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Cost Efficiency Analysis of Public Higher Education Institutions in Uzbekistan

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Abstract

This study examines the cost efficiency of public higher education institutions (HEIs) in Uzbekistan during the period 2000–2013, when the financing structure was gradually shifting from strong dependence on government funding toward greater reliance on tuition revenue. Using stochastic cost frontier analysis, the study evaluates 58 public HEIs and a balanced panel of 812 institution-year observations.

The results show that average cost efficiency remained relatively moderate, although institutional efficiency improved over the 14-year study period. HEIs receiving a larger share of government funding were generally less cost efficient than institutions relying more heavily on tuition revenue. The findings suggest that greater financial responsibility may have encouraged more careful use of institutional resources.

These historical results remain relevant as Uzbekistan's higher education system has expanded rapidly since 2017. By 2025, student enrolment had reached approximately 1.7 million and higher education coverage exceeded 44%. The study therefore provides a useful historical baseline for understanding cost efficiency during Uzbekistan's continuing higher education and financing reforms.

Keywords: Cost efficiency; stochastic frontier analysis; higher education finance; public universities; Uzbekistan.

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1. Introduction

Higher education institutions (HEIs) around the world continue to face pressure to provide high-quality teaching and research while managing limited financial resources. Rising institutional costs, expanding student numbers and increasing expectations from governments and society have made the efficient use of resources an important issue in higher education management. Recent research also shows that efficiency and financial sustainability remain major concerns for universities in both developed and developing countries (Badiee et al., 2024).

One common response to financial pressure has been to reduce universities' dependence on direct government funding and allow them greater financial autonomy. This often includes greater reliance on tuition income and other sources of revenue. However, increasing tuition revenue alone does not guarantee financial sustainability. Universities also need to manage their available resources carefully and ensure that spending produces

appropriate educational outcomes. For this reason, cost efficiency has become an important consideration for both university administrators and policymakers.

The issue is particularly relevant to Uzbekistan. The higher education system has changed considerably in recent years. Access to higher education has expanded rapidly, with enrolment increasing from around 8% in 2017 to approximately 48% in 2024. The number of higher education institutions has also increased substantially (World Bank, 2025). At the same time, reforms have provided greater academic, organizational and financial independence to a growing number of public universities. By 2025, 40 universities had been granted financial autonomy. These developments make effective financial management increasingly important, as universities are expected to expand access while maintaining quality and using their resources responsibly.

Measuring university efficiency is commonly based on the economic idea that institutions should produce the greatest possible level of output from the resources available to them. Farrell (1957) provided an important foundation for modern efficiency analysis by distinguishing between efficient and inefficient use of inputs. Since then, frontier methods, including stochastic frontier analysis (SFA) and data envelopment analysis (DEA), have been widely applied to universities. Recent reviews confirm that research on higher education efficiency has grown considerably, although evidence from developing countries remains less extensive than that from developed economies (Jain, 2025).

This study examines cost efficiency in 58 public HEIs in Uzbekistan over the period from 2000 to 2013. Although the data represent an earlier stage of the country's higher education development, they provide useful evidence on how universities managed the transition from predominantly government-supported financing toward greater dependence on tuition revenue. The study applies stochastic cost frontier analysis to measure institutional cost efficiency and to examine factors associated with differences in efficiency.

The study contributes to the literature in several ways. First, it provides evidence from Uzbekistan, a context that has received relatively limited attention in the international literature on higher education efficiency. Second, it uses a 14-year panel, which provides a longer observation period than many earlier stochastic frontier studies. Third, the analysis includes two student-related factors to account for differences in the quality of educational outputs. Finally, HEIs are compared according to the proportion of their revenue received from government funding. This makes it possible to examine whether institutions with a greater dependence on public allocations differ in cost efficiency from those receiving a smaller share of government support.

The remainder of the paper is organized as follows. The next section provides an overview of the higher education system in Uzbekistan. Section 3 explains the data, variables and stochastic frontier methodology used to estimate cost efficiency. Section 4 presents and discusses the empirical findings, including institutional inefficiency scores and the relationship between government funding and cost efficiency. The final section summarizes the main findings and their implications.

