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Analysing the relationship between education and economic growth in Uzbekistan: a VAR model approach

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This paper explores the relationship between education and economic growth in Uzbekistan using the Vector Autoregressive (VAR) model. Employing time-series data from 1991 to 2023, the study examines how government expenditure on education, industry value-added, and GDP per capita interact dynamically. The results reveal that government expenditure on education significantly influences economic growth, with impulse response analysis showing persistent and substantial impacts. However, the contributions of industry value-added and GDP per capita appear more limited and transient. Variance decomposition confirms the dominant role of education expenditure, explaining the largest share of forecast error variance over time. The findings underscore the critical role of educational investment in fostering long-term economic development, particularly in transitioning economies like Uzbekistan. This study contributes to the literature by providing empirical evidence specific to Uzbekistan, addressing gaps in previous qualitative research, and offering actionable insights for policymakers. The findings align with human capital theory and suggest that enhancing educational infrastructure and quality is essential for sustainable economic growth.

Keywords: education, economic growth, VAR model

The relationship between education and economic growth has been a central theme in economic literature for decades, with scholars consistently emphasising the critical role of human capital in driving economic development. Classical economic theories, such as those proposed by *Solow (1956)*, *Becker (1991)*, and *Lucas (1988)*, have laid the foundation for understanding how education enhances labor productivity, fosters technological innovation, and promotes long-term economic growth. Solow's growth model, for instance, highlights the importance of technological progress and human capital accumulation as key drivers of economic growth, while Becker's human capital theory underscores the role of education in improving individual productivity and earning potential. *Lucas*

(1988) further expanded on this by introducing the concept of "learning by doing," suggesting that education not only enhances individual skills but also contributes to broader economic growth through knowledge spillovers and innovation.

In recent years, the focus has shifted toward understanding the mechanisms through which education contributes to economic growth, particularly in the context of knowledge-based economies. *Romer (1986; 1990)* and *Hanushek–Woessmann (2012)* have emphasised the role of education in fostering technological innovation and improving cognitive skills, which are essential for sustained economic growth. These studies suggest that education is not just a passive contributor to growth but an active driver that can shape the trajectory of economic development, especially in emerging and transitioning economies.

Uzbekistan, a country undergoing significant economic and educational reforms, presents a unique case for examining the relationship between education and economic growth. Since gaining independence in 1991, Uzbekistan has implemented various reforms aimed at modernising its economy and improving its educational system. However, despite these efforts, the country still faces challenges in achieving sustainable economic growth, particularly in transitioning from a resource-based economy to a knowledge-based one. Understanding the role of education in this transition is crucial for designing effective policies that can foster long-term economic development.

While the relationship between education and economic growth has been extensively studied in various contexts, there is a notable lack of empirical research focusing on Uzbekistan. Most existing studies on Uzbekistan rely on qualitative analysis or simple regression models, which do not capture the dynamic interactions between education and economic growth. This study aims to fill this gap by employing a Vector Autoregressive (VAR) model to analyse the dynamic relationship between government expenditure on education, industry value-added, and GDP per capita in Uzbekistan. The VAR model is particularly suited for this analysis as it allows for the examination of interdependencies between multiple time series variables without imposing restrictive assumptions on the underlying economic structure.

This study is motivated by the need to provide robust empirical evidence on the role of education in economic growth, particularly in the context of a transitioning economy like Uzbekistan. By examining the dynamic interactions between education expenditure, industry value-added, and GDP per capita, this study seeks to answer the following research questions: (1) How does government expenditure on education impact economic growth in Uzbekistan? (2) What is the relative contribution of education expenditure compared to industry value-added and GDP per capita in explaining economic growth? (3) How do shocks to education

expenditure, industry value-added, and GDP per capita affect each other over time?

This study hypothesises that government expenditure on education has a significant and positive impact on economic growth in Uzbekistan, with long-term effects that outweigh the contributions of industry value-added and GDP per capita. Furthermore, it is expected that the relationship between education and economic growth is bidirectional, with economic growth also fostering further investment in education.

