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Analysis of Factors Affecting the Efficiency of Research and Innovation Activities of Higher Education Institutions

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Abstract

This article explores the determinants of efficiency in research and innovation activities within higher education institutions, focusing on selected institutions in Uzbekistan. The study involves 502 professors and teachers from various institutions, analyzing factors such as funding sources, scientific personnel qualifications, collaboration networks, material and technical support, institutional backing, student involvement, and external infrastructure. Utilizing STATA 15.0 software, the econometric analysis employs the Ordinary Least Squares (OLS) regression model to investigate the impact of these factors on research and innovation performance. The study formulates and tests hypotheses related to financial support, personnel collaboration, industry partnerships, resource availability, institutional support, student engagement, and external infrastructure. The findings contribute to understanding the dynamics shaping the effectiveness of research and innovation activities in higher education institutions.

Keywords: Higher Education, Research and Innovation Efficiency, Funding, Scientific Personnel, Collaboration, Material and Technical Support, Institutional Support, Student Involvement, External Infrastructure, Uzbekistan.

Introduction

The effectiveness of research and innovation activities of higher education institutions depends on many factors. This article analyses the factors affecting the efficiency of research and innovation activities of higher education institutions, higher education institutions such as Bukhara Institute of Engineering and Technology, Bukhara Institute of Natural Resources Management, Samarkand State University of Architecture and Civil Engineering, Samarkand branch of Tashkent University of Information Technology named after Muhammad Al-Khwarizmi, Navoi State Mining, and Technology University were selected. Muhammad Al-Khwarizmi University, Navoi State Mining and Technological University. The results of a social questionnaire consisting of 24 questions were studied by 502 professors and teachers of higher education institutions. 5.1 percent of those who took part in the survey were doctors of sciences (DSc), 30 percent were candidates of sciences or doctors of philosophy (PhD), and 65 percent were professors and teachers without degrees. Teachers were 66.7% of the respondents, lower-level managers were 6.4%, middle managers were 2.7%, and upper-level managers were 2.4%. In the questionnaire from "0" to "100" points were selected 7 factors influencing the

efficiency of research and innovation activities of higher education institutions, and the level of influence was assessed from "0" to "10" points.

STATA 15.0 software was utilized for the econometric analysis of the research work, following the methods outlined in Damodar Gujarati's "Basic Econometrics" (2003). The study designated research performance (y_1) and innovation performance (y_2) as the dependent variables. The questionnaire recorded the impact of independent variables on each dependent variable separately.

In establishing the influence of factors on the efficiency of research and innovation activities in universities, the following hypotheses were proposed:

H_0- Improving the efficiency of research and innovation activities of higher education institutions is ensured by their funding from various sources (x_1; z_1), availability of scientific personnel with high knowledge, qualification and experience (x_2; z_2), scientific cooperation with other university and research centers manufacturers (x_3; z_3), material and technical support of scientific and innovative processes (x_4; z_4), internal institutional support (x_5; z_5), student participation in scientific and innovative activities (x6; z6), external regional, there is no interaction between regional infrastructural support (x_7; z_7);

H_1 - The financial support and monetization factors positively influence the effectiveness of the scientific research and innovation activities of higher education institutions.

H_2 - The presence of positive attitudes and support between higher education institutions and qualified scientific personnel with increased research and innovation activities positively contributes to their efficiency.

H_3 - Collaborating with manufacturers in scientific research and innovation activities increases the efficiency of higher education institutions.

H_4 - Providing higher education institutions with material and technical resources such as modern laboratories, libraries, and computing facilities enhances the effectiveness of their scientific research and innovation activities.

H_5 - The improvement of internal institutional support and collaboration positively affects the effectiveness of scientific research and innovation activities in higher education institutions.

H_6 - Student involvement in scientific research and innovation activities contributes to the efficiency of higher education institutions in their scientific research and innovation activities.

H_7 - State policies, financial agencies, information support services, and overall external infrastructure support for scientific research and innovation activities enhance effectiveness.

In the analysis process, the effects of several independent variables on a dependent variable (y_1) were studied using the Ordinary Least Squares (OLS) regression model. (Table 1)

Table 1 ***Factors affecting the effectiveness of scientific research simple linear regression model (OLS)***

The efficiency of scientific research (y_1)	*Coef.*	*St.Err.*	*t-value*	*p-value*	*[95% Conf*	*Interval]*	*Sig*
x_1	-.986	0.243	-4.06	0	-1.463	-.509	***
x_2	4.682	0.458	10.21	0	3.781	5.583	***
x_3	-0.172	0.246	-0.70	.485	-.655	0.311	
x_4	3.65	0.446	8.18	0	2.774	4.527	***
x_5	-.373	0.244	-1.53	.127	-0.852	0.107	
x_6	1.759	0.357	4.93	0	1.057	2.46	***
x_7	-.559	0.237	-2.35	.019	-1.025	-.093	**
Constant	16.65	1.904	8.74	0	12.909	20.392	***

Mean dependent var	62.155	SD dependent var	21.420
R-squared	0.758	Number of obs	502
F-test	221.264	Prob > F	0.000
Akaike crit. (AIC)	3803.568	Bayesian crit. (BIC)	3837.316

*** $p<.01$, ** $p<.05$, * $p<.1$

In the process of defining the parameters of the econometric analysis and testing the hypotheses, he determined its overall adequacy. Fisher's criterion (F-criterion) was applied for this model and hypothesis H0 that all independent variables do not affect the dependent variable (y1) was put forward. However, according to our research, variables such as x_2, x_4, and x_6 whose p-value of F-test is less than 0.05 were found to be statistically significant. The p-value indicates the statistical significance of each independent variable. Asterisks next to p values indicate the level of significance: * for p<0.1, ** for p<0.05 and *** for p<0.01. Among the independent variables selected in our study, x_1, x_3, x_5, and x_7 were statistically insignificant and were not included in the model. The influence of factors affecting the efficiency of scientific research in higher education institutions was determined and the following equation was obtained.

$$\widehat{y_1} = 16.65 + 4.682 \times x_2 + 3.65 \times x_4 + 1.759 \times x_6$$

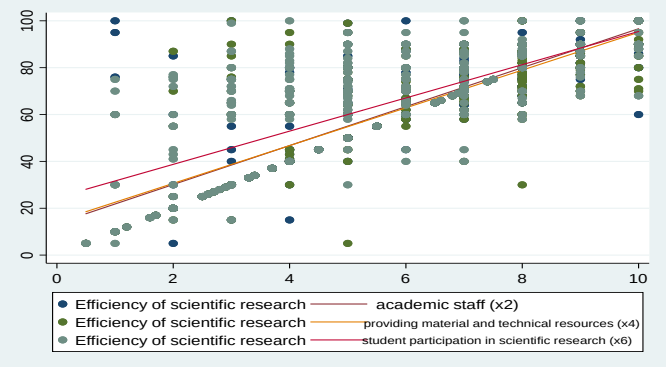

Figure 1. The correlation between the efficiency of scientific research and academic staff (x_2), providing material and technical resources (x_4), and student participation in scientific research (x_6).

From a simple linear regression model, it can be concluded that an increase in the number of experienced, skilled academic staff by one unit is associated with an increase in the efficiency of scientific research by 4.682 units. Similarly, providing material and technical resources, such as modern laboratories, libraries, and computing facilities, by one unit is associated with an increase in the efficiency of scientific research by 3.65 units. Additionally, increasing student participation in scientific research by one unit is associated with an increase in the efficiency of scientific research by 1.759 units.

Table 2 **The Pairwise correlations of the efficiency of scientific research and the influencing factors.**

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(1)The efficiency of scientific research	1.000							
(2) The financial support	0.247	1.000						
	(0.000)							
(3) experience, staff competencies R&D	0.827	0.413	1.000					
	(0.000)	(0.000)						
(4) scientific cooperation with other universities and research centers	0.350	0.430	0.462	1.000				
	(0.000)	(0.000)	(0.000)					
(5) material and technical support	0.821	0.371	0.856	0.408	1.000			
	(0.000)	(0.000)	(0.000)	(0.000)				
(6) internal institutional support	0.232	0.363	0.322	0.351	0.329	1.000		
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)			
(7) student participation in scientific research	0.706	0.340	0.726	0.446	0.740	0.382	1.000	
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)		
(8) External regional infrastructural support	0.235	0.245	0.327	0.283	0.327	0.384	0.381	1.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	

The analysis of research results demonstrated a strong correlation between the efficiency of scientific research and the provision of academic staff, accounting for 82.7%. Similarly, the correlation with material and technical resources was 82.1%, and ensuring student participation in research activities showed a strong correlation of 70.6%. Additionally, according to the Pearson correlation test, the statistical significance of the model was confirmed. (Table 2)

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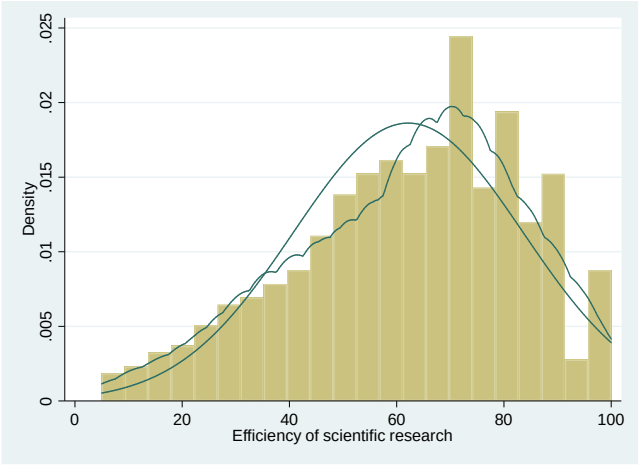

Figure 2. Histogram of the normal distribution of indicators of scientific research efficiency.

Table 3
Factors affecting the effectiveness of scientific research Robust linear regression

The efficiency of scientific research *(y_1)*	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
x_1	-.986	.263	-3.74	0	-1.504	-.469	***
x_2	4.682	.862	5.43	0	2.989	6.375	***
x_3	-.172	.197	-0.87	.384	-.56	.216	
x_4	3.65	.793	4.60	0	2.092	5.209	***
x_5	-.373	.24	-1.55	.121	-.845	.099	
x_6	1.759	.434	4.05	0	.906	2.611	***
x_7	-.559	.2	-2.79	.006	-.952	-.165	***
Constant	16.65	2.775	6.00	0	11.198	22.103	***

Mean dependent var	62.155	SD dependent var	21.420
R-squared	0.758	Number of obs	502
F-test	365.516	Prob > F	0.000
Akaike crit. (AIC)	3803.568	Bayesian crit. (BIC)	3837.316
*** $p<.01$, ** $p<.05$, * $p<.1$			

Robust regression is a method that minimizes the impact of outliers in each independent variable on the model, forming an R-squared value of 0.758 for the model. This value indicates that the model explains 75% of the variability in financial performance. The F-test yields an extremely low p-value of 0.000, demonstrating the statistical significance of the model. ANOVA test is a method used to determine the significance or insignificance of research results. In this approach, it assists in rejecting the null hypothesis and accepting the alternative hypothesis.

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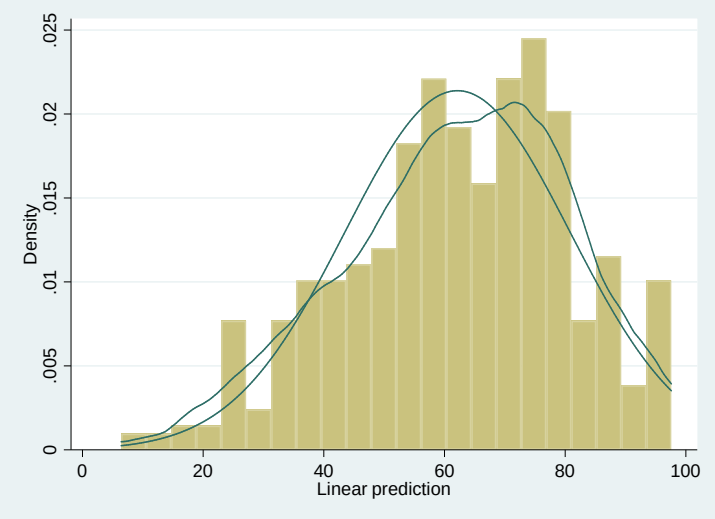

Figure 3. Dispersion analysis of factors influencing the efficiency of scientific research. (ANOVA test)

In regression analysis, the Variance Inflation Factor (VIF) is employed as a measure to assess multicollinearity among various variables, particularly for inflationary factors associated with independent variables. A high VIF value for a specific variable indicates a high degree of correlation with other independent variables in the model. The average VIF for all variables is 2.37, which is typically below the commonly used threshold of 5.

As part of the research, the second dependent variable chosen was the innovation performance (y_2) of higher education institutions. Using a simple linear regression model, Ordinary Least Squares (OLS), the direct effects of several independent variables on the dependent variable (y_2) were examined. (Table 4)

Table 4 ***Factors Influencing Innovation Performance Efficiency in Higher Education Institutions: Simple Linear Regression Model (OLS)***

Innovation performance efficiency, y_2	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
z_1	6.046	0.486	12.44	0	5.091	7	***
z_2	-0.217	0.235	-0.92	.358	-.678	.245	
z_3	-0.355	.242	-1.47	.143	-.83	.121	
z_4	2.348	.438	5.36	0	1.487	3.209	***
z_5	-0.462	.232	-1.99	.047	-.918	-.006	**
z_6	1.636	.361	4.53	0	.927	2.345	***
z_7	-0.304	.223	-1.37	.172	-.742	.133	
Constant	10.148	1.711	5.93	0	6.786	13.511	***

Mean dependent var	56.211	SD dependent var	21.419
R-squared	0.811	Number of obs	502
F-test	302.309	Prob > F	0.000
Akaike crit. (AIC)	3680.512	Bayesian crit. (BIC)	3714.261

*** $p<.01$, ** $p<.05$, * $p<.1$

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In the process of determining the parameters of econometric analysis and testing hypotheses, the researcher assessed the overall adequacy of the model. The Fisher's F-test was applied to the entire model, and the null hypothesis (H_0) was formulated, suggesting that all independent variables do not influence the dependent variable (y_2). However, based on our research, variables such as z_1, z_4, and z_6, whose p-values from the F-test were less than 0.05, turned out to be statistically significant. The p-values indicating the statistical significance of each independent variable are marked with asterisks, with significance levels specified, for example, * for p<0.1, ** for p<0.05, and *** for p<0.01.

Among the selected independent variables in our study, z_2, z_3, z_5, and z_7 were found to be statistically insignificant based on observations and were not included in the model. The impact of factors influencing the effectiveness of innovation activities in universities was determined, and the following equation was derived.

$$\widehat{y_2} = 10.148 + 6.046 \times z_1 + 2.348 \times z_4 + 1.636 \times z_6$$

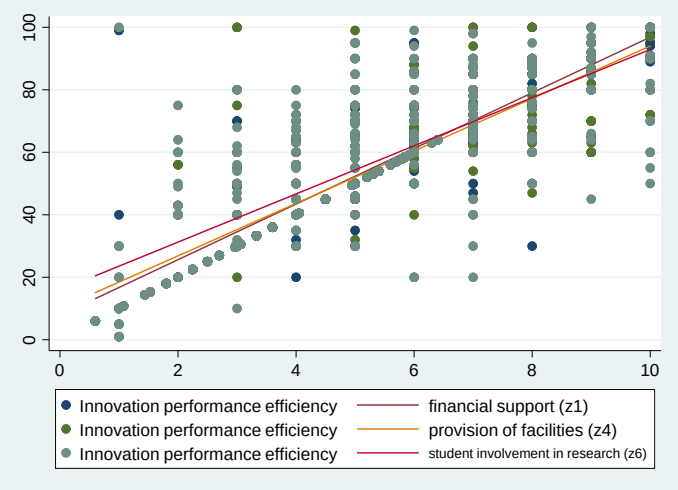

Figure 4. The relationship between innovation performance and financial support (z_1), provision of facilities (z_4), and student involvement in research (z_6).

The coefficient of financial adjustment in the simple linear regression model indicates that for every one-unit increase in financial support, the efficiency of innovative activities in higher education institutions increases by 6.046 units. Similarly, a one-unit increase in the provision of material-technical resources, such as modern laboratories, libraries, and computing resources, is associated with a 2.348-unit increase in the efficiency of scientific research. Additionally, a one-unit increase in student participation in research activities leads to a 1.636-unit increase in the efficiency of scientific research. This can be summarized as the conclusion drawn from the analysis.

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Table 5 ***The pairwise correlation of the efficiency of innovation activities in higher education institutions and the influencing factors***

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(1) The Innovation performance efficiency	1.000							
(2) The financial support	0.886	1.000						
	(0.000)							
(3)The experience, staff competencies R&D	0.433	0.512	1.000					
	(0.000)	(0.000)						
(4) scientific cooperation with other universities and research centers	0.447	0.543	0.426	1.000				
	(0.000)	(0.000)	(0.000)					
(5) material and technical support	0.842	0.887	0.469	0.490	1.000			
	(0.000)	(0.000)	(0.000)	(0.000)				
(6) internal institutional support	0.358	0.432	0.372	0.434	0.443	1.000		
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)			
(7) student participation in scientific research	0.785	0.822	0.461	0.498	0.795	0.467	1.000	
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)		
(8) External regional infrastructural support	0.279	0.336	0.253	0.377	0.333	0.400	0.405	1.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	

The analysis of research results demonstrated an effectiveness of 88.6% in the interaction between innovative activities and financial sustainability, provision of material and technical base with 84.2%, and ensuring student participation in research work with a 78.5% strong correlation. Additionally, according to the Pearson correlation test, the statistical significance of the model was confirmed. (Table 5)

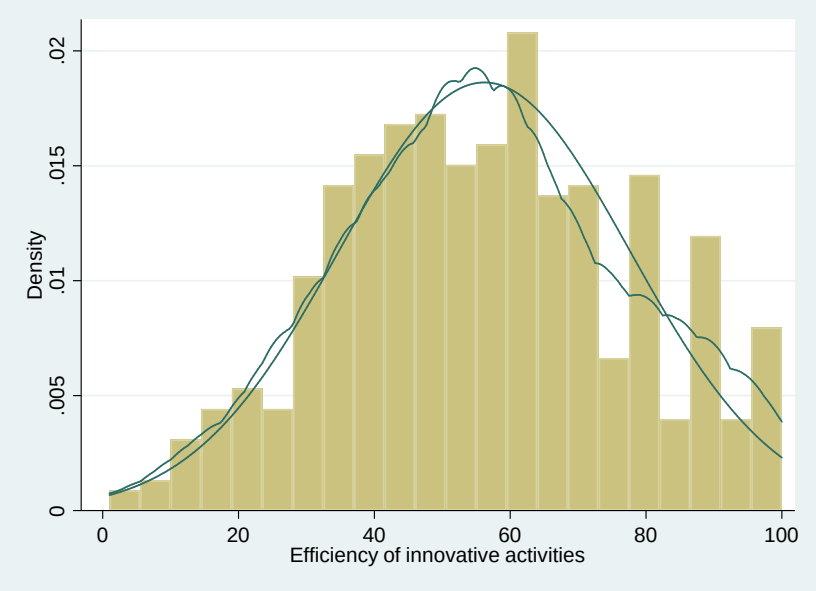

Figure 5. Normal distribution histogram of indicators of efficiency of innovative activities.

