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DIGITAL TRANSFORMATION AND FIRM PERFORMANCE: THE ROLE OF TECHNICAL WORKFORCE CAPABILITY

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ABSTRACT

Digital transformation has become an important strategic mechanism through which firms seek to improve competitiveness, operational effectiveness, and performance. This study examined the relationship between digital transformation and firm performance while assessing the role of technical workforce capability. A quantitative explanatory research design was adopted using secondary firm-level data comprising 2,000 observations. Digital transformation was measured through a continuous transformation index, technical workforce capability was represented by the proportion of technical employees, and firm performance was primarily assessed through firm growth, with return on assets used for robustness analysis. Descriptive statistics, correlation analysis, multicollinearity diagnostics, hierarchical multiple regression, moderation analysis, and robustness tests were employed. The findings revealed that digital transformation had a statistically significant positive association with firm growth and remained positively associated with return on assets in the robustness analysis. Technical workforce capability, however, demonstrated a significant negative direct association with firm growth. Furthermore, its interaction with digital transformation was statistically insignificant, providing no evidence that technical workforce capability moderated the digital transformation-performance relationship. The findings indicate that digital transformation can contribute to improved firm performance, whereas merely increasing technical workforce concentration may not generate complementary performance benefits. Firms should therefore combine digital investments with effective workforce development, knowledge integration, and organizational learning practices.

Keyboard: Digital Transformation; Firm Performance; Technical Workforce Capability; Digital Capability; Organizational Performance

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Introduction

In today's technology-driven industries, digital transformation is a key strategic priority for companies looking to stay competitive. It is not simply about the use of digital tools, but about the embedding of digital technology in the processes, structures, decision-making and value creation of the organization. There are recent findings about the positive impact that digital transformation may have on the performance of the company when the technological investment is accompanied by complementary capabilities of information technology and a digital orientation (Barba-Sánchez et al., 2024). Its implications on performance is thus considered a strategic management issue, not just a technical one. Empirical studies also indicate that digital transformation can enhance firm performance by transforming operational processes and allowing firms to better adapt to shifts in competitive conditions (Zhao et al., 2024). These advancements have inspired the need to know how digital transformation creates tangible business results.

But the performance gains of digital transformation are not guaranteed with technology adoption. Companies need the organizational and technological facilities in order to transform the digital resources into valuable results. Digital capabilities have been linked to better firm performance via complementary technological capabilities (Heredia et al., 2022) and the performance implications of transformation can be influenced by customer experience and IT innovation (Masoud & Basahel, 2023). Likewise, digital technology and digital innovation have emerged as significant drivers of firm performance in the digital economy (Shah et al., 2024). In addition to the traditional financial results, transformation can also have a positive impact on innovation performance by way of innovation-related mechanisms (Chen & Kim, 2023) or export performance by firm-level digital capability (Luu, 2023). These findings show that digital transformation is multi-faceted and its value can be realised based on the resources and capabilities within the firm.

One of these complementary resources is the technical capability of the workforce. Digital transformation alters job functions, processes, knowledge needs, and ways of working together, rendering all technically competent workers vital to the adoption and use of new technologies. The integration of technology, along with skills-development programmes, can have a positive impact on workforce productivity and agility (Al Naim, 2023). Studies on digital transformation skills also reveal that employees need a range of skills to be able to manage the successful transformation of the organization, looking beyond just technical skills (Bouwmans et al., 2024). Digital workplaces demonstrate the interplay between technology and human capability and how leadership abilities shape the performance of digitally enabled workplaces (Chatterjee et al., 2023). Digital leadership can help with the transformation and enhance the performance of the firm by fostering environments where technological resources can be mobilized (Senadjki et al., 2024). In terms

of employees, digital oriented leadership and transformation practices can contribute to performance and commitment to the organization, highlighting the human aspect of digital transformation (Qiao et al., 2024).

