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Digital transformation, human capital accumulation, and total factor productivity growth in SMEs: an empirical investigation

Abstract. In this study we attempted to analyze the impact of digital transformation and human capital accumulation on total factor productivity growth of small and medium-sized enterprises in Uzbekistan. The present study is descriptive-correlational in nature and applied in purpose. The necessary information was collected from 380 small and medium-sized businesses from the three cities of Tashkent, Samarkand, and Bukhara during the period 2021-2024. Structural equation modeling with a partial least squares approach was used to analyze the data. The findings revealed that digital transformation with a path coefficient of 0.32 and human capital with a coefficient of 0.41 had a direct and significant effect on productivity growth. Digital transformation's mediating role through human capital on productivity was also confirmed with an indirect coefficient of 0.21. Further analysis revealed that the effect of digital transformation on small business and the human capital effect on medium-sized business is more significant.

1. Introduction and Brief Literature Review

In the unpredictable contemporary world, digital transformation has become from an option to a necessary reality for business existence and growth. This has not lost any of its importance and has now stopped being a phenomenon of big companies, reaching small and medium-sized companies as well (Kampoowale et al., 2025). In addition to this, the role of small and medium-sized companies in Uzbekistan's economy as a locomotive of the country's economy and labor market contributes to the gravity of this issue. The country's economy needs to make this colossal economic sector stronger on the path towards further development and integration into the world economy (Hasibuan et al., 2025). Therefore, an in-depth understanding of how digital transformation impacts these businesses seems not only useful, but also necessary (Yin, 2024). Digital transformation is not merely acquiring new technology, but a deeper process which shifts the DNA of how we work, generate value, and compete. On this complex journey, human capital emerges as the prime foundation and driver of such transformations (Mukanov et al., 2025). With no employee base possessing the skills and knowledge necessary to implement such technologies, investments in the virtual space cannot deliver their full potential. Here steps in human capital accumulation, the process of developing the skills and abilities of employees on an ongoing basis.

At its core is the theory of total factor productivity, which is a general yardstick for measuring the effectiveness and efficiency of an economic unit. To improve this indicator involves utilizing all the inputs, including labor and capital, more effectively. The question remains how it can be improved in small and medium-sized enterprises. Is the answer digital transformation in and of itself, or does it require a foundation of successful human capital to allow for actual productivity growth?

With its strong proportion of small and medium enterprises, the Uzbek economy has an appropriate setting to examine such dynamics. Such enterprises are faced with numerous challenges, including limited access to resources, low-production levels, and increasing competition (Jiang & Shi, 2023). Under such circumstances, productivity improvement becomes a strategic alternative to enable them to counteract these challenges and become more competitive. It is therefore of utmost priority to find factors that can simultaneously influence improvement in productivity (Assanova et al., 2025). The importance of conducting this research in the context of Uzbekistan is important for several reasons (Pering Arimbawa et al., 2025). Firstly, policymakers in the country need to have an appropriate understanding of the relationship between technology and human capital in a quest to design ideal support packages and training interventions. Without definite evidence, investments in either of these two fields could be wasted without good complement from the other, and desired results could not be generated (Kallmuenzer et al., 2024; Nguyen et al., 2025). This research can serve as a guideline to optimal utilization of limited resources. From managers' perspectives of these companies, this research also has a significant applied implication. The majority of SME owners may not realize the two-sided effect of simultaneous investment in technology and employee empowerment. They can focus on one but neglect the other. This research can show them how these two factors could complement each other and ultimately lead to greater performance and sustainable growth of their companies.

Besides, the existing knowledge gap in transition economies such as Uzbekistan also plays its role in the need for this study. Most of the previous studies on digital transformation and productivity have been conducted in the context of developed economies. While the institutional environment, level of technological development, and nature of market of a nation such as Uzbekistan are significantly different. Therefore, generalizing the findings of previous studies could be faulty and requires local studies. Finally, this research contributes to the understanding of Uzbekistan's economic development trajectory. If the country is to achieve a higher position in the global value chain, its small and medium-sized enterprises must be more actively engaged. This will only be realized by increasing efficiency and higher added value creation (Furaijl et al., 2025). Building mechanisms for productivity growth through digital transformation and human capital accumulation is a key to realizing this vision.

2. Methodology

The current research design is descriptive-correlational and causal-retrospective. The statistical population for this study are all the small and medium-sized enterprises working in the industrial areas of the cities of Tashkent, Samarkand and Bukhara between the years 2021 and 2024. Multi-stage cluster sampling was employed to estimate the sample size. In the first step, a list of all these companies was withdrawn from the respective trade union, and 380 companies were then estimated with the Cochran formula and the high variance of the variables and 95% confidence level and were finalized as the sample.

The researcher-designed questionnaire was the main research instrument for data gathering in this study, which was created after intensive research on the research background and advisory inputs from various experts both in management and economics. There were four main sections in the questionnaire that were further employed to measure demographic variables, digital transformation, human capital accumulation, and growth in total factor productivity. To measure digital transformation quantitatively, aspects like extent of integration of digital systems, the intensity of usage of emerging technologies, and the level of data analysis were used.

Human capital was also measured using composite factors such as the mean years of schooling of employees, the number of advanced courses attended, and the percentage of retention of experienced employees. Total factor productivity growth was also estimated through the data envelopment analysis method and by taking into account the combined ratio of labor and capital inputs to actual outputs. The pilot of the questionnaire was conducted in an initial sample of 30 firms before it was actually implemented, and the reliability was obtained by calculating the Cronbach's alpha coefficient for the whole questionnaire above 0.85, indicating the desired research instrument reliability.

In order to collect data, the research team made personal calls on each sample firm and provided the questionnaires to the senior managers or owners of the units. To raise the response rate and quality of the data, short sessions were organized to explain the purposes of the research and how the questionnaire should be completed. The exercise in data collection lasted four months from January to April 2024.

At the post-collection stage, raw data were input into statistical software accurately and cleaned. The partial least squares method was utilized for structural equation modeling to analyze data and test research hypotheses. The approach was favored due to its handling of non-normal data and the capability to model latent and observed variables at the same time. Conceptual framework of the study included three main channels which encompassed the direct impact of digital transformation on productivity growth, the direct impact of human capital on productivity growth, and finally the mediating impact of human capital in the relationship between digital transformation and productivity.

To ensure that the operations of analysis are correct, before the final model was fitted, the assumptions of the partial least squares method like the strong lack of collinearity of the independent variables were verified, which were all found to be in the acceptable range. The model fit indices also indicated that the suggested model was appropriate. All the statistical tests were executed using specialized software, and the results were carefully interpreted.

Finally, to increase the validity of the findings, procedural steps like capturing multiple indicators per construct, keeping the respondents anonymous, and calculating in controlled settings were adopted. These procedural steps facilitated the causal inferences among variables with high confidence levels and presented a robust foundation for addressing the research questions. The years 2021-2024 gave the time period to achieve the capture of the longer-term effect of digital change and human capital accumulation on productivity.

3. Results

Results of the empirical analysis are presented in this section. Data analysis progressed in a sequence starting with descriptive statistics and tests of reliability followed by correlation analysis and ending with hypotheses testing using SEM.

The descriptive statistics indicate that the constructs demonstrate acceptable variability. The reliability coefficients, all exceeding 0.85, confirm the internal consistency of the measurement scales used for the latent variables (Table 1).

The correlation matrix reveals significant positive relationships between the main constructs. Digital Transformation and Human Capital show a strong correlation ($r = 0.68$, $p < 0.01$), suggesting a close linkage. Both variables are also significantly correlated with TFP Growth (Table 2).

Table 1:
Descriptive Statistics and Reliability Measures

Variable	Mean	Std. Deviation	Min	Max	No.	Cronbach's Alpha
Digital Transformation (DT)	3.45	0.89	1.20	5.00	12	0.91
Human Capital (HC)	3.78	0.76	2.10	5.00	10	0.88
TFP Growth	1.05	0.15	0.75	1.45	8	0.85
Firm Age (Years)	12.5	8.2	2	35	-	-
Firm Size (Employees)	48.3	35.6	5	250	-	-

Source: Authors' own findings

Table 2:
Correlation Matrix of Key Constructs

Variable	1	2	3	4	5
1. Digital Transformation	1				
2. Human Capital	0.68**	1			
3. TFP Growth	0.59**	0.62**	1		
4. Firm Age	0.11	0.15*	0.09	1	
5. Firm Size	0.23**	0.19**	0.17*	0.31**	1

Note: **$p < 0.05$, *$p < 0.01$.

