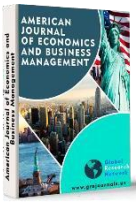

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Article

Econometric Assessment of The Impact of Scientific Potential on The Development of Entrepreneurial Universities: Evidence From Uzbekistan

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Abstract: This article investigates issues relating to the improvement of the organisational and economic management mechanisms of higher education institutions in the context of implementing the concept of the entrepreneurial university. The need to modernise management approaches stems from the increased financial autonomy of universities, intensified competition in the educational services market, and the growing role of the commercialisation of research outcomes. The paper develops the scientific and methodological foundations for improving management mechanisms and outlines directions for enhancing the operational efficiency of universities in the Republic of Uzbekistan. The study is based on methods of systemic, comparative and economic-statistical analysis, as well as econometric tools, including correlation-regression analysis, panel data methods, the fixed effects model and the weighted least squares method. The conclusions drawn and recommendations proposed can be used by relevant government departments and the management of higher education institutions for strategic planning, enhancing the competitiveness of universities, and the successful implementation of an entrepreneurial model within the academic environment.

Keywords: Entrepreneurial University, Research Capacity, Organisational and Economic Mechanisms, University Governance, Research Projects, Grants, Start-Ups, Research Commercialisation, Commercial Contracts, Higher Education

1. Introduction

Current trends in the development of the global higher education system are characterised by the growing role of universities as key players in the innovation-driven economy. In the context of the transition to a knowledge economy, the traditional educational function of universities is being complemented by research and entrepreneurial activities, which is driving the transformation of university governance models and the formation of a new paradigm for the development of higher education institutions [1].

In recent decades, the concept of the 'entrepreneurial university' has become one of the most significant trends in the modernisation of higher education. Under this concept, a university is viewed not only as an educational and research institution, but also as an active participant in the innovation ecosystem, capable of generating new knowledge,

ensuring its commercialisation, establishing innovative enterprises and generating additional financial resources for its own development [2].

In the Republic of Uzbekistan, the reform of the higher education system is accompanied by an expansion of university autonomy, improvements to funding mechanisms, the promotion of scientific and innovative activities, and the development of cooperation between educational institutions and the real sector of the economy. Issues relating to improving the effective use of universities' scientific potential are of particular importance as one of the key factors in shaping an entrepreneurial model for their development [3].

Despite the considerable body of research devoted to the development of 'entrepreneurial universities', there remains a lack of research into the quantitative assessment of how factors relating to research capacity influence the outcomes of universities' entrepreneurial activities. Further refinement is required of the methodological tools used to determine the optimal parameters for managing research activities, thereby ensuring the sustainable development of higher education institutions [4].

Literature Review

The concept of the 'entrepreneurial university' is one of the most significant trends in the transformation of the higher education system within the context of the emerging knowledge economy. The growing role of universities in the innovative development of the economy has led to the emergence of new approaches to the organisation of their activities, involving the integration of educational, research and entrepreneurial functions into a single system for the creation and commercialisation of knowledge [5].

The theoretical foundations of the 'entrepreneurial university' concept were laid in the works of B. Clark, who viewed the entrepreneurial university as an educational institution capable of independently formulating a development strategy, diversifying its sources of funding, and actively engaging with the external environment [6]. In the author's view, the key characteristics of an entrepreneurial university are a strong management core, a well-developed network of interaction with external partners, a diversified financial base and an entrepreneurial culture [7].

G. Itzkowitz made a significant contribution to the development of the 'entrepreneurial university' theory by devising the 'Triple Helix' concept, according to which sustainable innovative development is ensured through effective collaboration between universities, business and the state [8-9]. According to this approach, universities cease to be exclusively educational institutions and become active agents of innovation, capable of creating new enterprises, commercialising scientific developments and participating in the formation of national innovation systems [10-11].

Further development of research into 'entrepreneurial universities' was advanced in the works of J. Wissema, who emphasised the need to establish third-generation universities [12]. The author noted that the modern university should focus not only on educational and research activities, but also on creating economic value through the commercialisation of knowledge and innovation [13].