2. An Overview of the Uzbek Higher Education System

The higher education system of Uzbekistan has changed considerably over the past two decades. Traditionally, public higher education institutions (HEIs) depended heavily on state-budget funding, while additional income was generated mainly through tuition fees and other institutional activities. During the period covered by this study, 2000–2013, government allocations were largely based on student numbers, state grants, staff salaries, scholarships, infrastructure and other operating costs. At the same time, universities increasingly relied on extra-budgetary income, particularly tuition payments from fee-paying students.

Historical data show that the role of tuition revenue increased substantially during this period. By 2013, off-budget funding at public HEIs was considerably higher than at the beginning of the study period, and tuition payments represented the largest part of this income. Revenue from research, public services and other activities remained relatively limited. This shift made the efficient management of institutional resources increasingly important, especially as universities were expected to cover a growing share of their operating costs from non-budget sources.

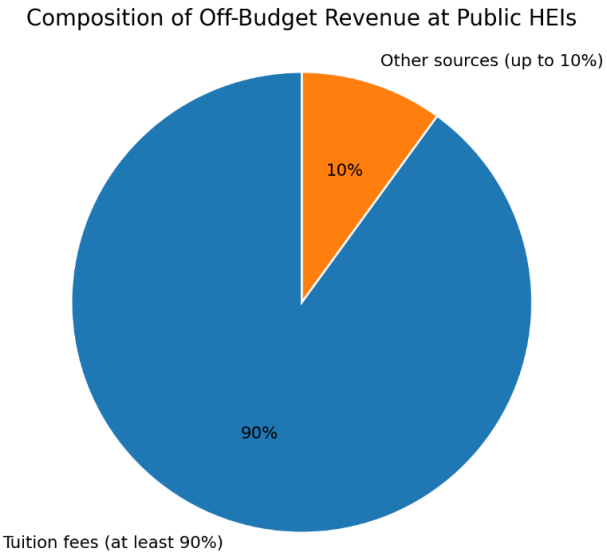


Figure 1. Reported composition of off-budget revenue at public HEIs

Note. The original data report tuition at more than 90% and other sources at less than 10%; the 90/10 split is shown only as the boundary for visualization.

Government expenditure on higher education also increased between 2007 and 2013, but a large share of public funding continued to be directed toward salaries and student stipends. This left relatively less funding for capital investment and other institutional needs. As a result, the question was not only how much funding universities received, but also how efficiently those resources were used. This issue is central to the present study, which compares cost efficiency across public HEIs with different levels of dependence on government funding.

Since 2017, the higher education sector has expanded much more rapidly. According to the Ministry of Higher Education, Science and Innovation, the number of HEIs reached 207 by 2025 and total student enrolment rose to approximately 1.7 million, compared with about 280,000 students in 2017 (Ministry of Higher Education, Science and Innovation, 2026). This expansion reflects a major change in the scale and structure of the national higher education system.

Participation has also increased sharply. The World Bank reports that youth enrolment in higher education rose from about 8% in 2017 to 48% in 2024 (World Bank, 2025). Figure 2 shows the 2024 participation rate as a share of the relevant youth population. Although access has widened considerably, rapid expansion also places greater pressure on financing, infrastructure and institutional management.

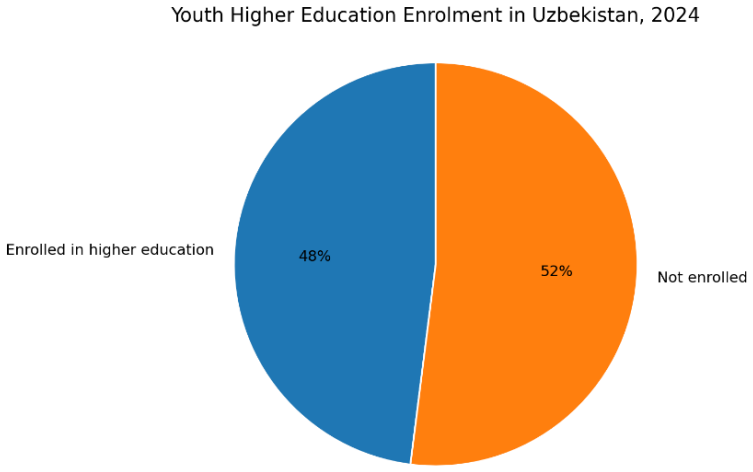


Figure 2. Youth higher education enrolment share in Uzbekistan, 2024

Source: World Bank (2025).

