Uneven Gains from Digitalization: The Moderating Role of Human Capital in Subnational Export Performance in Indonesia

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Abstract

The growing role of digital transformation in global trade has raised important questions about how technology and human capital jointly shape export performance, particularly in developing economies. This study examines the impact of digital technology, combined with high-quality human capital, on export performance across Indonesian provinces. Using fixed effects panel regression and quantile regression methods on provincial-level data from 2015 to 2023, the analysis captures both average effects and distributional heterogeneity. The results indicate that digital technology has a significant positive impact on exports, with this effect being stronger in provinces with higher levels of human capital. The interaction between digitalization and human capital is statistically significant, confirming their complementary role in enhancing export capacity. However, quantile regression findings reveal that the benefits of digitalization are more pronounced in provinces with higher export performance, while less developed regions remain less responsive. These results suggest that digital and human capital alone are insufficient in lagging regions without supporting structural conditions. Policy strategies should thus integrate digital and human development with targeted interventions to strengthen absorptive capacity, infrastructure, and institutional readiness, ensuring inclusive and regionally balanced export growth.

Keywords: Digital Technology; Human Capital; Export Performance; Regional Development.

1. Introduction

In the globalized economy, exports play a pivotal role in driving economic growth, especially for developing countries striving to improve their trade balance and integrate into global value chains. Despite its abundant natural resources and large labor force, Indonesia's export performance lags behind its potential when compared to other emerging economies. For instance, in 2023, Vietnam's total exports reached USD 355 billion, while Indonesia only recorded approximately USD 300 billion, a striking disparity given Indonesia's larger population and resource base. Moreover, countries such as Bangladesh and the Philippines have shown higher export growth rates in selected high-value sectors, indicating a missed opportunity for Indonesia to compete globally in non-commodity markets.

Simultaneously, Indonesia is experiencing rapid digital transformation across various sectors, including manufacturing, logistics, and trade facilitation. Government initiatives such as Making Indonesia 4.0 and Gerakan Nasional Literasi Digital (National Movement for Digital Literacy) are pushing the agenda of digital economy integration. Indonesia's internet adoption has accelerated markedly in recent years: at the start of 2024, approximately 185.3 million Indonesians (66.5 % of the population) were online, rising to about 212 million users (74.6 %) by early 2025, a net increase of 17 million or 8.7 % growth year over year. More recent analysis from April 2025 places the total number of internet users at over 223 million, equivalent to approximately 78.3% internet penetration, approaching saturation yet still growing at nearly 10% annually. This sustained upward trend highlights Indonesia's deepening digital engagement across the archipelago, fueling the broader digital transformation context within which export-enhancing technologies are emerging.

Indonesia is undergoing a rapid digital transformation, as evidenced by the country's digital economy becoming the largest in Southeast Asia, valued at USD 70 billion in 2021 and projected to contribute up to 10% of the country's GDP by 2025. Massive developments in e-commerce, digital payments, and infrastructure drive this growth. The QRIS digital payment system alone now serves

over 50 million users and 32.7 million merchants, with strong integration into MSMEs and cross-border interoperability. Major global tech firms such as Microsoft have committed substantial investments, including USD 1.7 billion for cloud and AI infrastructure, alongside national initiatives like Making Indonesia 4.0 and a forthcoming AI roadmap. Meanwhile, the expansion of broadband, fiber network rollouts, and the booming data center market further reinforce the country's digital readiness. This digital acceleration creates a compelling foundation for enhancing Indonesia's export competitiveness, provided that improvements match it in terms of human resource quality. The widespread adoption of digital platforms, e-commerce, and Industry 4.0 technologies has the potential to reduce transaction costs, increase market access, and enhance supply chain efficiency, ultimately improving export competitiveness. However, these technological advances do not automatically translate into improved export performance if not supported by adequate human resource capabilities.

In this context, the quality of human resources emerges as a crucial moderating factor. The digital transformation demands new skills, adaptability, and innovation-driven mindsets among workers and exporters. Without addressing the human capital gap, such as low digital literacy or inadequate vocational training, the benefits of digitalization might be unevenly distributed or underutilized across regions and sectors.