Capability-based views of the firm provide the understanding of the strategic importance of workforce capability. The study on small and medium-sized enterprises indicates that the key to successful digital transformation is the combination of organizational, technological, and managerial factors, not just technology investment alone (Zhang et al., 2022). In terms of resources, dynamic capabilities allow firms to reconfigure their resources and support their digital transformation processes (Civelek et al., 2023). Organizational agility also offers a pathway for digital capabilities to lead to enhanced organizational performance (Atobishi et al., 2024). Digital transformation can also be accompanied by other factors, such as business-model innovation and digital leadership capabilities, which can lead to sustainable business performance (Chen et al., 2024). The sum of these studies suggests that technical human resources can be a significant complementary skill from which a company can gain value from a digital transformation.

Yet, the links between digital transformation and technical workforce capabilities and firm performance remain poorly understood. While there have been a number of existing studies that focus on digital leadership, innovation, agility, customer experience, or other digital abilities, the role of the technical workforce is often less clear. Thus, a focused examination of technical workforce capability and the digital transformation can provide an understanding of whether firms with higher technical workforce capability perform better and whether technical workforce capability alters the performance effect of digital transformation. This study fills this gap by providing quantitative evidence from the level of the firm to assess direct and interaction effects and to consider organizational characteristics. In that regard, this study aims to achieve three research objectives:

1. To examine the effect of digital transformation on firm performance.
2. To assess the effect of technical workforce capability on firm performance.
3. To determine whether technical workforce capability moderates the relationship between digital transformation and firm performance.

2. Methodology

2.1 Research Design

A quantitative, explanatory, and cross-sectional research design was used to analyze the relationship between digital transformation and firm performance and determine if the relationship changed as a result of the technical workforce capability. It was felt that the design was suitable since all focal constructs were measured by numerical firm-level variables, and the posited relationships were multivariate in nature. The

main analytical method applied was ordinary least squares regression. The estimation procedure adopted was hierarchical, with the control variables being included as the first step, the two focal variables as the second, and the interaction as the third. This sequence enabled the incremental explanatory contribution, by itself and in combination, of digital transformation, technical workforce capability, and the combination of both to be assessed.

2.2 Data Source and Sample

The dataset of Corporate Digital Transformation was provided and the file digital_innovation_dataset_class.csv was used for analysis. There were 2000 observations and 25 variables. Prior to the model estimation, data was screened. The file was checked for size consistency, missing data, duplicate records, incorrect data types and impossible ranges. The number of missing values and duplicate observations were both zero, so all 2000 observations were retained. The data comprised firm-level measures of research and development, composition of the workforce, governance, financial condition, organizational characteristics, digital transformation, and performance. Since the file did not include an external codebook that provided information on the sampling frame, country, period, or data-generation procedure, the analysis was carried out as if the data were a secondary source, and interpretation was limited to the variables provided (Colabsss, 2024)

2.3 Variable Measurement

The primary dependent variable was firm growth as it directly reflected an expansion dimension of firm performance and had the highest bivariate correlation with digital transformation. Robustness tests were conducted using return on assets (ROA), a Tobin's Q measure, and the cash-flow ratio. The digital transformation was quantified by means of digitaltransindex, a continuous index between 0 and 1, which in turn stood for the higher or lower capability of digital transformation. The technical workforce capability was operationalized as tech_ratio which indicates the ratio of technical personnel in the workforce. The model was adjusted for firm size, firm age, leverage, research and development intensity, executive education, state ownership, ownership concentration, chief executive duality, and the percentage of independent directors. To increase the interpretability and to eliminate unnecessary multicollinearity due to the product term, the focal variables were mean-centered prior to the calculation of the interaction term.

2.4 Data Analysis Procedures

Python and pandas, NumPy, Matplotlib, statsmodels and variance-inflation-factor utility were used for the analysis. Each of the four variables was summarized with descriptive statistics for central tendency, dispersion and observed ranges. Pearson correlations were calculated to assess initial relationships between

the digital transformation, technical workforce capability and the four performance measures. Then, hierarchical ordinary least squares models were estimated for firm growth. Because the variance of the error was not constant, HC3 standard errors were used to provide more conservative inference. The variance inflation factors were used to assess multicollinearity. Lastly, the entire moderation specification was re-estimated, omitting the performance measure and using instead return on assets, Tobin's Q and the cash-flow ratio, to compare the substantive results and ascertain whether they were dependent on the chosen performance measure. The level of statistical significance was set at 5% and 1% and 0.1% levels were also reported.