Financial autonomy has also become a more important part of recent reform. In 2025, the President of Uzbekistan reported that 40 universities had been granted financial independence. This gives institutions greater responsibility for managing their own resources and strengthens the importance of financial performance, accountability and cost efficiency (President of the Republic of Uzbekistan, 2025).

The present study nevertheless focuses on the earlier 2000–2013 period. This period captures an important stage in the transition from a predominantly state-supported financing model toward greater reliance on tuition and institutional income. Examining cost efficiency during this period provides evidence on whether differences in the share of government funding were associated with differences in institutional financial performance. The recent expansion of higher education makes this historical evidence particularly relevant, because resource efficiency remains an important issue as the system continues to grow.

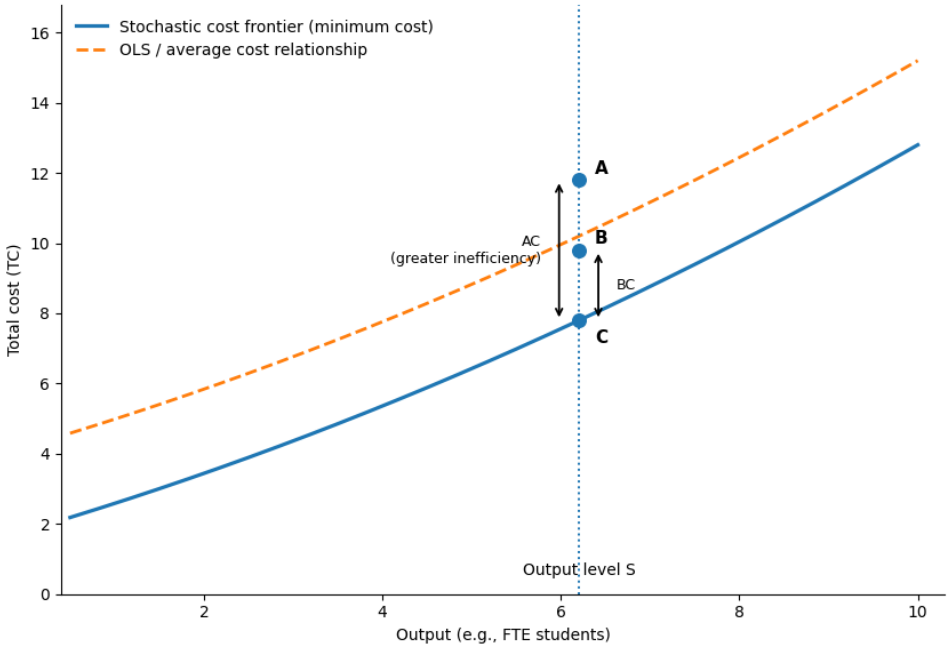
Note. Figure 1 summarizes historical funding composition within the study context, while Figure 2 provides current system context. Figure 2 is not part of the 2000–2013 panel used in the stochastic frontier analysis.

3. Methodology and Data

3.1 Stochastic cost frontier analysis

Using information on the outputs and the price of the inputs, together with a behavioural assumption that public universities' objective is to minimise costs, the cost frontier and efficiency of the Uzbek HEIs can be estimated (Kumbhakar and Lovell, 2000). This assumption seems a plausible since all public higher education establishments in Uzbekistan are not-for-profit entities, as in many other countries (NHDR, 2011).