This research aims to assess the impact of digitalization and human resources on export performance. Additionally, the study will examine how digitalization influences export performance, with this relationship being moderated by the quality of human resources.

The novelty of this research lies in its empirical investigation of how digitalization affects export performance through the moderating role of human resource quality. This area has received limited attention in the literature, particularly in the context of developing countries using panel data methods. Most existing studies examine digital infrastructure and exports in isolation, without integrating the mediating or moderating role of human capital. Moreover, this study adopts a fixed effects panel regression model, allowing for the control of unobserved heterogeneity across provinces or sectors, thereby providing more robust and policy-relevant insights.

Literature Review
Theoretical Framework
Resource-Based View (RBV)

The Research-Based View (RBV) is a theory that provides a foundational understanding of how resource capabilities contribute to competitive advantage, which is central to assessing the impact of digitalization on export performance (Dong et al., 2024; Elia et al., 2021; Q. Wang et al., 2023). Digitalization is proposed to enhance operational efficiencies and the quality of export outputs. Research indicates that digitalization can mitigate financing constraints and enhance human capital quality, leading to improved export product quality through increased productivity (Qian & Qun-zhi, 2023; Zhang & Duan, 2023). The integration of digital technologies enables firms to harness information more effectively, facilitating a transformation in organizational dynamics where digital skills become pivotal for successfully navigating export markets (Elia et al., 2021; F. Wang & Ye, 2023).

Moreover, the moderating role of human resource quality is crucial as it determines how effectively firms leverage digital tools for export enhancement. High-quality human resources are essential for maximizing digital capabilities and aligning technological capabilities with strategic goals (Erdey et al., 2024; Y. Wang et al., 2024). This relationship is supported by studies that emphasize the significance of skilled human capital in amplifying the benefits resulting from digital transformation (Qian & Qun-zhi, 2023; Zhao & Li, 2024). Furthermore, the organizational ambidexterity framework suggests that firms need to balance exploiting existing capabilities and exploring new digital trends to optimize export strategies (Erdey et al., 2024).

Meta-analytic evidence indicates that various internal and external contingencies, including human resource capabilities, significantly influence the outcomes of digitalization on export performance (Dong et al., 2024; Nham et al., 2023). Hence, incorporating these aspects into the theoretical framework enables a nuanced understanding of how digitalization influences export capability, moderated by the quality of human resources within organizations. Additionally, some studies identify nonlinear effects of digitalization on export activities, pointing out that while initial investments in digital technologies may create challenges, the long-term benefits often outweigh these (Nham et al., 2023).

Previous Study
The Nexus of Digitalization toward Export

The relationship between digitalization and export performance has been a focal point of academic inquiry. One of the pivotal studies by Dong et al. (2024) employs a meta-analytic approach to determine the direct effects of digitalization on export performance (EP). Their findings indicate a statistically significant positive effect of digitalization on EP, represented by a correlation coefficient of r = 0.36. The analysis encompasses extensive data drawn from 81 studies, confirming that firms leveraging digital technologies witness improved export outcomes. Such results underscore a broader trend where digitalization facilitates enhanced operational efficiencies, streamlining processes and reducing costs associated with export activities, ultimately leading to an increase in export volume.

In a distinct yet complementary study, Zhao and Li (2024) reveal that advancements in the digital economy, particularly through improved Information and Communication Technologies (ICT), have significantly bolstered China's export trade. They emphasize that enhanced ICT infrastructure minimizes geographical barriers, thereby facilitating smoother international transactions and greater market access for Chinese exporters. The research confirms that digitalization reduces transaction costs and accelerates communication, which are critical for effective export operations.

Additionally, Vasilyeva et al. (2022) emphasize that digital technologies are crucial for developing high-tech products that boost export potential. They contend that, to stay competitive in global markets, regions must invest in digital resources and innovation, as digitalization allows local firms to produce higher-quality goods and services, thereby enhancing export performance.

