $Z_0(z)$- a weak function of z, showing that the plasma density is constant along the length of a semiconductor cylindrical sample, $f_1(r)$ is a function of the radius, which is approximated by first-order Bessel function $J_1(\beta_1 r)$, $\beta_1=(\alpha_1/a)$, α_1 - the first zero J_1, a - radius of the cylindrical sample.

It is remarkable that the recent spiral instability has been discovered and researched in plasma self-organizing living matter of plant ecosystems. Bioplasma was researched in sunflower samples, soybean and wheat [5]. In our case, this fact indicates the validity of a multidisciplinary approach, using the method of analogy.

For the Triple Helix model it is characterized by the use of bio-analogies, starting with the model name. As noted in [4] the Triple Helix theory was created by synthesizing a number of sociological theories, as well as borrowings and analogies from the biological sciences.

Spiral density wave plasma occur and are strengthened by the joint action of two factors: 1) the electric field E directed along the length of the specimen and creating a voltage applied to the end contacts of a cylindrical semiconductor rod, and 2) the external magnetic field B parallel to E. By the action of the E field a slight separation takes place of quasi-neutral plasma density on the electron and hole components and the appearance of the transverse length of the sample and the z-axis electric field $E_\perp \sim E$, caused by this shift. In the interaction of the exterior and the transverse electric field $E_\perp \sim E$ enhances the amplitude of the spiral wave.

Well-researched patterns of spiral instability [6, 7] contribute to understanding qualitatively the regularities of the Triple Helix model. These patterns, which can be first noted, are the following:

1) the emergence of spiral instability has threshold character, occurs when the B and $E_\perp \sim E$ thresholds are sufficient for the appearance of the main spiral $m = 1$, which has the lowest threshold of excitation;

2) the amplitude of the basic helix increases with B and E above the threshold B_{th} and E_{th} and the corresponding growth of supercriticality parameter $\Delta_{E=const} = (E - E_{th})/E_{th}$ и

$\Delta_{B=const} = (B - B_{th})/B_{th}$

3) with a significant output of the threshold at each supercriticality parameters (with respect to E or B) $\Delta_{E,B} >> 1$ are excited spiral wave with $m = 2$ and $m = 3$ the excitation threshold is greater than the threshold of the fundamental harmonic $m = 1$ and the amplitudes of which also increase with the corresponding supercriticality parameters. The configuration of the perturbation becomes, respectively, two or three helixes, which interact with each other;

4) the amplitude of each of the spiral waves tend to saturate or saturate with significant output over the threshold of excitation, when $\Delta_{E,B} >> 1$

5) in a “bulk” oscillistor, most suitable for the Triple Helix model, reducing the rate of recombination of electrons and holes at the semiconductor surface lowers the threshold for spiral instability and promote strengthening and development of spiral waves. A “bulk” oscillistor is that in which spiral waves occur in the entire volume of the semiconductor sample.

Qualitatively similar to patterns of development and interaction of helixes in the spiral instability model and TH model is presented in Table1,which compares the known patterns of spiral instability and quality embodied in the Triple Helix model.

TABLE 1

Spiral Instability	**Triple Helix**
1) The threshold nature of spiral waves	
Upon reaching the threshold *B* and $E_{\perp} \sim E$ arises a basic helix with the angular number *m* =1.	As a result of scientists who create new knowledge into an uncharted field of innovative themes, when the threshold level of knowledge first arises in the main spiral *U*–component.
2) The significant output of the threshold for the basic helix leads to the formation and strengthening of new spiral harmonics	
When $\Delta_{E,B} >> 1$ appears and develops spiral waves with the angular number $m = 2$ и $m = 3$.	Development activity in the spiral of *B*- and *G*–components
3) For each spiral component with a significant output of the threshold excitation amplitude growth slows down and/or amplitude saturates	
Saturates at values above the supercriticality parameter $\Delta_{E,B} >> 1$	Slower growth in the *B*–components due to market regulation.
4) The dissipative effect of the environment	
Recombination of electrons and holes at the semiconductor surface increases the threshold of spiral instability, which leads to weakening and dissipation of the helical waves.	In view of market conditions - the death, "recombination" of small manufacturing enterprises.

Let us consider all the patterns in order of their relationship to the Triple Helix model. As a result of scientists who create new knowledge the amplitude of the helix *U*–component occurs and increases, which as far as scientific problems are solved slows its growth and its amplitude saturates. Upon reaching a sufficiently large number of publications, citation indexes and co-citation in your chosen field of research there are threshold conditions for the transition of knowledge in the domain of technology transfer, receipt of patents, the creation of technology firms and businesses. Thereby the threshold conditions are reached for the emergence of the helix *B*–component, which increases with the number of patents and industrial enterprises using the knowledge created during the development of the *U*–helix. As a consequence of market regulation (the balance of supply and demand, competition), this growth cannot be continued indefinitely, so that the growth of the *B*–component slows down and its amplitude saturates. However, for the same market conditions, there is death and "recombination" of industrial enterprises. It becomes especially important in contributing to innovative development of the third activity, *G*–components aimed at reducing the loss of high-tech manufacturing firms.

In determining the role of universities in the Triple Helix model we are primarily interested in the threshold character of the spiral generations. In the undeveloped field of innovative themes, chosen by scientists and their work, resulting in the accumulation of scientific data are the threshold conditions for excitation of the spiral, having the lowest among all possible helixes, the excitation threshold – a spiral *U*–component. At this stage, yet there is no prerequisite or threshold conditions for excitation of other helixes, *B*–components and *G*–components. In this process the main role is played by universities, creating the preconditions for the emergence of *B*–components. Without the development of *U*–components the emergence of *B*–components in the Triple Helix model is impossible. These preconditions occur only with a sufficiently large and relevant threshold for the occurrence of *B*–components – the values of knowledge in your chosen field of research. Here, there are conditions for the transfer of knowledge and technology and the creation of technology companies and enterprises.

There are situations when government (the *G*–component) or the industrial sector of the economy (the *B*–component) assign tasks of developing particular scientific problems to researchers. The area of research is usually connected with developing technologies, technological business and getting profit. It also might be associated with government interests or national security. That was the case of developing nuclear projects in Germany, the USA and the USSR in the 1940s.

Nevertheless, the occurrence of feedback from one triple helix component to another does not reduce the role of universities (the *U*–component). The results of these feedback might be perceived only by the scientifically developed field of the *U*–component when there are significant scientific reserves. Feedback might be positive when their signals correspond to the scientific reserves and provide for its further development, or negative on the contrary. However, generation and accumulation of scientific knowledge in universities is always the primary phenomenon.

Thereby, universities always play dominant role in the Triple Helix model, as well as in the development of a knowledge-based economy. A qualitative consideration of aspects of the Triple Helix model with analogies from the well-studied patterns of the helical instability eases the understanding of Triple Helix mechanisms and does not imply a quantitative analysis. It is possible that the provided path will prove to be a subject of further research. For the checking of the discovered qualitative laws in the Triple Helix model, as before, factual material is important – numerical statistical data of each of the three Triple Helix components and their analysis.

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