While previous studies have explored the relationship between education and economic growth in various contexts, there is a notable lack of empirical research focusing on Uzbekistan. Most existing studies on Uzbekistan rely on qualitative analysis, with limited use of advanced econometric methods. This study addresses this gap by employing a VAR model to analyse the dynamic relationship between education and economic growth, providing robust empirical evidence that can inform policy decisions. Additionally, this study contributes to the broader literature by examining the role of education in a transitioning economy, offering insights that may be applicable to other similar contexts.

The remainder of this paper is organised as follows. Section 1 provides a literature review, focusing on the theoretical and empirical foundations of the relationship between education and economic growth. Section 2 outlines the methodology, including the VAR model specification, data sources, and variable descriptions. Section 3 presents the empirical results, including impulse response analysis and variance decomposition, and discusses their implications. Section 4 concludes the study by summarising the key findings and offering policy recommendations based on the results.

1. Literature review

1.1 Education and economic growth

Understanding the factors driving a country's economic growth has long been a central concern in economics. Solow examined the sources of economic growth in the United States from 1909 to 1949 and concluded that the primary drivers of growth during this period were the combined contributions of knowledge, technology, and other factors. His findings sparked increased interest among scholars in exploring the impact of elements like education, knowledge, and

technology on economic growth *(Solow, 1956)*. *Schultz (1961)*, *Becker (1962)*, and *Lucas (1988)* analysed the relationship between education and economic development through the lens of human capital, highlighting the importance of education and the "Learn by Doing" approach as key mechanisms for human capital formation.

In the context of developing and transitioning economies, the role of education in economic growth has been further elaborated by scholars such as *Romer (1986; 1990)* and *Hanushek–Woessmann (2012)*. Romer's endogenous growth theory posits that technological progress, driven by human capital and knowledge accumulation, is a key driver of long-term economic growth. *Hanushek–Woessmann (2012)* emphasise the importance of cognitive skills, arguing that the quality of education, rather than just the quantity, is critical for economic development. These theories suggest that education is not merely a passive contributor to growth but an active driver that can shape the trajectory of economic development, particularly in emerging economies.

Empirical studies have also provided substantial evidence supporting the positive relationship between education and economic growth. *Barro (1991)* and *Mankiw et al. (1992)* conducted cross-country analyses and found that higher levels of educational attainment are strongly correlated with economic growth. Barro's study, which examined data from 98 countries, revealed that initial levels of human capital, measured by enrollment rates and GNP per capita, significantly influenced economic growth. Similarly, *Mankiw et al. (1992)* found that education variables had a statistically significant impact on economic growth, reinforcing the idea that human capital development is a key driver of economic progress.

The role of government expenditure on education has also been a focal point in the literature. *Glomm–Ravikumar (1998)* and *Blankenau–Simpson (2004)* explored the internal mechanisms linking public education investment, human capital, and economic growth. Their findings suggest that government spending on education can significantly enhance human capital formation, which in turn drives economic growth. *Özdoğan (2021)* further supports this view, demonstrating that higher education expenditures have dynamic effects on human capital and economic growth, particularly in OECD countries.

In the context of developing countries, studies such as those by *Afzal et al. (2011; 2012)* and *Glewwe et al. (2014)* have examined the relationship between education and economic growth. *Afzal et al. (2011)* found a strong positive relationship between education and economic growth in Pakistan, *Dănăcică (2011)* and *Goumrhar (2024)* had similar result in case of Romania and Morocco, respectively. While *Glewwe et al. (2014)* highlighted the challenges faced by Sub-Saharan African countries, where the quality of education often limits its impact on economic growth. These studies underscore the importance of not only

increasing educational investment but also improving the quality of education to achieve sustainable economic development.