Furthermore, Wang et al. (2023) provide empirical evidence from China's manufacturing export enterprises, indicating that digital transformation initiates a positive trajectory for enterprise performance. Their multifaceted analysis elucidates how digitalization improves human resources, increases research and development intensity, and ultimately enhances export capabilities. This aligns with the resource-based view (RBV) framework, asserting that digital skills and resources become crucial assets that firms must develop to thrive in competitive international markets.

The findings of Nham et al. (2023) further substantiate the importance of digitalization. They document nonlinear relationships between digitalization's effects on export activity, emphasizing that improvements in logistics, documentation processes, and operational efficiencies lead to reduced costs and time in exporting, consequently boosting export activities. The integration of digital technologies in businesses is posited as a critical factor for diversification and expansion into new international markets.

However, some studies indicated digitalization has a significant negative effect on exports. A notable study by Huang and Song (2019) examines how widespread Internet use, commonly believed to enhance exports, has led to a counterintuitive outcome of reduced export quality for certain firms. Additionally, Wang and Ye (2023) note that while many studies argue digital technology significantly improves trade modes and enhances export quality, there are notable deficiencies in the existing literature. They highlight that measuring export product quality can yield varied results, some of which may be negative. This suggests that digitalization, although generally beneficial, can lead to the proliferation of low-quality exports as firms respond to the competitive pressures of digital economies.

H1: Digitalization has a significant positive impact on exports.

Influence of Human Resources on Export

Research has consistently demonstrated that human resources play a significant and positive role in enhancing export performance across various sectors and industries. One influential study by Fernández-Olmos and Vial (2015) identifies the critical role that human resources play in determining export channel strategies. Their research reveals that firms lacking substantial human resources are inclined to favor indirect exporting channels, which require less commitment compared to direct exporting. Similarly, Munawar et al. (2019) highlight that the commitment of both human and financial resources significantly correlates with improved export performance.

Opiyo et al. (2023) confirm the positive impact of human resource management practices on performance in selected tea exporters in Kenya. Their study suggests that effective human resource planning has a direct impact on employee performance, which in turn enhances export outcomes. This supports the notion that organizations investing in human capital development can achieve superior performance in export activities owing to higher employee engagement and capability. Wang & Xiaowei Zhou (2024) provide insights into the role of structured human capital in influencing

export quality. Their findings demonstrate that a solid foundation in human capital structures not only enhances innovation capacity but also positively impacts the quality of exports.

Wang et al. (2024) illustrates that digital transformation can significantly improve enterprise performance, particularly among manufacturing export enterprises in China. They identify that digital advancements help reduce operational costs and improve human resource processes, enhancing overall productivity. This suggests that integrating digital tools and platforms, when combined with effective human capital development, can create synergistic effects that drive export success. Hitt et al. (2006) underline the importance of both human and relational capital, claiming that success in international markets relies heavily on the quality of human resources. They posit that a firm's ability to customize services and understand client needs hinges on having a skilled workforce.

H2: Human Resources has a significant positive impact on exports.
H3: Digitalization moderated by human resources has a significant positive effect on exports.

2. Methods

Data and Data Sources

This study examines the impact of digital technology adoption, influenced by the quality of human capital, on export performance in Indonesia, taking into account heterogeneity across provinces. Exports are selected as the primary focus of analysis, reflecting their strategic importance in the Indonesian government's efforts to foster sustainable economic growth (Ministry of Trade, 2024). To address this objective, the study utilizes a panel dataset encompassing 34 provinces in Indonesia from 2015 to 2023. During this period, export performance across provinces showed moderate growth, while the adoption of digital technologies and improvements in human capital advanced significantly.

The data used in this study are sourced from nationally recognized institutions to ensure validity and comprehensive coverage. Export data is obtained from Statistik Indonesia, published by Statistics Indonesia (BPS). The level of digitalization is proxied by the Information and Communication Technology Development Index, compiled by the Ministry of Communication and Informatics. Human capital quality is represented by the Human Development Index, which BPS also provides.

To strengthen the accuracy of the model estimation, several control variables are included. Demographic controls consist of the total population and the number of workers in the formal sector. Macroeconomic controls include gross domestic product and the level of investment. All control variables are sourced from BPS. Following the recommendations of Bland & Altman (1996), selected variables are transformed using the natural logarithm to enhance model specification and inferential precision. A summary of the variables used in this study is presented in Table 1.