A particular focus of contemporary research is on assessing the effectiveness of 'entrepreneurial universities'. Most authors suggest using indicators such as the volume of research, the number of patents, start-ups, grant funding, the level of commercialisation of research outputs, and revenue generated from collaboration with industrial enterprises [14]. However, existing approaches are predominantly focused on analysing individual performance outcomes and do not sufficiently account for the interrelationships between the factors shaping scientific potential and the final indicators of university development.

Recent research has focused considerable attention on the challenges of commercialising research outcomes and developing innovative university ecosystems. In

particular, it is emphasised that a key prerequisite for the successful development of an 'entrepreneurial university' is the presence of a well-developed research capacity capable of generating new knowledge and creating competitive innovative products [15].

In the academic literature of the Republic of Uzbekistan, issues relating to the improvement of the higher education management system are addressed in works by domestic scholars focusing on the modernisation of universities, the enhancement of the quality of educational services, the development of innovative activities, and the improvement of higher education funding mechanisms. Domestic researchers Sh. Zainutdinov, R. Nurimbetov and A. Sultanov call for state education policy to be geared towards increasing the supply of qualified personnel by improving the quality of education and implementing institutional reforms that stimulate investment in the technology sector [16]. At the same time, institutional reforms are needed to stimulate investment in the technology sector, which creates demand for highly qualified personnel and helps to establish a sustainable link between the education system and the innovation-driven economy.

At the same time, research aimed at quantitatively assessing the impact of scientific capacity factors on the outcomes of universities' entrepreneurial activities remains limited.

An analysis of the scientific literature shows that existing studies are predominantly focused on the theoretical justification of the concept of the 'entrepreneurial university' and the examination of individual aspects of its activities. At the same time, the issues of determining quantitative parameters of the influence of personnel, organisational and economic factors on the results of universities' scientific and innovative activities remain insufficiently developed [17].

Thus, the need to develop a scientific and methodological approach to determining the optimal ratios of factors shaping scientific potential and their impact on the performance of the 'entrepreneurial university' determined the focus of this study and defined its scientific novelty.

2. Materials and Method

The methodological framework of the study is based on contemporary principles of the 'entrepreneurial university' theory and scientific approaches to assessing the effectiveness of higher education institutions in the context of innovative development. The study is based on the assumption that the effectiveness of a university's entrepreneurial activity is determined by the level of its scientific potential and the efficiency of the organisational and economic mechanism for managing scientific and innovative activity.

To achieve this objective, a range of general and specialised research methods was employed. The application of a systems approach enabled the university to be viewed as a complex socio-economic system operating within a framework of interaction between educational, research and entrepreneurial activities. Methods of comparative analysis, data grouping and summarisation were used to identify trends in the development of scientific potential and to determine the characteristics of the formation of entrepreneurial activity in higher education institutions. To quantitatively assess the relationships between the indicators under study, economic and statistical methods were applied, including correlation and regression analysis and panel data econometric tools.

The study's data set comprised statistical indicators of the performance of higher education institutions in the Republic of Uzbekistan. Based on official data, a panel sample of universities was formed, with statistical information that was sufficiently comprehensive and comparable to allow for econometric analysis. The use of panel data made it possible to take into account both inter-university differences and the dynamics of changes in the indicators under study over time, which ensured greater accuracy of the results obtained.

As performance indicators for the development of an 'entrepreneurial university', we selected indicators characterising the main outcomes of research and innovation activities: the number of research projects, grants, start-ups and commercial contracts; the number of participants involved in their implementation; and the revenue generated from research projects, start-ups and commercial contracts. These indicators reflect the key areas of the university's entrepreneurial function and enable an assessment of the effectiveness of its scientific potential.

The study was based on indicators characterising the human resources and institutional components of a university's research capacity, namely the number of Doctor of Science (DSc) holders, the number of Doctor of Philosophy (PhD) holders, and the level of research capacity within the higher education institution. These factors were selected due to their significance in the processes of shaping scientific and innovative activity and the commercialisation of research results.