The role of higher education in fostering innovation and technological progress has also been widely discussed in the literature. *Nelson (1993)*, *Lundvall (1999)*, *Etzkowitz–Leydesdorff (1995),* and *Etzkowitz–Klofsten (2005)* argue that higher education institutions play a crucial role in knowledge creation and dissemination, which are essential for innovation-driven economic growth. *Shaffer (2015)* and *Lilles–Rõigas (2017)* further emphasise the role of higher education in promoting innovation, knowledge transfer, and the creation of value-added products and services. These studies suggest that strengthening the linkages between universities, industries, and research institutions is critical for maximising the economic benefits of higher education.

1.2 Methodological approaches in empirical studies

In recent years, advanced econometric techniques such as the Vector Autoregressive (VAR) model have been increasingly used to analyse the dynamic relationship between education and economic growth. *Yu et al. (2014)* employed a VAR model to examine the relationship between higher education investment and economic growth in China, finding that education investment has a significant and positive impact on GDP growth. Similarly, *Seetanah–Teeroovengadum (2019)* analyse the role of higher education in African economic growth, concluding that education is a key driver of economic development. These studies highlight the importance of using dynamic models to capture the complex interdependencies between education and economic growth.

In the context of Uzbekistan, the relationship between education and economic growth has been explored in a limited number of studies. *Ochilov (2014; 2017)* examined the interplay between higher education and economic growth in Uzbekistan, using regression models to analyse the impact of higher education on economic development. However, these studies primarily rely on qualitative analysis and simple regression models, which do not capture the dynamic interactions between education and economic growth. *Nabiyev et al. (2023)* investigated the relationship between higher education and economic growth in Uzbekistan, using regression analysis to assess how variables such as the number of graduates, per capita expenditure on graduates, and the average duration of study correlate with GDP growth. While these studies provide valuable insights, they lack the dynamic perspective offered by VAR models.

The literature also highlights the importance of governance and institutional quality in the effectiveness of education investments. *Pasara (2021)* expanded the

analysis to include governance, highlighting that the effectiveness of education investments in fostering sustainable economic growth depends on institutional quality. This suggests that while education is a critical driver of economic growth, its impact may be moderated by the quality of governance and institutional frameworks.

In summary, the literature on education and economic growth is extensive, with numerous studies highlighting the importance of human capital development in driving economic progress. However, there is a notable lack of empirical research focusing on Uzbekistan, particularly studies that employ advanced econometric techniques such as the VAR model. This study aims to address this gap by providing a dynamic analysis of the relationship between education and economic growth in Uzbekistan, offering robust empirical evidence that can inform policy decisions and contribute to the broader understanding of the role of education in economic development.

2. Methods and data

This study employs a Vector Autoregressive (VAR) model to analyse the dynamic relationship between government expenditure on education, industry value-added, and GDP per capita in Uzbekistan. The VAR model, introduced by *Sims (1980)*, is a widely used econometric tool for analysing the interdependencies between multiple time series variables. Unlike traditional structural models, the VAR approach does not impose restrictive assumptions on the underlying economic structure, making it particularly suitable for capturing the complex and dynamic interactions between education and economic growth. The VAR model is especially useful in this context, as it allows for the examination of how shocks to one variable (e.g., education expenditure) affect other variables (e.g., GDP per capita) over time *(Zhou–Lou, 2018; Li–Liu, 2021; Liu–Li, 2023; Fahim et al. 2023).*