Category	Unit	Variable	Description	Source
Dependent Variable	log _ekspor	export	Net export (export – import)	Statistics Indonesia
Main Independent Variable	dig_tech	Digital Technology	Development index of Information communication and technology (Index)	Statistics Indonesia and Ministry of Communication and Informatics
	hdi	HDI	Human Development Index (HDI)	Statistics Indonesia
Interaction Term	dig_tech $\times$ hdi	Interaction	Moderating effect	Author Calculation
Control Variable	log_pop	Population	Logarithmic transformation of the population of each province (log)	Statistics Indonesia
	formal_emp	Employment	Percentage of workforce in the formal sector (%)	Statistics Indonesia
	log_grdp	GRDP	Logarithmic transformation of Gross Regional Domestic Product (GRDP) percapita	Statistics Indonesia

log_invest	Investment	Logarithmic transformation of Gross Fixed Capital Formation (log)	Statistics Indonesia

Table 1. Summary of Data

Empirical Estimation Method

To achieve the research objectives, this study employs two complementary quantitative estimation methods: fixed-effects panel regression and quantile regression. This combined approach enables a comprehensive understanding of the relationship between digital technology, human resource quality, and export performance in Indonesia.

The primary method employed is a fixed-effects panel regression model. The fixed effects (FE) estimator is selected to control for unobserved heterogeneity across provinces that could potentially bias the estimates if omitted. By focusing on within-province variation over time, this method enhances the precision of the estimated coefficients while mitigating concerns related to endogeneity due to omitted time-invariant factors. The model estimation is conducted using robust standard errors clustered at the provincial level to correct for heteroskedasticity and serial correlation. The model is specified as follows:

$$\text{log\_export}_{it} = \alpha + \beta_1 \text{ dig\_tech}_{it} + \beta_2 \text{ hdi}_{it} + \beta_3 (\text{dig\_tech}_{it} \times \text{hdi}_{it}) + \gamma' X_{it} + \mu_i + \lambda_t + \varepsilon_{it}$$
....(1)

In this specification, log_export_{it} denotes the export performance of province i in year t, proxied by net exports and expressed in natural logarithmic form. The variable, dig_tech_{it} represents the ICT Development Index, used as a proxy for digital technology adoption. The variable hdi_{it} refers to the Human Development Index, which captures the quality of human capital across provinces in Indonesia. The interaction term $\text{dig}_{\text{tech}_{it}} \times \text{hdi}_{it}$ is included to assess the moderating effect of human capital on the relationship between digital technology and export performance. X_{it} is a vector of control variables, including the natural logarithm of population, formal sector employment, gross regional domestic product (GRDP) per capita, and investment. The term μ_i captures province-specific fixed effects to control for time-invariant unobserved heterogeneity. In contrast, λ_t accounts for year-specific effects such as macroeconomic shocks or national policy changes. The idiosyncratic error term is denoted by ε_{it} .

To capture the heterogeneous effects of digital technology and human capital across the distribution of export performance, we extend the analysis using quantile regression. Unlike ordinary least squares (OLS), which estimates the conditional mean, quantile regression allows estimation at different points of the conditional distribution, such as the 25th, 50th (median), and 75th percentiles. This method is particularly relevant in the context of export disparities among provinces.

The quantile regression model for a given quantile $\tau \in (0,1)$ is specified as equation 2.

$$Q_\tau(\text{log\_export}_{it} | X_{it}) = \alpha_\tau + \beta_{1\tau} \text{ dig\_tech}_{it} + \beta_{2\tau} \text{ hdi}_{it} + \beta_{3\tau}(\text{dig\_tech}_{it} \times \text{hdi}_{it}) + \gamma'_\tau X_{it} \dots\dots (2)$$

In this specification, $Q_\tau(\text{pov}_{it} | X_{it})$ represents the conditional quantile τ of the poverty rate given the covariates. The explanatory variables are defined similarly to the baseline fixed effects model, with coefficients that are allowed to vary across different quantiles.