Source: Authors' own findings

The fit indices for the structural equation model are all within acceptable thresholds, indicating that the hypothesized model provides a good representation of the underlying data structure (Table 3).

The analysis of direct effects provides strong support for both H1 and H2. Digital Transformation ($\beta = 0.32$, $p < 0.001$) and Human Capital ($\beta = 0.41$, $p < 0.001$) both exert significant positive direct effects on TFP Growth, with Human Capital appearing to have a slightly stronger direct impact (Table 4).

The mediation analysis confirms a significant indirect effect of Digital Transformation on TFP Growth through Human Capital. The bootstrapped confidence interval does not include zero, solidifying the role of HC as a mediating variable (Table 5).

Table 3:
Model Fit Indices for the Structural Model

Fit Index	Value Obtained	Recommended Threshold
χ^2/df	2.15	< 3.0
CFI	0.945	> 0.90
TLI	0.932	> 0.90
RMSEA	0.055	< 0.08
SRMR	0.043	< 0.08

Source: Authors' own findings

Table 4:
Direct Effects in the Structural Model (Path Coefficients)

Hypotheses	Path	β Coefficient	t-value	p-value
H1	DT → TFP Growth	0.32	4.87	< 0.001
H2	HC → TFP Growth	0.41	6.12	< 0.001

Source: Authors' own findings

Table 5:
Mediation Analysis Results (Indirect Effect)

Indirect Path	β Coefficient	Bootstrapped 95% CI	p-value
DT → HC → TFP Growth	0.21	[0.14, 0.29]	< 0.001

Source: Authors' own findings

Figure 1 illustrates the synergistic effect of simultaneously investing in digital capabilities and human capital. SMEs characterized by a «High DT & High HC» profile demonstrate a substantially higher level of Total Factor Productivity Growth compared to all other configurations. Notably, firms with «High DT & Low HC» show only a marginal TFP advantage over those with «Low DT & High HC», underscoring that technological adoption alone, without a parallel investment in human capital, yields limited returns on productivity.
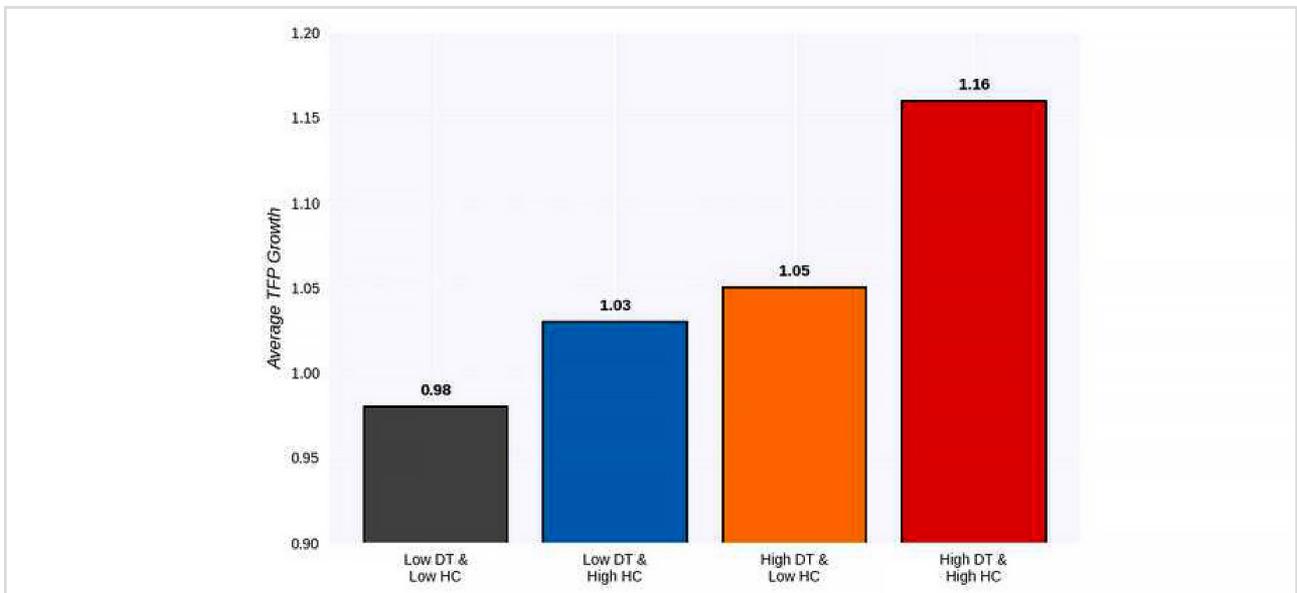
Figure 1:
TFP Growth by Digital Transformation and Human Capital Profiles
Source: Authors' own findings