To determine the degree of influence of the factors under study on performance indicators, a Fixed Effects Model (FEM) was used, which allows for the individual characteristics of universities to be taken into account and minimises the influence of characteristics of the objects under study that remain constant over time. The use of this model is driven by the need to obtain more objective assessments of the relationships between scientific potential factors and the performance of universities.

In general terms, the model used can be represented as follows:

$$Y_{IT}=\alpha_I+\beta_1 X_{it}+\beta_2 X_{2it}+\ldots\beta_n X_{nit}+\varepsilon_{it}$$

where: Y_{IT}– a performance indicator of the university's entrepreneurial activity; X_{it}– a system of factor indicators; α_I– individual effects of the universities; ε_{it}– a random error.

To verify the robustness of the results obtained and to address any potential heteroscedasticity, the Weighted Least Squares (WLS) method was additionally applied, thereby enhancing the statistical reliability of the coefficient estimates and ensuring the correct interpretation of the identified relationships.

3. Results

An One of the key characteristics of an 'entrepreneurial university' is the ability to transform existing research potential into tangible outcomes of research and innovation, manifested in the implementation of research projects, the securing of grant funding, the development of start-ups, the expansion of commercial contracts, and increased revenue from the commercialisation of research results [18]. In this regard, identifying the quantitative patterns of how scientific potential factors influence the performance of higher education institutions is of particular relevance.

To assess these relationships, an econometric analysis was conducted based on panel data from universities in the Republic of Uzbekistan. The results of the study established that the development of a university's entrepreneurial activity is directly dependent on the qualitative characteristics of its scientific potential and is determined by the following equation:

$$X_{13}=-88{,}15+2{,}26*X_2-1{,}04*X_3+3{,}78*X_4$$

where: X_{13} — the number of research projects, grants, start-ups and commercial contracts; X_2— the number of Doctor of Science (DSc) holders; X_3— the number of Doctor of Philosophy (PhD) holders; X_4— the university's research capacity.

The results obtained indicate that the level of a university's research capacity has the most significant impact on the development of research and innovation activity. A one-per-cent increase in this indicator is accompanied by an average increase of 3.78 units in the number of research projects, grants, start-ups and commercial contracts. At the same time, it has been established that an increase of one person in the number of PhD holders

leads to an average increase in the indicator under consideration of 2.25 units. This confirms the decisive role of highly qualified scientific staff in the development of universities' entrepreneurial activities.

However, the negative value of the coefficient for the number of PhDs (–1.04) indicates the presence of institutional constraints that hinder the full involvement of young researchers in the commercialisation of scientific developments and the implementation of innovative projects. This result points to the need to improve mechanisms for incentivising the research activity of this category of academic and teaching staff:

$$X_{14}=127,88+3,54*X_2-2,84*X_4$$

where: X_{14} *— the number of participants in research projects, grants, start-ups and commercial contracts.*

According to the findings, an increase in the number of PhD holders per person leads to an average increase of 3.54 people in the number of participants in research and innovation activities. At the same time, a negative impact of the scientific potential indicator on the number of project participants was identified (–2.84). This result indicates that an increase in formal indicators of scientific potential is not always accompanied by an expansion of the circle of researchers involved in the university's entrepreneurial activities. In some cases, scientific activity is concentrated among a limited number of specialists, which reduces the efficiency of human resource utilisation and limits the potential for further development of the university's entrepreneurial ecosystem.

Of particular interest are the results of the assessment of factors influencing the generation of revenue from scientific and innovative activities. The analysis carried out has established the following relationship:

$$X_{15}=82,14*X_2$$

where: X_{15} *— revenue generated from research projects, grants, start-ups and commercial contracts, in millions of soums.*

The results obtained show that an increase in the number of PhD holders per capita leads to an average increase in the university's revenue of 82.4 million sum. No statistically significant influence of other factors was identified. This leads to the conclusion that it is precisely highly qualified academic staff who are the main source of financial performance at an entrepreneurial university and ensure the sustainability of the commercialisation of research.

Based on the research conducted, the author has developed a methodological approach to assessing the scientific potential of an entrepreneurial university, based on determining the quantitative parameters of the relationship between human resource potential, the results of scientific and innovative activity, and the volume of revenue generated. Unlike existing approaches, which focus primarily on the analysis of absolute indicators of scientific activity, the proposed approach allows for the assessment of the effectiveness of the organisational and economic mechanism for university management through a system of interrelated performance indicators.

The scientific novelty of this study lies in the identification of optimal ratios among the factors shaping the research potential of higher education institutions. It has been established that the effectiveness of research and innovation activities is determined by the ratio (2.25; –1.04; 3.78), reflecting the influence of the number of Doctors of Science, Doctors of Philosophy and the level of scientific potential on the number of research projects, grants, start-ups and commercial contracts. The development of human capital in scientific and innovative activity is characterised by the ratio (0; 3.54; –2.84), reflecting the influence of these factors on the number of participants in scientific projects. In turn, the financial performance of an entrepreneurial university is determined by the ratio (82.4; 0; 0), characterising the influence of scientific potential on the volume of revenue from scientific and innovative activities.

The proposed system of coefficients constitutes a set of quantitative benchmarks that enable the assessment of the effectiveness of the organisational and economic mechanism for university management, the identification of priority areas for the development of scientific potential, and the formulation of management decisions aimed at enhancing the competitiveness and financial sustainability of higher education institutions.

The findings of the study confirm that a key factor in the development of an entrepreneurial university is the human resources component of its research capacity, particularly the number of Doctor of Science (DSc) holders, who are instrumental in attracting research projects, expanding collaboration with the real sector of the economy, and increasing revenue from the commercialisation of research outcomes. For the first time in the context of higher education institutions in the Republic of Uzbekistan, scientific potential is viewed not as a static characteristic of staffing levels, but as a manageable resource that determines the effectiveness of the organisational and economic mechanism of the 'entrepreneurial university'.

4. Discussion

The findings suggest that the effectiveness of developing an 'entrepreneurial university' is determined not so much by the volume of available resources as by the ability of the organisational and economic management mechanism to ensure that these resources are transformed into scientific and innovative outcomes and sustainable financial returns. In today's environment, universities act not only as educational and scientific institutions, but also as active players in the innovation economy, participating in the creation, dissemination and commercialisation of new knowledge. In this context, mechanisms for developing and effectively utilising scientific potential are of particular importance as the foundation for ensuring the competitiveness and financial sustainability of higher education institutions.

The results of the study confirm that the human resources component of scientific potential plays a key role in the system of factors driving the development of an 'entrepreneurial university'. It has been established that an increase in the number of PhD holders has a sustained positive impact on all performance indicators examined: the number of research projects, grants, start-ups and commercial contracts; the extent of academic staff involvement in research activities; and the volume of revenue generated from research and innovation activities. This conclusion indicates that it is precisely highly qualified scientific staff who constitute the main resource for the development of the university's entrepreneurial activity and determine its capacity to commercialise research results.

The findings are consistent with the principles of resource-based theory, according to which sustainable competitive advantages are built on unique human resources and accumulated competencies. In the context of an 'entrepreneurial university', highly qualified academic and teaching staff act not only as bearers of scientific knowledge, but also as initiators of innovative projects, grant-funded research and forms of interaction with the real sector of the economy. Consequently, the development of human resource potential becomes one of the key areas for improving the university management system.

At the same time, the analysis revealed the presence of certain structural constraints in the process of building scientific capacity. For instance, the negative value of the coefficient for the number of PhDs in the model assessing scientific and innovative activity indicates an insufficient level of involvement of young researchers in scientific entrepreneurship processes. This leads to the conclusion that there is a need to improve mechanisms for stimulating scientific activity, develop a mentoring system, and expand opportunities for young scientists to participate in grant programmes, start-up projects and commercial contracts.