This approach enables the identification of whether digitalization and human capital exert stronger or weaker effects on provinces with low, median, or high export activity. For instance, digital technology might be more effective in enhancing export performance in already export-intensive regions. At the same time, its marginal effects may be limited in lagging provinces with lower human capital quality. By combining fixed effects and quantile regression, the study provides both average and distributional insights into how digital readiness and human development interact to influence Indonesia's export performance.

3. Results and Discussion

Statistic Descriptive

Table 2 presents summary statistics for the key variables of interest, revealing substantial heterogeneity across Indonesian provinces over the study period. The dependent variable, log export, exhibits a mean of 9.908 with a considerable range from 5.357 to 12.532, indicating pronounced

disparities in export performance. The digital technology index (dig tech), representing ICT development, has a mean of 5.164 and varies widely between 2.13 and 7.73, reflecting uneven levels of digital infrastructure and adoption. Human capital, as proxied by the Human Development Index (HDI), averages 70.729, with values ranging from 57 to 82, indicating significant regional disparities in health, education, and income dimensions. The interaction term (Tech × hdi), constructed to capture the complementary effect of digital technology and human capital on export performance, ranges from 121.41 to 633.86 with a standard deviation of 93.027, underscoring the diversity in provinces' capacity to harness digitalization in the context of human development. The observed variation in these core variables highlights the importance of employing estimation techniques that can address both cross-sectional and distributional heterogeneity, as implemented in the subsequent empirical analysis.

Variable	Mean	Std. Dev.	Min	Max
log export	9.908	1.435	5.357	12.532
dig tech	5.164	1.06	2.13	7.73
hdi	70.729	4.077	57	82
Tech x hdi	368.703	93.027	121.41	633.86
log pop	8.384	1.009	6.464	10.817
formal emp	40.972	10.792	15.57	72.96
Log_grdp	10.481	.549	9.314	12.166
log_invest	4.689	.497	3.76	5.88

Table 2. Descriptive Statistics
Source: Author's data processing results

Table 3 presents the correlation matrix among the key variables, revealing generally modest relationships with the dependent variable, log export. Digital technology (dig_tech) and human capital (hdi) are positively correlated with export performance, with coefficients of 0.195 and 0.251 respectively, suggesting a weak to moderate association. The interaction term (tech_hdi) also shows a low correlation with log export (0.208), but is highly correlated with its constituent variables, dig_tech (0.987) and hdi (0.857), which is expected due to its construction. The strongest correlation with log export is observed for investment (0.600), indicating the importance of capital accumulation in supporting export activity. Overall, the matrix indicates no severe multicollinearity among control variables, though the high correlation between the interaction term and its components necessitates further diagnostic testing during model estimation.

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(1) log_export	1.000							
(2) dig_tech	0.195	1.000						
(3) hdi	0.251	0.776	1.000					
(4) tech_hdi	0.208	0.987	0.857	1.000				
(5) log_pop	0.091	-0.104	-0.082	-0.096	1.000			
(6) formal_emp	0.322	0.511	0.572	0.540	0.037	1.000		
(7) log_grdp	0.431	0.032	0.030	0.038	0.066	0.033	1.000	
(8) log_invest	0.600	0.216	0.399	0.264	-0.214	0.156	0.281	1.000

Table 3. Matrix of Correlations
Source: Author's data processing results

Estimation Result
Table 4 presents the fixed effects estimation results, focusing on the influence of digital technology (dig_tech) and human capital (hdi) on provincial export performance in Indonesia. The coefficient for digital technology is consistently positive and statistically significant at the 1% level across all model specifications. In Model 3, the estimated coefficient of 0.264 implies that a 1% increase in the digital technology index is associated with an approximate 0.264% increase in net exports, holding other factors constant. This underscores the substantial role of digital infrastructure and technology adoption in enhancing regional trade competitiveness. Meanwhile, the coefficient of human capital, proxied by the Human Development Index (HDI), is also positive and statistically significant, though relatively smaller in magnitude. In Model 6, a 1-point increase in the HDI index (which ranges from 0 to 100) corresponds to a 0.064% increase in exports, ceteris paribus. These

results suggest that while both digitalization and human development contribute positively to export performance, the effect of digital technology is more economically meaningful. The findings support the hypothesis that digital readiness is a critical enabler of trade activity at the provincial level. However, its effectiveness may be enhanced when complemented by improvements in human capital.