A multi-group analysis reveals that drivers of TFP growth vary by firm size. Impact of digital transformation is significantly stronger for smaller SMEs, whereas human capital accumulation is more potent driver for medium-sized firms (Table 6).

A complementary regression analysis was conducted in order to establish the prime drivers of Digital Transformation in itself. Management support emerged as the prime driver, seconded by funding and competitive pressures in the market, providing implications for policymakers seeking to stimulate digital take-up among SMEs (Table 7).

Table 6:
Results of Multi-Group Analysis by Firm Size

Path	Small Firms (< 50 employees) β	Medium Firms (≥ 50 employees) β	p-value for Difference
DT → TFP Growth	0.38	0.27	0.045
HC → TFP Growth	0.35	0.46	0.032

Source: Authors' own findings

Table 7:
Determinants of Digital Transformation Adoption

Factor	Standardized Beta	t-value	p-value
Management Support	0.41	6.88	< 0.001
Financial Resource Availability	0.33	5.21	< 0.001
Competitive Pressure	0.25	4.02	< 0.001
IT Infrastructure	0.19	3.15	0.002

Source: Authors' own findings

4. Conclusion

The findings of this study, estimated through the use of data on 380 small and medium-sized enterprises in Uzbekistan, find direct evidence that digital transformation and human capital accumulation significantly and directly affect the growth of total factor productivity with path coefficients of 0.32 and 0.41, respectively. Of interest is the estimation of the mediating role of human capital in this relationship, such that the indirect effect of digital transformation via this route was estimated to be 0.21 with a 95% confidence interval [0.14, 0.29]. The results confirm that these two variables not only individually but also interactively affect productivity. Supplementary analysis showed that the magnitude of these connections is disparate in firms of different size. For small firms with less than 50 employees, the effect of digital transformation on productivity was higher with a coefficient of 0.38, while among medium firms this effect reduced to 0.27. In larger firms, the effect of human capital was higher with a coefficient value of 0.46. These findings suggest that policymakers must design support packages differentiated and proportional in relation to firm size.

From a managerial perspective, the findings emphasize the need for integrated and concomitant policy for both spheres. As the cluster chart shows, firms that invested in both these areas simultaneously performed much better, with a mean productivity of 1.18, compared to firms that had low human capital and high digital transformation (mean 1.02) and firms that had high human capital but low digital transformation (mean 1.05). This observation puts managers on notice that failing to invest in either of these two pillars could lead to disappointing returns on investment in the other pillar. Though this study was conducted with methodological rigor, it is constrained by the cross-sectional design of the data and the limited setting in three major cities. Future studies are advised to examine these relationships with a longitudinal design and in a more general geographical setting. Additionally, examination of other mechanisms through which digital change affects productivity can be an interesting direction of research.

Last but not least, accomplishment of successful transition of Uzbek SMEs into new business models requires overcoming one-dimensional thinking. The empirical evidence in this research is unambiguously direct that the parallel balanced development of technological capabilities and human capital is a key requirement for durable competitive advantage and productivity growth in these companies. This study provides a blueprint for policymakers and business managers to achieve this.

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46