Figure 3. Conceptual Illustration of Stochastic Cost Frontier and Cost Inefficiency



The cost frontier shows the best that can be attained economically, and it also describes standards against that the economic efficiency of institutions can be measured (Kumbhakar and Lovell, 2000). In other words, in a given output level and input prices relying on available technology of production that the stochastic cost frontier model estimates minimum cost. Afterwards, institutional cost efficiency can be defined by dividing the estimated (minimum) cost to actual (observed) cost. The concept of cost frontier analysis and cost inefficiency is presented in Figure 3 in order to give a more intuitive explanation for how SFA works. This figure describes the relationship between total costs (TC) and an output (e.g., a FTE student) of institutions. As an example, the author uses three imaginary HEIs (A, B and C) each with different costs but produce same level of output, S. A typical regression analysis such as OLS characterises the relationship between average costs and output, thus it predicts the behaviour of the average institution (Wooldridge, 2002). In the OLS estimation, contrary to the cost-minimisation assumption, some observations can lay below the regression line as a university C in Figure 3. However, the stochastic frontier predicts a minimum cost at given level of output relative to OLS, therefore there cannot be any institution with observed cost less than the minimum cost.

According to the SFA, the university C is cost efficient and it shows the minimum feasible cost for producing a FTE student. However, universities A and B are less cost efficient in producing output, S. The cost inefficiency for university B with output, S, and total cost, TC_B, is the ratio of the distance between C and S to the distance between B and S. Therefore, the institution A is less efficient than institution B, because the distance AC is longer than distance BC. Since actual total costs, TC_A, TC_B and TC_C, are observable, estimation of cost frontier is required to evaluate cost efficiency level of the HEIs. According to many scholars, universities should be treated as multiproduct organisations, since their activities are aimed to teaching, research and public services (Cohn et al., 1989; Johnes and Johnes 2013; Kumbhakar and Lovell, 2000; Robst, 2001). The traditional multiple-output cost function which examines the impacts of the multiple outputs and input prices on the institutional cost is usually interpreted as:

$$TC = c(y, w; \beta, \gamma) \quad (1)$$

Where, TC - is the total cost; y - is a vector of output variables; w - is a vector of input prices; and β and γ are parameters to be estimated.

Stochastic frontier cost function (SFCF) following the pioneering works of Aigner, Lowell and Schmidt (1977) and Meeusen and Van den Broeck (1977) is specified as:

$$TC_i = c(y_i, w_i; \beta, \gamma) + v_i + u_i \quad \text{or} \quad TC_i = \beta y_i + \gamma w_i + v_i + u_i \quad (2)$$

Where, $\beta y_i + \gamma w_i + v_i$ is the optimal, frontier target (e.g., the minimum cost) pursued by institution. $\beta y_i + \gamma w_i$ is the deterministic fraction of the frontier and $v \sim N[0, \sigma_v^2]$ is the stochastic fraction, these two parts together constitute the stochastic frontier (Greene, 2008).

The SFCF was extended to panel data by Battese and Coelli (1993, 1995), and the general form of total cost for university i and time t can be represented as:

$$TC_{it} = c(y_{it}, w_{it}, z_{it}; \beta, \gamma, \theta) + v_{it} + u_{it} \quad (3)$$

$i = 1, 2, \dots, N; \qquad t = 1, 2, \dots, T,$

z_{it} - is a vector of observable explanatory variables that impact costs directly, and θ is a parameter to be estimated.

Also, equation (3) can be interpreted in the following way:

$$TC_{it}^M = \beta y_{it} + \gamma w_{it} + \theta z_{it} + v_{it} \leq TC_{it}^O \quad (4)$$

$$TC_{it}^O = TC_{it}^M + u_{it} \quad (5)$$

Where, $u_{it} \geq 0$.