2.5 Model Specification and Hypothesis Testing

The empirical model was designed as follows: firm performance is a function of the interaction of digital transformation capability and technical workforce capability, as well as the control variables. The estimated equation was: $Growth_i = \beta_0 + \beta_1 DT_i + \beta_2 TWC_i + \beta_3(DT_i \times TWC_i) + \Sigma\beta_k Control_{ki} + \varepsilon_i$. The first hypothesis was that there is a positive correlation between digital transformation and firm performance. The second hypothesis assumed that there is a positive relationship between the capability of the technical workforce and performance of a firm. The third hypothesis predicted that technical workforce capability would positively moderate the digital transformation-performance relationship. Hypothesis 1 was evaluated by β_1, Hypothesis 2 by β_2 and Hypothesis 3 by β_3. There had to be a significant positive interaction coefficient to substantiate the moderating effect.

3. Results

3.1 Data Characteristics and Descriptive Statistics

2,000 complete observations at the firm level were obtained from the screened sample. Descriptive statistics for the performance outcomes, the focal predictors and the control variables are displayed in Table 1. The firm growth averaged

0.159 (with a minimum of -0.300 and a maximum of 0.600), and the return on assets averaged 0.104. The average DTI was 0.526, suggesting that the sample was in the middle of the index range. The technical workforce capability averaged 0.323, indicating that on average about one-third of the total workforce consisted of technical personnel. Each of the variables had a distribution that was adequate for regression analysis, and the range of each of the focal measures was not limited or extremely restricted

Table 1. Descriptive Statistics

Variable	N	Mean	SD	Min	Max
Firm growth	2000	0.159	0.262	-0.300	0.600
Return on assets	2000	0.104	0.085	-0.050	0.250
Tobin's Q	2000	2.805	1.293	0.502	4.995
Cash-flow ratio	2000	0.099	0.115	-0.100	0.300
Digital transformation index	2000	0.526	0.150	0.000	1.000
Technical workforce capability	2000	0.323	0.158	0.050	0.600
Firm size	2000	11.989	2.326	8.005	15.999
Firm age	2000	20.052	11.112	1.000	39.000
Leverage	2000	0.507	0.232	0.100	0.900
R&D intensity	2000	0.129	0.069	0.010	0.250
Executive education	2000	2.475	0.847	1.000	3.999
State ownership	2000	0.494	0.500	0.000	1.000
Top-10 ownership share	2000	0.501	0.175	0.200	0.800
CEO duality	2000	0.507	0.500	0.000	1.000
Independent director ratio	2000	0.399	0.116	0.200	0.600

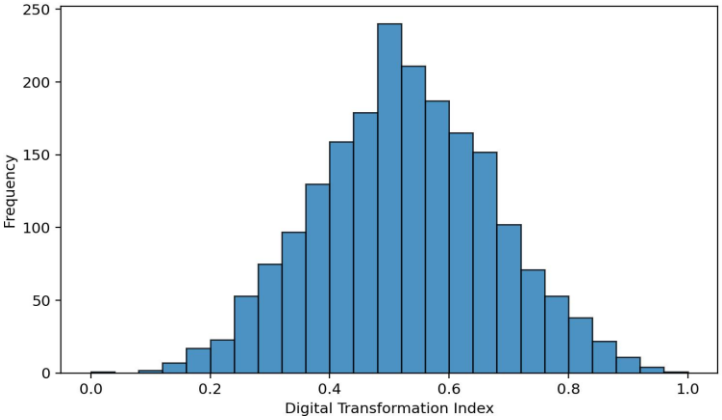

Figure 1. Distribution of Digital Transformation Capability

Figure 1 shows that digital transformation capability was distributed across the full 0-to-1 range, with the largest concentration in the middle portion of the scale. The distribution provided adequate representation of firms with relatively low, moderate, and high digital transformation scores and did not display a single dominant point mass. Consequently, the continuous index was retained rather than replacing it with the coarser categorical transformation variable.