Equally important is the identified negative impact of the level of research capacity on the number of participants in research projects. This pattern suggests that an increase in formal indicators of research capacity is not always accompanied by an expansion of the pool of researchers involved in research and innovation activities. In some cases, scientific activity is concentrated within a limited group of specialists, which reduces the efficiency of human resource utilisation and limits the potential for further development of the university's entrepreneurial ecosystem. This points to the need to improve organisational mechanisms for the distribution of research activities and to expand the participation of academic and teaching staff in the implementation of scientific and innovation projects.

From a practical perspective, the results obtained confirm the advisability of moving away from traditional approaches to the evaluation of scientific activity, based primarily on quantitative indicators, towards a management system focused on the effectiveness of scientific and innovative activity and the degree of human capital involvement in the processes of forming an entrepreneurial university.

Unlike existing studies, in which the 'entrepreneurial university' is primarily examined through a set of qualitative characteristics, the proposed approach makes it possible to identify quantitative parameters of the relationship between human resource potential, research and innovation activity, and the financial performance of higher education institutions.

For the first time in the context of higher education in the Republic of Uzbekistan, a system of optimal ratios of factors shaping scientific potential has been established, reflecting the influence of human resource and institutional parameters on key indicators of an entrepreneurial university's development. To assess the effectiveness of scientific and innovative activity, this ratio is (2.25; –1.04; 3.78), for assessing the involvement of academic staff in research activities — (0; 3.54; –2.84), and for generating revenue from scientific and innovative activities — (82.4; 0; 0).

The proposed system of indicators constitutes a set of analytical benchmarks that enable the assessment of the effectiveness of the organisational and economic framework for university management, the identification of problem areas in the development of research capacity, and the justification of management decisions aimed at enhancing the effectiveness of research activities. The practical application of the developed approach is possible in the formulation of university development strategies, the improvement of human resources policy, the allocation of financial resources, and the monitoring of the effectiveness of the implementation of the 'entrepreneurial university' concept.

Thus, the research findings lead to the conclusion that the sustainable development of an 'entrepreneurial university' is ensured not only by the presence of scientific potential, but also by the effectiveness of the mechanisms for its utilisation. Of decisive importance here is the development of the human resources component of scientific potential, which ensures the formation of scientific and innovative activity, the expansion of cooperation with external partners, and an increase in revenue from the commercialisation of research results. It is precisely the university's ability to transform its existing scientific potential into innovative outcomes and economic value that is the key condition for enhancing its competitiveness in the current context of higher education development.

5. Conclusions

The results of this study have revealed the quantitative patterns underlying the development of universities' research and innovation activities and identified the key factors influencing the effectiveness of their operations. The application of econometric methods of analysis, in particular fixed-effects models and the weighted least squares method, has established a consistent correlation between indicators of scientific potential and the results of entrepreneurial activity at higher education institutions.

The study has shown that the human resources component of scientific potential plays a decisive role in the development of an 'entrepreneurial university'. It has been established that an increase in the number of PhD holders has a positive impact on the number of research projects, grants, start-ups and commercial contracts, contributes to the expansion of academic staff's participation in research and innovation activities, and also ensures growth in revenue derived from the commercialisation of research results. The results obtained confirm that highly qualified scientific staff are a key resource ensuring the sustainable development of the university's entrepreneurial model.

The application of the proposed quantitative benchmarks will improve the effectiveness of scientific potential management, expand the scale of research commercialisation, and strengthen the financial stability of universities.

Overall, the findings of the study confirm that the sustainable development of an 'entrepreneurial university' is determined by the ability of its organisational and economic management mechanisms to ensure the effective transformation of academic potential into innovative outcomes, entrepreneurial initiatives and economic value. It is precisely this transformation that is a key condition for enhancing the competitiveness of higher education institutions in the context of the knowledge economy.

Prospects for further research include the development of integrated models for assessing the level of development of 'entrepreneurial universities', the improvement of mechanisms for commercialising scientific developments, studying the impact of digital transformation on the management of scientific and innovative activities, and establishing a system of indicators to monitor the effectiveness of the organisational and economic management mechanism of universities in the context of developing the entrepreneurial ecosystem of higher education.

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