Combining equations (4) and (5) leads to:

$$TC_{it}^O = \beta y_{it} + \gamma w_{it} + \theta z_{it} + \varepsilon_{it} \quad (6)$$

Where, TC_{it}^M - represents university i's minimum potential (estimated) cost at time period t; TC_{it}^O - the actual (observed) total expenditures for university i and time t. The institution's actual total cost (TC_{it}^O) is normally greater than or equal to the minimum estimated cost (TC_{it}^M). Moreover, SFA characteristically assumes that the regression residual consists of two error components ($\varepsilon_{it} = v_{it} + u_{it}$). The first error component, a normally distributed random error (v_{it}) captures the factors outside the control of the institutions, measurement errors and the usual statistical noise. The second component (u_{it}) evaluates the causes of cost efficiency such as input characteristics, various environmental factors and managerial decisions. This term can be estimated in the following way:

$$\text{Cost efficiency} = \frac{\beta y_{it} + \gamma w_{it} + \theta z_{it} + v_{it}}{\beta y_{it} + \gamma w_{it} + \theta z_{it} + v_{it} + u_{it}} = \frac{TC_{it}^M}{TC_{it}^O} \quad (7)$$

This cost efficiency term is assumed to have a strictly non-negative distribution ($u_{it} \geq 0$) and A HEI can be interpreted as cost efficient if that institution reaches its minimum cost, where ($u_{it} = 0$). The u_{it} is usually assumed to be half-normal distribution truncated at zero, or an exponential distribution (Greene, 1993). A researcher selects and imposes the shape of the distribution of the efficiency term.

In the early 1990s, Kumbhakar, Gosh and McGulkin (1991) introduced a method for measuring both frontier and inefficiency term of firms with external factors serving as determinants of inefficiency. Further, Battese and Coelli (1993, 1995) modified the method for panel data with time-varying inefficiency which allows inefficiency to change over time. In this study, we employ the method of Battese and Coelli (1995) which can rest upon the assumption that the cost frontier is indirectly influenced by the external factors through

influencing the inefficiency term. Therefore, z_{it} are assumed as determinants of cost inefficiency and the inefficiency influences in the stochastic cost frontier equation (6) is defined as:

$$u_{it} = \delta_0 + \sum \delta z_{it} + w_{it} \quad (8)$$

Where w_{it} is the random variable which is defined by the truncation of the normal distribution with zero mean and (σ^2), such that ($w_{it} \geq -\sum \delta z_{it}$). Battese and Coelli (1995) stated that "these assumptions are consistent with u_{it} being a non-negative truncation of the $N(\delta z_{it}, \sigma^2)$ distribution".

The next step is to choose a relevant functional form in order to assess the relationship between the institutional expenditure and explanatory variables. In general, the selection of functional form is mostly motivated by the data character and availability, as well as by sample size. In the context of higher education, the total costs of universities have been estimated using different functional forms in the case of different countries. For example, Izadi et al. (2002) opted for CES functional form for the UK HEIs; McMillan and Chan (2006) used Cobb-Douglas functional form for the Canadian universities; in their recent published papers, Daghbashyan (2011) and Sav (2012) applied Cobb-Douglas cost function for the Swedish and American universities, respectively. However, there are some other scholars who preferred to use the more flexible functional forms: Agasisti (2016), Horne and Hu (2008) and Robst (2001) utilised the trans-log cost function for the HEIs in Australia, Taiwan and America, respectively; Johnes and Johnes (2009) and Agasisti and Johnes (2015) opted for Quadratic cost functional form for the British HEIs.

In many efficiency studies, the trans-log and Cobb-Douglas specifications have been eschewed by many scholars considering the costs of multiproduct entities because the predicted value of costs for HEIs that produce zero values of some outputs are nonsensical. According to Baumol, Panzar, and Willig (1982) that the cost function of a multiproduct entities should meet a number of requirements. Foremost, "cost functions must allow sensible predictions to be made for the costs of institutions that produce zero levels of some outputs" (Agasisti and Johnes, 2015; p. 71). In this study, none of the HEI in the sample produces zero of any of the outputs. Therefore, this research does not violate the desiderata of Baumol et al. (1982). Moreover, the function need not be linear in order to allow for economies of scale or scope. Since the main purpose of this study is to measure efficiency level of HEIs using the determinants of inefficiency rather than issues such as economies of scale and scope, this study does not face this problem and can apply the translog functional form. I specify the following translog cost function, which will be estimated using the SFA:

$$lnTC_{it} = \beta_0 + \beta_1 lnUG_{it} + \beta_2 lnPG_{it} + \beta_3 lnRES_{it} + \gamma_1 \, ln\, SALARY_{it} + 0.5\beta_{11}(lnUG)^2 + 0.5\beta_{22}(lnPG)^2 + 0.5\beta_{33}(lnRES)^2 + 0.5\gamma_{11}(lnSALARY)^2 + \beta_{12} lnUG lnPG + \beta_{13} lnUG lnRES + \beta_{14} lnUG lnSALARY + \beta_{23} lnPG lnRES + \beta_{24} lnPG lnSALARY + \beta_{34} lnRES lnSALARY + \sum_m^8 \theta_m Z_{m,it} + v_{it} + u_{it} \quad (9)$$

Where UG_{it}, PG_{it} and RES_{it} are outputs produced by institution i during time t. UG_{it} - is number of full time equivalent undergraduate students, PG_{it} - is number of full time equivalent postgraduate students, and RES_{it} - is total revenue generated from research and other non-tuition activities. The input price in this analysis is average staff expenditures (total staff costs divided by staff FTE), $SALARY_{it}$. Z_{it} - captures the determinants of cost inefficiency which are institution, staff and student specific characteristics, including two revenue sources; the share of government allocations and the share of tuition revenue. Finally, v_{it} – is a symmetric error component reflects the statistical noise and u_{it} – is a non-negative truncated distribution captures the influences of inefficiency. Additional to the outputs, input-price and determinants of efficiency, this flexible functional form contains quadratics for each output and input variable as well as six interaction terms in order to account for possible nonlinearities.

Battese and Coelli (1995) time-variant inefficiency model is narrated as:

$$u_{it} = \delta_o + \delta_1 STIP_{it} + \delta_2 LOAD_{it} + \delta_3 PROF_{it} + \delta_4 FTS_{it} + \delta_5 SIZE_{it} + \delta_6 MED_{it} + \delta_7 GA_{it} + \delta_8 TR_{it} + w_{it} \quad (10)$$

Through assuming that v_{it} and w_{it} are distributed independently of each other, a simultaneous equations approach that uses one-stage Maximum Likelihood Estimation (MLE) method is applied in this study. The MLE is employed in order to estimate the regressors' parameters of the cost function and the cost inefficiency effect model.

3.2 Data Description

The study uses historical administrative and financial data for public higher education institutions (HEIs) in Uzbekistan covering the period from 2000 to 2013. The main financial variables were obtained from the annual financial reports of public universities and include total institutional costs, research and other non-tuition income, staff expenditure, government allocations and tuition revenue. Data on undergraduate and postgraduate FTE students, together with staff and institutional

characteristics, were obtained from official higher education records.

The government agencies named in the original dataset reflect the administrative structure that existed during the study period. Today, the related functions are carried out within the Ministry of Economy and Finance and the Ministry of Higher Education, Science and Innovation.

All financial variables were originally reported in Uzbek sums. To ensure comparability across years, nominal values were converted into real 2013 Uzbek sums using the Consumer Price Index (CPI). The 2013 price base is retained because it forms part of the original study design.

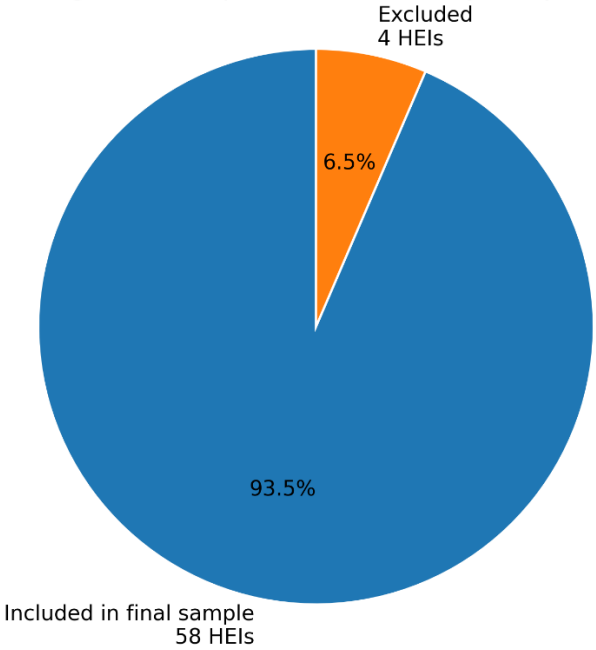
The initial sample contained 62 public HEIs observed over 14 years. Four institutions were excluded because of substantial missing data and zero recorded teaching or research outputs. The final balanced panel therefore consists of 58 HEIs and 812 institution-year observations.

Figure 4 summarizes the composition of the final study sample.

Over the study period, the structure of institutional revenue also changed. Government allocations became less important after the early 2000s, while tuition revenue increased as tuition charges and the number of contract-based students grew. The original data show that tuition revenue rose from approximately 40% of total institutional revenue in 2000 to above 60% by 2013, while the share of government funding declined.

The descriptive statistics of the variables used in the stochastic frontier analysis are presented in Table 4.

Figure 4. Composition of the Study Sample



4. Results

This section presents the results of the stochastic cost frontier analysis using the translog multiproduct specification. It first examines the estimated cost frontier and the main determinants of cost inefficiency, followed by the average efficiency performance of public HEIs and the role of government funding.

4.1 Cost Efficiency Estimates

The Battese and Coelli (1995) time-varying inefficiency model was estimated using one-stage Maximum Likelihood Estimation (MLE). Three models were specified. Model 1 includes institutional and staff characteristics, Model 2 adds student-related factors to account for differences in educational quality, and Model 3 further includes the two main revenue sources: government allocations and tuition revenue.

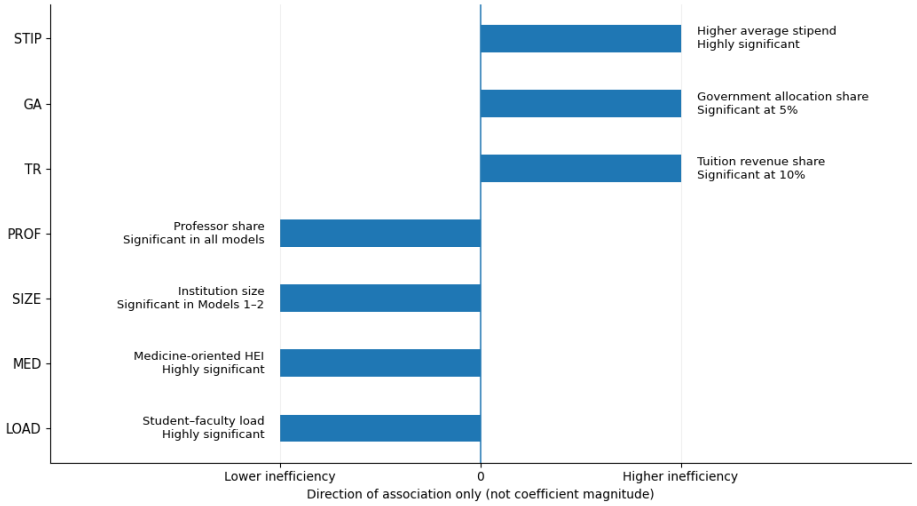
The results reported in Table 3 confirm the presence of cost inefficiency among Uzbek public HEIs. The estimated lambda parameter is statistically significant at the 1% level in all three models, indicating that a substantial part of the variation from the cost frontier is associated with institutional inefficiency rather than random noise.

Undergraduate (UG) and postgraduate (PG) enrolments have positive and statistically significant relationships with total institutional costs across all models. Research and other non-tuition revenue (RES) is also positively

related to cost, although its effect becomes statistically significant only in Model 3 at the 10% level. Staff salary expenditure becomes positive and significant in Model 3, with an estimated cost elasticity of approximately 1.74.

Some interaction effects are also important. The interactions between UG and PG and between PG and RES are negative and statistically significant at the 1% level across all three models, suggesting substitution effects between these outputs.

Figure 5. Direction of Key Determinants of Cost Inefficiency



The inefficiency results provide several important findings. A higher proportion of professors (PROF) is associated with lower cost inefficiency across all models. Institution size (SIZE), measured by total FTE enrolment, is also negatively associated with inefficiency in Models 1 and 2. This suggests that larger universities may benefit from economies of scale.

Medicine-oriented institutions (MED) also show significantly lower cost inefficiency. Although this result may appear unexpected because medical education is generally resource intensive, the estimates indicate that these institutions operated relatively closer to the cost frontier during the study period.

Two student-related factors, average stipend expenditure (STIP) and student–faculty load (LOAD), are highly significant. Higher stipend expenditure is associated with greater institutional cost inefficiency, while a higher student–faculty ratio is associated with lower measured inefficiency. However, lower costs resulting from larger student loads should not automatically be interpreted as better educational performance, since heavier teaching loads may affect teaching quality.

The financing variables provide another important result. Both the share of government allocations (GA) and the share of tuition revenue (TR) are positively associated with cost inefficiency. Government funding is statistically significant at the 5% level, while tuition revenue is significant at the 10% level. This suggests that, during the sample period, a greater dependence on either major revenue source was associated with higher cost inefficiency.

Figure 5 summarizes the direction of the main statistically significant factors. Positive relationships indicate factors associated with higher cost inefficiency, while negative relationships indicate factors associated with lower inefficiency. The figure presents only the direction of the estimated relationships and should not be interpreted as showing coefficient magnitudes.

A Cobb-Douglas specification was also examined as a robustness check. The likelihood-ratio test rejected the restriction that all second-order terms were equal to zero, supporting the use of the more flexible translog specification.

5. Conclusion

This study examined the cost efficiency of 58 public higher education institutions (HEIs) in Uzbekistan during 2000–2013 using stochastic frontier analysis and the Battese and Coelli (1995) model. The results show that cost efficiency improved over the study period, although the average efficiency level remained below its potential. Institutional spending was more strongly associated with undergraduate teaching than with postgraduate education and research activities.

Several factors were linked to cost efficiency. A higher share of professors and a larger institutional size were associated with lower cost inefficiency, suggesting possible benefits from stronger academic capacity and economies of scale. At the same time, a higher student–faculty ratio reduced measured costs. This result should be interpreted carefully because reducing costs through larger teaching loads may negatively affect educational quality.

The financing structure also produced an important finding. HEIs with a larger share of tuition revenue and a lower dependence on government funding generally showed better cost efficiency. Institutions where the government funding share fell below 40% improved more than those where public funding remained at 50% or above. However, this result should not be interpreted as evidence that government funding itself causes inefficiency. Greater financial responsibility may simply have encouraged institutions to manage their resources more carefully.

The present higher education system is very different from the system observed during 2000–2013. In its January 2026 review, the Ministry of Higher Education, Science and Innovation reported that Uzbekistan had 207 HEIs and around 1.7 million students, while higher education coverage had exceeded 44%. The system also includes state, private and foreign universities and branches. This rapid expansion has made efficient resource management even more important.

Financial reform is continuing in 2026. The government is developing new approaches to higher education financing, including reforms to student financial support and preparation for an income-contingent student loan model. Financially autonomous universities also have greater responsibility for managing resources and institutional services. These changes mean that cost efficiency should now be considered together with educational quality, student outcomes, access and financial sustainability.

For university management, the main lesson is that efficiency should not simply mean spending less. Institutions need to use resources in ways that improve teaching, research and student outcomes. Universities with lower efficiency levels may benefit from examining the practices of better-performing institutions, while maintaining appropriate staffing, academic quality and student support.

Future research should therefore use more recent institutional-level data covering the period of rapid expansion and financial reform after 2017. Comparing stochastic frontier analysis with Data Envelopment Analysis (DEA) could provide an additional robustness check. New studies should also include indicators such as graduate employment, research performance, student progression, learning outcomes and institutional financial sustainability. This would provide a more complete picture of whether recent higher education reforms have improved both efficiency and educational performance.

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