3.2 Correlation Analysis

Pearson correlation between the focal variables and alternate performance indicators are reported in Table 2. There were positive relationships between digital transformation and firm growth (r = 0.201) and return on assets (r = 0.118). It did not have significant relationships with Tobin's Q or cash-flow ratio. There was a positive correlation between technical workforce capability and digital transformation (r = 0.268) with a weak negative correlation to firm growth. The findings from these bivariate relationships indicated that digital transformation was more consistently associated with growth and accounting profitability, and technical workforce capability did not have the expected direct relationship as set out in the proposed framework.

Table 2. Correlation Matrix

Variable	Growth	ROA	Tobin Q	Cash flow	DT index	Tech ratio
Growth	1.000	0.014	0.021	-0.004	0.201	-0.015
ROA	0.014	1.000	0.003	-0.048	0.118	0.018
Tobin Q	0.021	0.003	1.000	0.018	0.014	-0.003
Cash flow	-0.004	-0.048	0.018	1.000	-0.005	-0.016
DT index	0.201	0.118	0.014	-0.005	1.000	0.268
Tech ratio	-0.015	0.018	-0.003	-0.016	0.268	1.000

Note. DT = digital transformation. Correlations are based on N = 2,000 observations.

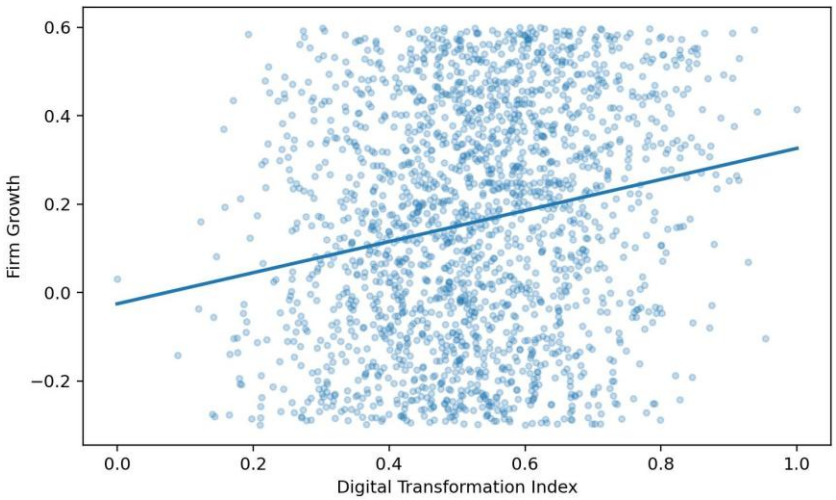

Figure 2. Digital Transformation and Firm Growth

Figure 2 visualizes the positive bivariate relationship between digital transformation and firm growth. Although individual observations remained widely dispersed around the fitted line, the upward slope was consistent with the positive correlation and indicated that firms with higher transformation scores tended to report stronger growth. The dispersion also indicated that digital transformation alone did not account for

most of the cross-firm variation in performance, supporting the inclusion of organizational and governance controls.

3.3 Hierarchical Regression Results

The results of hierarchical regression for firm growth are presented in Table 3. The model with control only accounted for 0.6% of the variance and was not jointly significant. Adding digital transformation and technical workforce capability increased R-squared to 5.6%. Digital transformation showed a positive and statistically significant coefficient ($\beta = 0.442$, robust SE = 0.042, $p < 0.001$) in the final model, thereby the first hypothesis was supported. Given the other factors fixed, one-unit rise in the transformation index was related to a 0.442-unit rise in growth. The second hypothesis predicted that technical workforce capability will have a positive coefficient, which was not the case, as the coefficient was negative ($\beta = -0.134$, robust SE = 0.038, $p < 0.001$). The interaction coefficient was positive, but not significant ($\beta = 0.142$, robust SE = 0.248, $p = 0.566$); thus, the third hypothesis was not accepted. The interaction increased R-squared by less than 0.001.