VARIABLES	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
			Dependent: Net Export			
dig_tech	0.338***	0.296***	0.264***			
	(0.043)	(0.054)	(0.070)			
hdi				0.115***	0.091***	0.064***
				(0.019)	(0.021)	(0.024)
log_pop		1.439*	1.412*		2.469***	2.039**
		(0.813)	(0.816)		(0.777)	(0.797)
formal_emp		0.032**	0.030**		0.039***	0.035**
		(0.013)	(0.013)		(0.013)	(0.013)
log_grdp			0.115			0.114
			(0.081)			(0.082)
log_invest			0.487			1.679*
			(0.976)			(0.883)
Constant	8.118***	-5.157	-8.197	1.721	-19.043***	-22.520***
	(0.229)	(6.865)	(7.816)	(1.321)	(6.116)	(6.212)
Covariates	No	Yes	Yes	No	Yes	Yes
Observations	185	185	185	185	185	185
R-squared	0.281	0.313	0.323	0.195	0.265	0.293
Number of id	25	25	25	25	25	25

Note: (i) Dependent Variable is net export; (ii) Estimation was conducted using Fix Effect Model; (iii) Standard errors are in parentheses; (iv) ***), **), and *) indicate statistical significance at the 1%, 5%, and 10% levels, respectively.
Table 4. Estimation Result for Export Model
Source: Author's data processing results

Building upon the previous findings, which showed that both digital technology and human capital independently contribute to enhancing export performance, Table 5 provides further evidence on their interactive effect. The inclusion of the interaction term tech_hdi, representing the combined influence of digital technology and human capital, reveals a positive and statistically significant coefficient of 0.004 across all model specifications. This result confirms that the positive impact of digitalization on exports is significantly stronger in provinces with higher levels of human development. Specifically, for every one-unit increase in the interaction index, net exports rise by approximately 0.4%, ceteris paribus. This interaction effect underscores the complementarity between technological readiness and human capital quality in driving trade performance. The implication is that digital infrastructure alone is insufficient; rather, its benefits for export activity are amplified when accompanied by improvements in education, health, and income, which enhance the workforce's ability to adopt and utilize digital tools effectively. These findings underscore the importance of adopting integrated policy approaches that simultaneously foster digital transformation and human capital development to maximize the full potential of regional export growth.

VARIABLES	Model 1	Model 2	Model 3
	Dependent: Net Export		
tech_hdi	0.004***	0.004***	0.004***
	(0.001)	(0.001)	(0.001)
log_pop		1.266	1.271
		(0.823)	(0.824)
formal_emp		0.033**	0.031**
		(0.013)	(0.013)
log_grdp			0.116

			(0.080)
log_invest			0.226
			(1.003)
Constant	8.258***	-3.692	-5.844
	(0.209)	(6.945)	(8.090)
Covariates	No	Yes	Yes
Observations	185	185	185
R-squared	0.285	0.318	0.328
Number of id	25	25	25

Note: (i) Dependent Variable is Net Export; (ii) Estimation was conducted using Fixed Effect Model; (iii) Standard errors are in parentheses; (iv) ***), **), and *) indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

Table 5. Estimation Result for Moderating Effect (Interaction Digital Technology* Human Quality)
Source: Author's data processing results

To further enrich the analysis and explore heterogeneous effects across the export distribution, Table 6 reports the results of the quantile regression estimations at the 25th, 50th, and 75th percentiles. Unlike the fixed effects model, which estimates average effects, the quantile regressions allow for a more nuanced understanding of how the influence of digital technology and human capital varies across provinces with low, medium, and high levels of export performance. The results reveal that digital technology (dig_tech) does not exhibit a statistically significant effect at the lower and median quantiles (Q25 and Q50), but becomes positive and marginally stronger at the upper quantile (Q75) with a coefficient of 0.107, though still statistically insignificant. This suggests that the impact of digitalization on exports may become more pronounced in more developed or export-intensive provinces, likely due to their better absorption capacity and complementary infrastructure. In contrast, human capital (HDI) exhibits a statistically significant negative effect at the 25th percentile, suggesting that improvements in human development alone do not immediately translate into better export outcomes in lagging regions, possibly due to limited integration with market opportunities or inadequate digital infrastructure.