The estimation of a simplified trivariate VAR model is as:

$$\mathrm{GDPpc}_t = \gamma_1 + \sum_{i=1}^{k} \alpha_{1i}\mathrm{GDPpc}_{t-1} + \sum_{i=1}^{k} \delta_{1i}\mathrm{GovEx}_{t-1} + \sum_{i=1}^{k} \sigma_{1i}\mathrm{IndVA}_{t-1} + \mu_{1t} \quad (1)$$

$$\mathrm{GovEx}_t = \gamma_2 + \sum_{i=1}^{k} \alpha_{2i}\mathrm{GDPpc}_{t-1} + \sum_{i=1}^{k} \delta_{2i}\mathrm{GovEx}_{t-1} + \sum_{i=1}^{k} \sigma_{2i}\mathrm{IndVA}_{t-1} + \mu_{2t} \quad (2)$$

$$\mathrm{IndVA}_t = \gamma_3 + \sum_{i=1}^{k} \alpha_{3i}\mathrm{GDPpc}_{t-1} + \sum_{i=1}^{k} \delta_{3i}\mathrm{GovEx}_{t-1} + \sum_{i=1}^{k} \sigma_{3i}\mathrm{IndVA}_{t-1} + \mu_{3t} \quad (3)$$

where GDPpc is GDP per capita, GovEx is government expenditure on education, IndVA is industry value-added, α, δ, and σ are coefficients, μ is shocks, γ is a constant, i = 1, 2, 3, … k are lags and k is the optimal.

The VAR model captures the dynamic interactions between the variables by regressing each variable on its own lagged values and the lagged values of the other variables in the system. This approach allows for the examination of both short-term and long-term relationships between government expenditure on education, industry value-added, and GDP per capita.

The data used in this study are obtained from the World Bank's World Development Indicators (WDI) database, covering the period from 1991 to 2023 (see Table 1).

Table 1

Variable descriptions

Symbol	Variable name	Measurement	Source
GDPpc	Economic growth	GDP per capita (current USD)	WDIs
GovEx	Investment in human capital	Government expenditure on education (% of GDP)	WDIs
IndVA	Industrial development	Industry value-added (in USD)	WDIs

Source: author preparation.

The analysis of the dataset's fundamental statistical properties, including the Jarque-Bera, Ljung-Box, ARCH-LM, and ADF tests, was conducted using MATLAB. Additionally, EViews software was employed to assess the stationarity of the time series data.

3. Results

3.1 Descriptive statistics

Table 2 provides the descriptive statistics for the variables used in the analysis, covering the period from 1991 to 2023. The mean value of government expenditure on education is 6.91% of GDP, with a standard deviation of 1.36%, indicating moderate variability over the study period. The mean GDP per capita is 1,289.72, with a standard deviation of 822.75, reflecting significant fluctuations in economic output per person. The mean industry value-added is 9.97 billion, with a standard deviation of 7.71 billion, highlighting the variability in industrial output over time. The skewness and kurtosis values suggest that the data are not perfectly normally distributed, but the Jarque-Bera test probabilities indicate that the normality assumption holds at a basic level for the purposes of the VAR analysis.

Table 2

Descriptive statistics

Variables	GDPpc	GovEx	IndVA
Mean	1289.72	6.91	9973030303.03
Median	830.41	7.42	5990000000.00
Standard deviation	822.75	1.36	7708899274.88
Skewness	0.48	0.29	0.69
Kurtosis	1.63	2.40	2.21
Jarque-Bera	3.81	0.97	3.48
Probability	0.15	0.62	0.18
Observations	33	33	33

3.2 Stationarity and lag selection

When using secondary data, it is essential to check for stationarity, as non-stationary data can lead to misleading conclusions *(Hendry–Clements, 2003)*. A unit root test is a widely used method to assess stationarity and improve data forecasting accuracy *(Berkowitz–Kilian, 2000)*. The Phillips-Perron tests *(Phillips–Perron, 1988)* were employed to assess the stationarity of differenced variables. It is more reliable when homoscedasticity is assumed and improves accuracy in differentiating between a true unit root and a near-unit process *(Alwago, 2023)*.

The results confirm that GovEx, GDPpc, and IndVA are stationary, as evidenced by adjusted t-statistics that exceed the critical values at the 5% significance level. This ensures that the VAR model is based on stationary data, mitigating issues of spurious regression and aligning with standard econometric practices. Unit root test shows probability 2,55E-07 for GovEx, 0,034229 for GDPpc, and 0,009005 for IndVA.