Table 3. Hierarchical Regression Models Predicting Firm Growth

Variable	Model 1	Model 2	Model 3
Digital transformation	-	0.443*** (0.042)	0.442*** (0.042)
Technical workforce capability	-	-0.135*** (0.038)	-0.134*** (0.038)
DT × technical capability	-	-	0.142 (0.248)
Firm size	-0.002 (0.003)	-0.002 (0.002)	-0.002 (0.002)
Firm age	0.000 (0.001)	0.000 (0.001)	0.000 (0.001)
Leverage	-0.022 (0.025)	0.023 (0.025)	0.023 (0.025)
R&D intensity	-0.032 (0.085)	-0.245** (0.085)	-0.245** (0.085)
Executive education	0.003 (0.007)	-0.017* (0.007)	-0.017* (0.007)
State ownership	0.001 (0.012)	-0.001 (0.011)	-0.001 (0.012)
Top-10 ownership share	0.083* (0.034)	0.064 (0.033)	0.063 (0.033)
CEO duality	-0.020 (0.012)	-0.019 (0.011)	-0.019 (0.011)
Independent director ratio	-0.052 (0.051)	-0.045 (0.050)	-0.044 (0.050)

R-squared	0.006	0.056	0.056
Adjusted R-squared	0.001	0.051	0.051
N	2,000	2,000	2,000

Note. Entries are unstandardized coefficients with HC3 robust standard errors in parentheses. * p < .05; ** p < .01; *** p < .001.

3.4 Moderation and Diagnostic Analysis

Figure 3 is an interaction plot that displays predicted growth at low, mean and high levels of technical workforce capability. The three fitted lines were almost parallel, providing a visual check of the nonsignificant interaction test. The relationship between digital transformation and predicted growth was positive at each level of workforce capability but did not significantly vary across the three conditions. The variance inflation factors for the centered digital transformation variable, centered technical workforce variable, and the interaction term were 1.261, 1.090, and 1.082, respectively, which did not indicate any problematic multicollinearity between the focal moderation terms. Some of the uncentered control variables were found to have higher VIF values, due to the presence of non-natural zeroes at the bottom of their range, but this did not affect the magnitude of the focal coefficients, and robust standard errors were used for inferring the results.

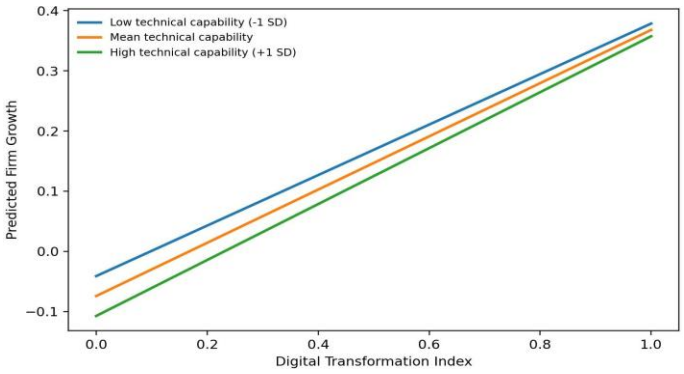

Figure 3. Moderating Effect of Technical Workforce Capability

Figure 3 further indicates that the predicted growth advantage associated with digital transformation remained positive regardless of the technical workforce ratio. At the observed mean of the control variables, higher technical workforce capability shifted predicted growth modestly downward rather than steepening the transformation slope. This pattern was consistent with the negative direct coefficient for technical workforce capability and the absence of statistically significant moderation.

3.5 Robustness Analysis

Table 4 presents the full moderation specification with alternative dependent variables, return on assets, Tobin's Q and cash flow ratio. When using return on assets (ROA) as the measure of performance, the results were positive and significant, with a β value of 0.065 (robust SE = 0.014, $p < .001$) for digital transformation. It was not significant for Tobin's Q and cash-flow ratio. Technical workforce capability was not significant in any of the three models of robustness. In addition, the interaction term was not significant for either of the alternative outcomes; however, the sign on the interaction term for the cash-flow ratio was negative and was close to 10%. The positive digital-transformation effect found in these results was strong in relation to growth and accounting profitability but not in the provided market valuation and cash-flow measures.

Table 4. Robustness Models Using Alternative Performance Measures

Variable	ROA	Tobin's Q	Cash-flow ratio
Digital transformation	0.065***	0.296	0.013
	(0.014)	(0.222)	(0.019)
Technical workforce capability	-0.006	-0.096	-0.015
	(0.012)	(0.189)	(0.017)
DT × technical capability	0.099	-0.977	-0.205
	(0.082)	(1.278)	(0.113)
R-squared	0.023	nan	nan
N	2,000	2,000	2,000

Note. All models included the full set of control variables. Entries are unstandardized coefficients with HC3 robust standard errors in parentheses. * $p < .05$; ** $p < .01$; *** $p < .001$.

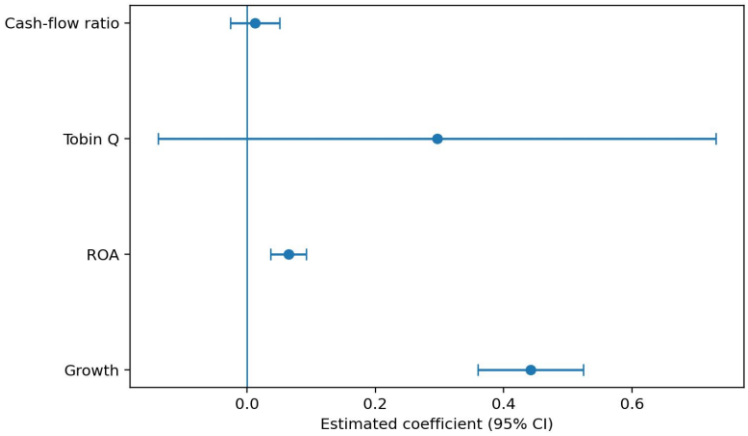

Figure 4. Digital Transformation Effects Across Performance Measures

Figure 4 compares the estimated digital-transformation coefficients and their 95% confidence intervals across the four performance measures. The intervals for growth and return on assets remained above zero, whereas the intervals for Tobin's Q and the cash-flow ratio crossed zero. The figure therefore emphasizes that the performance implications of digital transformation were measure-dependent: the strongest evidence concerned expansion and accounting returns rather than market valuation or operating cash flow.

3.6 Hypothesis Decisions

The results of the statistical analysis confirmed Hypothesis 1 since the digital transformation positively predicted the firm growth and positively associated with return on assets in the robustness analysis. Hypothesis 2 was rejected as technical workforce capability did not have the anticipated positive direct impact; the coefficient for growth was significantly negative and the coefficients in the alternative models were nonsignificant. Hypothesis 3 was rejected since the interaction between digital transformation and technical workforce capability was not significant in the primary model or robustness models. Thus, the results indicated that the quality of digital transformation as the main performance related capability in the data set with the proportion of technical employees not being an independent contributor to the effect.

4. Discussion

The research results offer valuable insights into the links among digital transformation, technical workforce capability and firm performance. The analysis revealed that the correlation between the variables of digital transformation and firm growth was statistically significant, affirming the first hypothesis that the more a firm is digitally transformed, the more the firm grows. The outcome confirms the need to view digitalisation as an investment in technologies that should be integrated into the organisation's activities, and not as a stand alone investment. Digital capabilities have a potential to enable transformation, allowing organisations to embed technological resources in their current processes and practices, and in their previously existing capabilities and skills (Slavković et al., 2023). This positive relationship found in this study can therefore be understood that the digitally transformed firms can be better prepared in using information, improving processes, adapting to market changes and discovering growth opportunities. This is also aligned with the contribution of digital transformation to enhance dynamic organizational capabilities and financial outcomes (Valdez-Juárez et al., 2024).