When incorporating the interaction term (tech_hdi), the results indicate that the moderating effect of human capital on digital technology remains statistically insignificant across all quantiles. However, the direction of the coefficients remains consistently positive, albeit small, reinforcing the earlier fixed-effects findings that human capital enhances, but does not independently drive, the effectiveness of digitalization for export performance. These results highlight an important asymmetry the benefits of digitalization appear to be concentrated in higher-performing provinces. In contrast, provinces at the lower end of the export distribution may not yet be in a position to convert digital and human capital inputs into tangible trade gains. From a policy standpoint, this underscores the need to address structural bottlenecks in low-export provinces such as infrastructure deficits and institutional weaknesses, before digital and human capital investments can yield optimal outcomes in those regions.

The findings from Tables 4 to 6 collectively highlight the important role of digital technology in enhancing export performance across Indonesian provinces, while also illustrating that its effectiveness depends on specific contextual factors. The fixed effects results indicate that digital technology consistently contributes positively and significantly to net exports, and this impact becomes stronger when supported by higher levels of human capital, as evidenced by the significant interaction effect. However, the quantile regression analysis provides further insight by showing that the positive influence of digital technology is more evident in provinces with higher export performance, while it remains insignificant in lower-performing regions. Similarly, the effect of human capital is limited at the lower quantile, suggesting that improvements in education, health, and income may not immediately lead to export growth unless supported by adequate economic and institutional conditions. These results suggest that digital and human capital are important enablers of trade, but their effectiveness relies on a province's overall readiness to integrate such capacities into productive export activity. Accordingly, policy strategies should focus not only on expanding digital and human development but also on strengthening complementary infrastructure and institutional support to ensure inclusive and regionally balanced export growth.

VARIABLES	Digital Technology			hdi			Digital Technology x hdi		
	Model 1 Q.25	Model 2 Q.50	Model 3 Q.75	Model 4 Q.25	Model 5 Q.50	Model 6 Q.75	Model 7 Q.25	Model 8 Q.50	Model 9 Q.75
dig_tech	-0.003	0.043	0.107						
	(0.123)	(0.137)	(0.119)						
hdi				-0.105***	-0.029	0.008			
				(0.030)	(0.037)	(0.030)			
tech_hdi							-0.001	0.000	0.001
							(0.002)	(0.002)	(0.001)
log_pop	0.413***	0.159	0.057	0.271***	0.207*	-0.057	0.377***	0.158	0.038
	(0.100)	(0.112)	(0.097)	(0.087)	(0.109)	(0.087)	(0.107)	(0.108)	(0.093)
formal_emp	0.011	0.019	0.024**	0.047***	0.024*	0.026**	0.026**	0.020	0.024**
	(0.011)	(0.013)	(0.011)	(0.010)	(0.013)	(0.010)	(0.012)	(0.012)	(0.011)
log_grdp	0.479**	0.917***	0.779***	0.663***	0.953***	0.850***	0.649***	0.914***	0.778***
	(0.212)	(0.237)	(0.205)	(0.186)	(0.233)	(0.186)	(0.227)	(0.230)	(0.196)
Log_invest	1.976***	1.533***	1.263***	1.875***	1.787***	1.096***	1.861***	1.532***	1.224***
	(0.227)	(0.253)	(0.220)	(0.212)	(0.266)	(0.212)	(0.246)	(0.248)	(0.212)
Constant	-9.180***	-9.395***	-5.620**	-3.545	-9.309***	-4.720*	-10.291***	-9.303***	-5.205**
	(2.353)	(2.629)	(2.282)	(2.642)	(3.313)	(2.641)	(2.501)	(2.525)	(2.161)
Covariates	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	185	185	185	185	185	185	185	185	185

Note: (i) