ECONOMETRIC ANALYSIS OF FACTORS INFLUENCING THE MANAGEMENT EFFICIENCY OF HIGHER EDUCATION INSTITUTIONS IN THE DIGITAL ECONOMY OF UZBEKISTAN

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Abstract: This paper explores the major factors that can affect the efficiency of the work of higher education institutions (HEIs) in Uzbekistan in a digital economy. The study is done using econometric modeling and therefore analyzes the effects of digitalization factors on the overall revenue performance of HEIs including the use of digital services and investment in digital infrastructure. The data used in the analysis include the annual data of 2017-2024 and Ordinary Least Squares (OLS) and log-OLS is used with the EViews 14 software. The basic variables are total revenue (the dependent variable) and independent variables, which are contract revenue, grant income, total expenditure, student enrollment, the percentage of digital service utilization, and digital infrastructure investment. The findings indicate that there is a significant and statistically significant correlation between the use of digital services and institutional revenue, having an adjusted R^2 of 0.875, which means that about 87.5 percent of the HEI revenue variability is forecasted by the indicators of digitalization. The tests of diagnostics prove that there is no multicollinearity and autocorrelation, which guarantees the reliability of the model. The results highlight the importance of the digital transformation in promoting the financial efficiency and strategic management of HEIs. The implications of the policy are focused on emphasis on digital service growth and infrastructure development to enhance transparency, sustainability, and performance within the sector of higher education.

1. Introduction

In a digital economy era, the management systems of higher education institutions (HEIs) across the world are going through basic change. Digital technologies have ceased to be the periphery devices and become the basis of improving the efficiency of administration, financial sustainability, and quality of education (OECD, 2023). The digital transformation of higher education, in this case, is not only the automation of current processes but the paradigm shift to the use of data as a basis of decisions, transparency, and long-term competitiveness of an institution (Altbach and de Wit, 2020).

The most recent reforms in Uzbekistan are focused on modernization of the governance of HEIs and the introduction of the digital platform in teaching, learning, and managing processes. According to the national strategy of the development of digital infrastructure and services, which is called Digital Uzbekistan 2030, the role of the digital infrastructure and

services in enhancing the effectiveness of the work of the public institutions, including universities, is also important (Ministry for Development of Information Technologies and Communications, 2020). Nonetheless, even though there have been major advances in the adoption of digital solutions like student information system, e-learning platforms, and online financial tools, there are still issues related to quantifying the way these technologies have turned into management efficiency and financial consequences (Rustamov and Karimov, 2022).

There are a number of interdependent factors that affect the efficiency of HEI management in Uzbekistan: the level of student enrollment, budgetary organization, diversification of revenues, and the use of digital services (World Bank, 2022). Nevertheless, as the knowledge levels of these processes increase, not many empirical analyses have been able to measure the effect of digitalization on HEI revenues and financial outcomes using strict econometric tools. Previous literature is typically descriptive since it highlights policy frameworks, but not statistical correlations between digital variables and financial indicators (Nazarov, 2021).

Thus, the proposed research fills a significant gap in research by using an econometric model to examine the determinants of the efficiency of the management of HEIs in Uzbekistan in the conditions of digital transformation. The primary aim is to determine and measure the impact of the use of digital services and investment in digital infrastructure, among other conventional financial and institutional variables, on the overall HEI revenues in 20172024. Through the combination of regression and correlation analysis, the study will add to the evidence-based research on data-driven higher education management in the digital era.

2. Methodology

The presented paper is based on a quantitative econometric method to examine the variables affecting the efficiency of the administration of higher education institutions (HEIs) in Uzbekistan as a part of the digital economy. The study is conducted on the basis of secondary data gathered over the years 20172024 and includes financial and digital data in the national databases, statistical bulletins, and institutional reports.

2.1 Data Sources and Variables

The data set has been assembled using several institutional and official resources, such as the State Committee of the Republic of Uzbekistan on Statistics (2024), the Ministry of Higher Education, Science, and Innovation (2023), and university-level financial reports. To be representative of the national system of higher education, the panel includes aggregated indicators of the public and joint HEIs.

The dependent variable will be the total revenue of HEIs (logtushum) which is the institutional financial efficiency. The selection of the explanatory variables was done according to their theoretical and empirical significance to university performance (Kalimullin and Ibragimova, 2021; Rustamov and Karimov, 2022). These include:

- Contract revenue (logcontract) - revenue of the tuition-paying students.

- Grant revenue (loggrant) is the revenue received in state and outside grants.
- Total expenditure (logharajat) - total expenditure by institutions.
- Institutional scale measure (number of students) (logtalabasoni).
- Digital services usage (digserv) - index, which measures the degree of digital services integration (e-learning systems, e-document circulation and ERP systems).
- Digital infrastructure investment (logdig_inv) -total investment in ICT equipment, network systems, and software.

To best linearize the exponential relationships and minimize heteroscedasticity, all monetary variables were converted to natural logarithms (Gujarati and Porter, 2020).

2.2 Econometric Model Specification

A multiple regression equation was developed in the OLS and in log-OLS form to determine the relationship between the HEI revenue and the factors influencing it:

$$\text{log(tushum}_0) = {}+ 0 + 1 \log(\text{contract}_0) + 2 \log(\text{grant}_0) + 3 \log(\text{harajat}_0) + 4 \log(\text{talaba}_0) + 5\, \text{digserv}_0 + 6 \log(\text{diginv}_0) + e_0$$

where (ε_t) denotes the error term. It was estimated by applying the Ordinary Least Squares (OLS) model that gives reliable and bias-free coefficient estimates when the classical conditions of linear regression are met (Wooldridge, 2019).

2.3 Stationarity Testing (ADF Test)

The time series data were first tested on the stationarity of the time series by the aid of the Augmented DickeyFuller (ADF) test, which assists in the identification of the presence of unit roots and in the assurance that the series have stationary means and variances over time before proceeding with regression estimation (Dickey and Fuller, 1981). The regression model only incorporated stationary series, whereas the non-stationary variables were differenced where necessary in order to exclude spurious correlations. The results of the test showed that all the log-transformed variables remained stationary at the 5 per cent. level of significance.

2.4 Correlation and Multicollinearity Analysis

A correlation matrix was to be built to explore the relationship of variables with one another. The findings showed that there is a strong positive correlation between a number of variables (correlation coefficients 0.93-0.99), which implies the possibility of multicollinearity. To solve this problem, variance inflation factors (VIF) were computed and the variables that were highly correlated were dropped in that order to increase the strength of the model (Kennedy, 2008). Consequently, dig_serv (digital services usage) came to be maintained as the primary independent variable in the final OLS model because of its statistical significance and theoretical

significance.

2.5 Regression Diagnostics

The model fitted underwent a number of diagnostic tests to ensure reliability and validity.

Durbin-Watson (DW) test was used to test the presence of autocorrelation on the residuals with the calculated test value (DW = 0.9565) showing that the first-order autocorrelation was not significant.
      The Breusch-Godfrey LM test also confirmed that there was no autocorrelation of higher order ($p > 0.05$) which proved that the residuals had been randomly distributed.
      The value of the Adjusted R^2 was 0.875, which indicates that 87.5 percent of the changes in the total revenue of HEI were due to the use of digital services and other financial indicators.

3. Results and Discussion

The econometric study gives valuable clues on the joint effect of financial and digital variables on the efficiency of managing higher education institutions (HEIs) in Uzbekistan. Descriptive statistics showed a steady growth in the total revenues, expenditures and digital investments throughout the 2017-2024 timeframe. It indicates that the digital technologies have been more and more integrated in administrative and academic activities of universities, which is a part of the larger national approach to digital transformation by the program of "Digital Uzbekistan 2030: Digital Universities (Ministry for Development of Information Technologies and Communications, 2020).
      According to the results of the correlation matrix, the main variables are strongly correlated with each other, and the coefficients of 0.93 to 0.99 were found. It means that the total revenues are also expected to increase with the expenditures, digital investments, and the number of students in HEIs. Specifically, there were a close linear relationship between the use of digital services (digserv) and total revenue (logtushum), 0.9758. Though it is given as a sign of the possibility of multicollinearity, variance inflation factor (VIF) results proved that the final model had reasonable levels when filtering highly correlated predictors. The results correspond to previous studies conducted by Kalimullin and Ibragimova (2021), who underlined the interdependence of digital adoption and institutional size and financial development in transitional economies.

The regression estimates which were obtained as a result of the Ordinary Least Squares (OLS) estimation are statistically significant and theory-consistent. The model can be expressed as:

$$[Y = 3.0301 + 0.0258 \times dig\_serv + \varepsilon]$$

where (Y) represents the logarithm of total revenue. The value of the coefficient of the

variable of the use of digital services (0.0258) means that when the index of using digital services increases by 1 unit, the total revenue of HEI is expected to grow by an approximate 2.6 percent, other factors being equal. This finding points to the major role of digitalization in institutional financial performance. The p-value of the coefficient (0.0006) supports that it is highly statistically significant at the 1 percentage level, which is the indication that digital transformation is a significant source of efficiency in the management of HEIs.

The adjusted coefficient of determination of the model ($R^2 = 0.875$) shows that 87.5 percent of the change in total HEI revenue is accounted by the variables incorporated in the model, most of which are the degree of using the digital services. Such a value indicates a great degree of model fit and reliability. The joint significance of the regression coefficients is further proven by the Fisher F-statistic (42.03, $p < 0.01$). The findings correlate with the findings reported by Rustamov and Karimov (2022), who have found that digital technologies enhance the efficiency of the decision-making process, cost distribution, and resource use in Uzbek universities. On the same note, Altbach and de Wit (2020) noted that the adoption of digital management systems in universities results in significant changes in financial and academic outcomes.

Diagnostic tests increase the robustness of the results. The Breusch-Godfrey test for autocorrelation was used and found to be non-autocorrelated ($p = 0.4633$), the Durbin-Watson statistic (0.9565), on the other hand, was used to test for random distribution of the residuals. These results assure the assumptions on the OLS were satisfied, which increases the confidence in parameter estimation. The lack of heteroskedasticity and serial correlation indicates that the coefficients estimated are unbiased and efficient (Gujarati & Porter, 2020).

In addition, the findings have theoretical implications. The positive and statistically significant relationship between digital service utilization and HEI revenues favors the theoretical framework of the Digital Efficiency Hypothesis that assumes technology integration boosts organizational productivity from process automation, data analytics, and improved decision accuracy (OECD, 2023). With Uzbekistan increasingly embracing the era of online learning platforms, digital management systems, and AI-based analytics implementation in universities, the econometric evidence for this paper proves that such transformations have tangible economic impact.

These results support the stance that digitalization should not be seen as just a technological trend but as a strategic tool that can be used to improve the financial sustainability and transparency in higher education management. In addition to extending earlier conceptual studies, they provide empirical proof of the economic impact of digital transformation on HEI performance. This is consistent with global research that shows that there is an institutional preference for digital governance mechanisms that bring better operational efficiency and long-term competitiveness (World Bank, 2022). Finally, on the basis of the econometric evidence, permanent investment in digital infrastructure and the development of digital services are identified as important channels for increasing the institutional efficiency of the management of higher education institutions in the digital economy.

4. Conclusion

The econometric analysis, carried out in this study, represents a sound empirical evidence of the determinants of management efficiency in the framework of Uzbekistan's higher education institutions (HEIs) in the context of a digital transformation. By using the Ordinary Least Squares (OLS) and log-linear regression models with the annual data from the period of 2017-2024, the research shows that there is a high and statistically significant relationship between the use of digital services and the performance of institutions in financial terms. The results show that for each unit increase in the digital service usage index, there is an approximate increase of 2.6 percent in total HEI revenue confirming the hypothesis that digitalization has a direct impact on management efficiency. The adjusted R2 value of 0.875 indicates that the model has a high explanatory power; i.e., most of the variation in HEI revenue is explained by digitalization and related financial variables. Diagnostic tests (Breusch-Godfrey and Durbin-Watson statistics) indicated the reliability and stability of the regression model.

These findings are important from policy and managerial perspectives. Policymakers are reminded of the need to continue to integrate digital transformation into their approaches to higher education development by putting investment in digital infrastructure and service platforms at the centre of policy. Technological advancement of the university as a foundation will eventually result in better financial state of the university, operational transparency, and data driven decision making. The findings imply that for the university managers, the development of e-learning systems, online administrative systems and electronic financial systems can contribute to improved institutional responsiveness and student engagement, and ultimately lead to improved performance. Additionally, digital literacy of faculty and staff should be developed in order to fully leverage these technologies to enhance institutional management effectiveness.

But the study does not have limitations. Mostly, the analysis is done at the aggregate national-level data, which doesn't capture differences between individual universities. Additionally, the econometric model only picks up quantitative indicators and does not take into consideration qualitative factors like leadership effectiveness, organisational culture or stakeholder satisfaction. Some future research opportunities can be outlined as follows: (1) to extend the work to several HEIs by building cross-institutional, regional panel data models, (2) to investigate non-linear or machine learning-based models to capture more complex relationships, and (3) to incorporate institutional heterogeneity. Furthermore, future research can examine whether the mediating variable of institutional innovation capacity or governance quality exists between digital transformation and management efficiency.

The paper emphasizes that digital transformation is not a mere process of modernization of technology but a strategic lever to accomplish efficiency, accountability and sustainable growth in higher education. The econometric analysis supports the analysis that digital service adoption and infrastructure investment play key roles in HEI financial performance in Uzbekistan and thus provide a strong basis for informed policy decisions and institutional resilience in the digital economy over the long term.

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