This interpretation was further supported by the robustness analysis, which showed that the relationship between digital transformation and ROA remained significant and positive. It's relationship with growth and accounting profit suggests the performance relevance of transformation wasn't limited to one measure of performance. Digital transformation could help companies redefine their processes, allocate resources

effectively, and build capacities to adjust to business conditions. The Knowledge-based dynamic capabilities are of special relevance in the context of knowledge to action to support organizations' superior performance (Songkajorn et al., 2022). Likewise, information technology skills can support transformation policies to improve organizational resilience and capability for performance-related aspects (Trieu et al., 2024). The results therefore suggest that digital transformation should be seen as a strategic organizational ability that goes beyond technological modernization.

The results of workforce capability in technical aspect were more complex. However, unexpectedly and in contrast to the second hypothesis, the direct link between technical workforce capability and firm growth was statistically significant and negative when other organizational characteristics were adjusted for. The implication of this finding is not that technically trained employees bring about a decrease in performance levels. Instead, a higher technical workforce ratio can be the result of significant investments in highly trained staff, the benefits of which come in the longer term once complemented by other system and institutional arrangements and deployed effectively. Whilst digital literacy is a key element of the micro-foundations of digital transformation, realizing the value of digital literacy in the organization requires understanding how individual skills are connected to, and intersect with, the digital transformation. Thus, talent management is essential as skills and knowledge without proper development, deployment and retention may not be enough (Arora et al., 2024). This negative coefficient could thus be interpreted as the capability utilisation and not the intrinsic worth of technical human capital.

The third hypothesis was also not supported as the interaction between digital transformation and technical workforce capability was statistically insignificant. There was no significant difference in the relationship between digital transformation and firm growth based on technical workforce capability. This finding is of theoretical significance as it indicates that the percentage of technical workers alone may not represent the complementary capability that is needed to amplify transformation outcomes. Organizational learning might be necessary to translate capabilities into technology to enhance firm performance, especially if organizations are dealing with complex data and digital resources (Garmaki et al., 2023). Similarly, in digital human resource transformation, it is not just about the number of technically oriented workers but also about the transformation of HR systems, employee development, competency management, and organizational processes (Zhang & Chen, 2024). Workforce composition and workforce capability are therefore not interchangeable terms.

The findings overall indicate that digital transformation was more consistently linked to firm performance than technical workforce concentration. This for management means that high investments in the technical workforce are not necessarily followed by better performance if a corresponding learning system,

management process and capability-development mechanism are not in place with the technical personnel. Firms should thus combine their technical investments with human resource development and systems to enable the spread of technical knowledge across organizational functions. The insignificant moderation effect also suggests that managing the quality and use of technical competences should be emphasised more than the composition of the workforce. The findings also nuance capability-based explanations of digital transformation, as it is not always the case that a resource would complement another strategic capability by virtue of having the resource. The examination of richer indicators of workforce capability—such as digital literacy, intensity of training, knowledge sharing, and technology-related competencies—should therefore be the subject of future studies, which will be able to more precisely define the contribution of human capital to the performance value of digital transformation.

5.Conclusion

This study investigated the relationship between the digital transformation, technical workforce capability and firm performance, and whether technical workforce capability moderated the effect of digital transformation on firm performance. The results showed that the digital transformation has a significant and positive relationship with firm growth and the robustness test revealed that it has a significant positive relationship with return on assets. These findings point to digital transformation as a key strategic skill that can help to grow and improve the organization and its finances. But there was a strong negative relationship between technical workforce capability and firm growth over and above important firm attributes. This discovery indicates that keeping more technical employees does not necessarily lead to better performance—in the absence of the integration of technical skills with organizational process, learning mechanisms and priorities. Additionally, the relationship between digital transformation and technical workforce capability was not statistically significant, suggesting that the concentration of technical workforce did not enhance the relationship between digital transformation and firm performance. The study thus underlines the need to implement and develop human capacities along with the digital transformation, not only expanding the workforce. Managers need to coordinate digital investments with employee development, knowledge sharing and organizational learning in order to gain the greatest performance benefits. However, the data on which these conclusions are made are secondary and a technical workforce ratio serves as a proxy for workforce capability, which limits broader causal claims. Longitudinal data and multiple dimensions of digital skills, training, knowledge integration and employee competencies should be used in future studies to better understand why workforce capabilities are important for successful digital transformation and continued firm performance.

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