At lag 1, the Akaike Information Criterion (AIC) = 59.34, Schwarz Criterion (SC) = 59,90, and Hannan-Quinn Criterion (HQ) = 59.52 (almost all minimum values). This indicates that lag 1 is optimal for the VAR model. The Final Prediction Error (FPE) at lag 1 is 1.20e+22*, the smallest among the lags tested.

Table 3

VAR lag order selection criteria

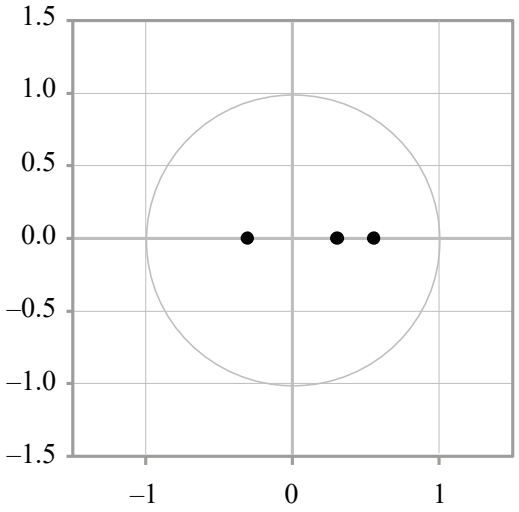
Lag	LogL	LR	FPE	AIC	SC	HQ
0	–893.3752	NA	1.80E+22	59.75835	59.89847*	59.80317
1	–878.1671	26.36069*	1.20E+22*	59.34447*	59.90495	59.52378*
2	–876.1028	3.165256	1.94E+22	59.80685	60.78769	60.12063

3.3 Diagnostic and stability tests

VAR Residual Serial Correlation LM Tests showed probability of 0,936028. Ljung-Box Test Results: At lag 1 LRE* statistic equals to 3,594386066, p-value = 0,936028 (significant at 5% level), indicating the presence of serial correlation. The absence of significant serial correlation at lag 1 and higher lags supports the robustness of the model. Joint test chi-square = 67,70475, with a p-value of 0,099536. The test for heteroskedasticity yields a Chi-squared value with a p-value of 0.0995, suggesting marginal concerns but no severe violations. The Jarque-Bera test results indicate significant deviations from multivariate normality. Results of data do not meet for long term forecasting.

Figure 1

Inverse roots of AR characteristic polynomial



The stationarity test results for the VAR model confirm that all characteristic roots lie within the unit circle (Figure 1), indicating that the model satisfies the conditions for stationarity. The impulse response analysis illustrates how shocks to GDPpc generate persistent and significant responses across the system, affirming its central role. Conversely, shocks to GovEx and IndVA have limited and short-lived impacts, reflecting their minimal explanatory power in the model. These findings align with theoretical expectations that prioritise GDP growth as a key channel through which higher education investments influence economic outcomes *(Pasara, 2021)*.

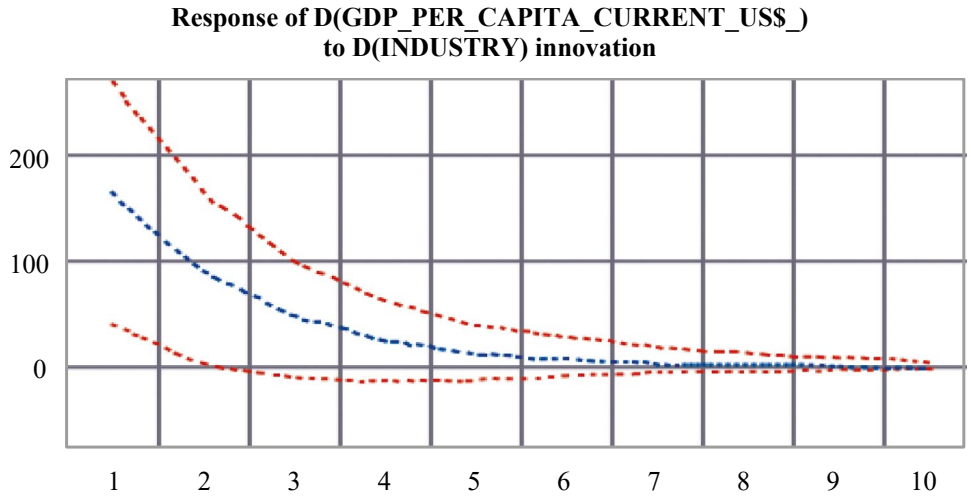
3.4 Impulse response analysis

The impulse response functions (IRFs) illustrate how shocks to one variable affect the other variables over time. Figure 1 shows the IRFs for the VAR model, with a 95% confidence interval. The results reveal that shocks to government expenditure on education have a persistent and significant impact on GDP per capita, with the effects lasting for several periods. This finding aligns with the human capital theory, which posits that investment in education enhances labor productivity and fosters technological innovation, thereby driving economic growth *(Lucas, 1988; Becker, 1991)*.

In contrast, shocks to industry value-added and GDP per capita have limited and short-lived impacts on the other variables. This suggests that while industrial development and economic growth are important, their contributions to the system are relatively transient compared to the long-term effects of education expenditure. These findings are consistent with studies such as *Yu et al. (2014) and Seetanah–Teeroovengadum (2019)*, which also found that education expenditure has a more significant and lasting impact on economic growth compared to other variables.

Figure 2

Impulse response



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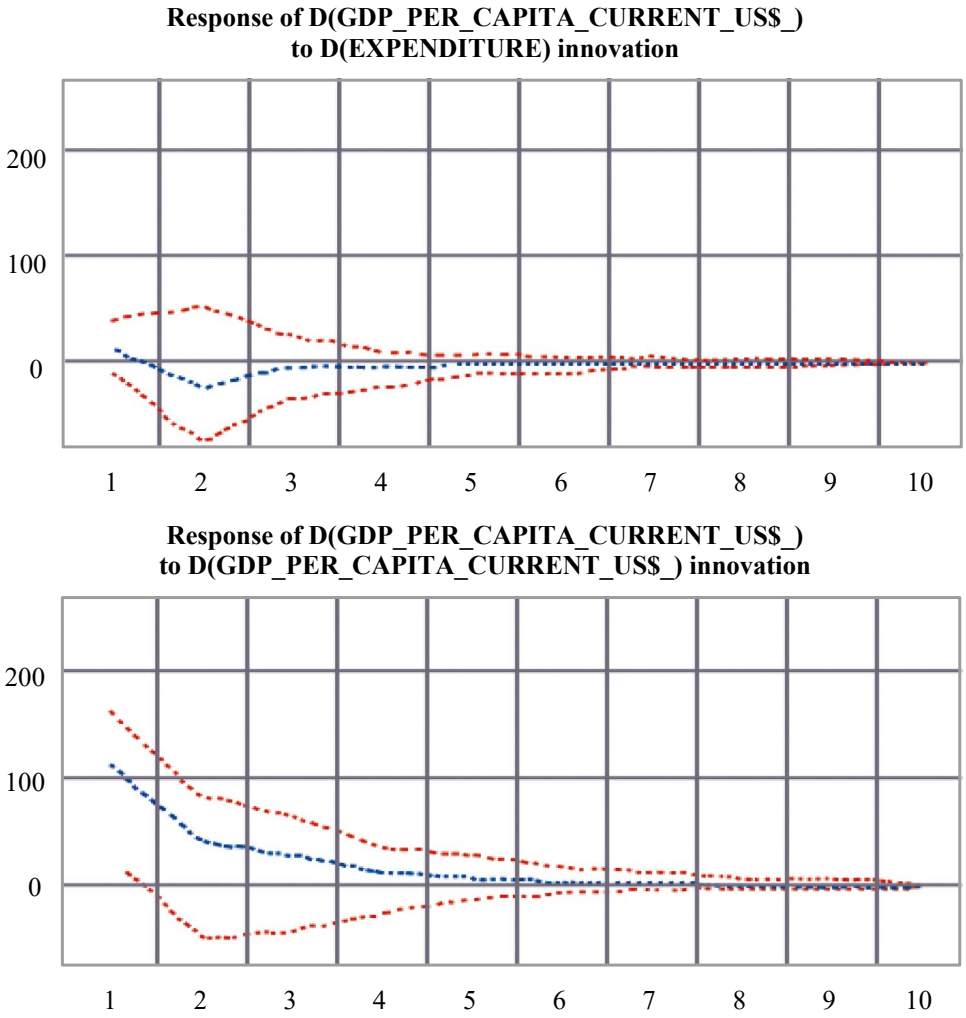

Notes: response to Cholesky one S.D. (d.f. adjusted) innovations. 95% CI using standard percentile bootstrap with 999 bootstrap repetitions.

3.5 Variance decomposition

The variance decomposition analysis quantifies the proportion of the forecast error variance in each variable that is attributable to shocks in the other variables. Table 4 presents the results of the variance decomposition over a 10-period horizon.

Table 4

Variance decomposition

Period	GovEx	GDPpc	IndVA
1	67.66742	0.400668	31.93192
2	69.75238	1.413711	28.83391
3	70.04834	1.351919	28.59974
4	70.17272	1.37385	28.45343
5	70.20275	1.372491	28.42476
6	70.21253	1.37332	28.41415
7	70.21519	1.373342	28.41147
8	70.21599	1.373385	28.41063
9	70.21621	1.373391	28.4104
10	70.21628	1.373394	28.41033

The results show that government expenditure on education explains the largest share of the forecast error variance, starting at 67.67% in period 1 and stabilising around 70.2% by period 10. This highlights the dominant role of education expenditure in driving economic outcomes in Uzbekistan. In contrast, the contributions of GDP per capita and industry value-added are relatively small, with GDP per capita explaining only 1.37% of the variance by period 10, and industry value-added declining from 31.93% to 28.41% over the same period. These findings suggest that while industrial development and economic growth are important, their influence diminishes over time, reflecting the growing importance of human capital development in Uzbekistan's transitioning economy.

The impulse response analysis illustrates how shocks to GDPpc generate persistent and significant responses across the system, affirming its central role. Conversely, shocks to GovEx and IndVA have limited and short-lived impacts, reflecting their minimal explanatory power in the model.

4. Discussion

The results of this study provide valuable insights into the dynamics between government expenditure on education, industrial value added, and GDP per capita in Uzbekistan, framed within the context of the broader economic growth literature. The findings highlight the central role of education spending, aligning with the

foundational economic theories that emphasise the importance of human capital in fostering economic development. The significant role of government expenditure on education in explaining the variability in economic outcomes is consistent with *Schultz's (1961)* and *Becker's (1962)* perspectives, which argue that education, as a form of human capital investment, is a key driver of economic growth. These findings align with *Romer's (1986; 1990)* new growth theory, which emphasises the accumulation of knowledge, human capital, and technological progress as essential drivers of sustained economic growth. In this study, the dominance of government expenditure in explaining variance in economic growth supports the view that educational investment is crucial for long-term economic development, particularly in emerging economies like Uzbekistan.

The impulse response analysis further corroborates this perspective, with shocks to expenditure producing persistent and significant impacts across the system, affirming its central role in shaping economic outcomes. This result is consistent with *Hanushek–Woessmann (2012)*, who found that education substantially contributes to economic growth in OECD countries. The relationship between education and economic growth is further supported by *Barro (1991)*, who demonstrated that higher initial levels of human capital, measured through educational enrollment rates, are strongly correlated with economic growth. In Uzbekistan's case, education expenditure appears to act as a major catalyst for economic transformation, driving GDP growth and influencing industrial development. The minimal contribution of industrial value added to the forecast error variance, which decreases over time, may reflect structural shifts within the economy, where industrial activities play a less prominent role compared to human capital development. This finding resonates with the work of *Nelson (1993)* and *Lundvall (1999)*, who argued that the role of industries in economic growth may diminish as knowledge-based economies emerge. Similarly, the marginal influence of GDP per capita on the variance decomposition suggests that the economic growth in Uzbekistan is still in the process of transitioning to a more education-driven growth model, where human capital accumulation takes precedence. In line with the findings of *Yu et al. (2014)*, this study also suggests a feedback loop in which increased government expenditure on education enhances human capital, which in turn stimulates GDP growth. This feedback mechanism reinforces the notion that educational investment has a multiplicative effect on economic development, as more educated individuals contribute to technological innovation and productivity improvements across various sectors. However, unlike *Pasara (2021)*, who emphasised the role of governance and institutional quality in the effectiveness of education investments, this study does not directly address the influence of governance structures. It is possible that the impact of educational expenditure in Uzbekistan may be moderated by institutional factors,

which could warrant further investigation. This gap could also explain why industrial value added, although important, has a diminishing influence over time. The lack of robust institutional support for industrial growth could limit the sector's ability to translate education-driven innovation into long-term economic benefits. The findings align with *Ochilov's (2017)* study, which emphasises the critical role of education in promoting economic development of Uzbekistan. It highlights that investments in educational infrastructure and quality contribute to the enhancement of human capital, ultimately driving economic growth.

Overall, this study highlights the critical role of educational investment in shaping Uzbekistan's economic trajectory. The results demonstrate that government expenditure on education is a fundamental driver of long-term economic growth, while the role of industrial value added is diminishing, reflecting broader shifts toward a knowledge-based economy. These insights suggest that policies focused on further increasing education spending and fostering human capital development are essential for sustainable economic growth in Uzbekistan.

5. Conclusion

This study examines the dynamic relationship between government expenditure on education, industry value-added, and GDP per capita in Uzbekistan using a Vector Autoregressive (VAR) model. The findings highlight the critical role of education expenditure as a key driver of economic growth, with impulse response analysis showing persistent and significant impacts on GDP per capita. Variance decomposition further confirms that education expenditure explains the largest share of forecast error variance, underscoring its dominant role in shaping economic outcomes. In contrast, the contributions of industry value-added and GDP per capita are more limited and transient, reflecting Uzbekistan's transition toward a knowledge-based economy.

The results align with human capital theory, emphasising that investment in education enhances labor productivity, fosters innovation, and drives long-term growth. The persistent impact of education expenditure supports the view that educational investment is essential for sustainable development, particularly in transitioning economies *(Aka–Dumont, 2008; Akwei et al., 2022; Apostu et al., 2022)*. These findings are consistent with studies such as *Yu et al. (2014)* and *Seetanah–Teeroovengadum (2019)*, which also found that education expenditure

has a more significant and lasting impact on economic growth compared to other variables.

The diminishing role of industry value-added suggests that traditional industries may play a less prominent role as Uzbekistan shifts toward a knowledge-based economy. However, the relatively small contribution of GDP per capita to the variance decomposition indicates that the country's growth model is still evolving. Institutional and governance challenges, as highlighted by *Pasara (2021)*, may also influence the effectiveness of education investments.

In conclusion, this study underscores the importance of government expenditure on education as a key determinant of economic growth in Uzbekistan. Policymakers should prioritise increasing educational investment and improving education quality to foster sustainable development. Strengthening linkages between universities, industries, and research institutions could further maximise the economic benefits of education-driven growth, offering valuable insights for transitioning economies.

Declarations

The author declares that he has no conflicts of interest.

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