Table 6 ***Robust linear regression model for factors influencing the efficiency of university innovative activities.***

The Innovation performance efficiency	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
z_1	6.046	.486	12.44	0	5.091	7	***
z_2	-.217	.235	-0.92	.358	-.678	.245	
z_3	-.355	.242	-1.47	.143	-.83	.121	
z_4	2.348	.438	5.36	0	1.487	3.209	***
z_5	-.462	.232	-1.99	.047	-.918	-.006	**
z_6	1.636	.361	4.53	0	.927	2.345	***
z_7	-.304	.223	-1.37	.172	-.742	.133	
Constant	10.148	1.711	5.93	0	6.786	13.511	***

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*** $p<.01$, ** $p<.05$, * $p<.1$

Robust regression, a model that minimizes the standard errors of each independent variable in the regression process, forms an R-squared value of 0.811 for the model. This R-squared value indicates that the model explains 81% of the variance in financial outcomes. The F-test with a very low p-value of 0.000 indicates the statistical significance of this model.

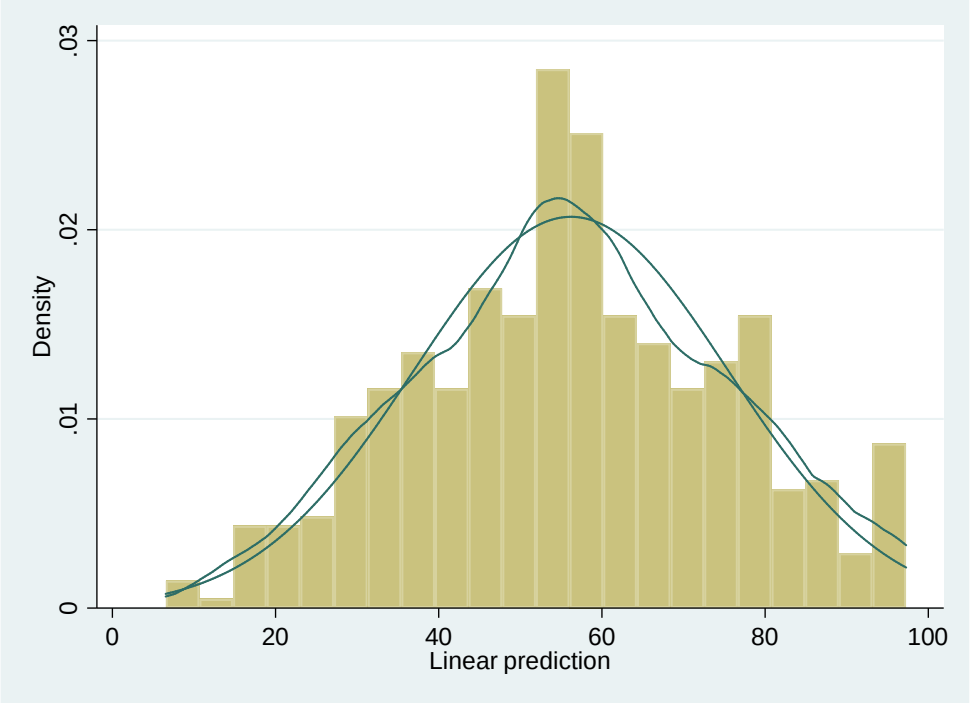

Figure 6. Analysis of variance (ANOVA test) for the dispersion of factors influencing the efficiency of university innovative activities.

In summary, the conducted research revealed that only hypotheses H_1, H_2, H_4, *and* H_6, which are related to x_2, x_4, x_6, *and* z_1, z_4, *and* z_6 variables, respectively, were confirmed based on the collected data.

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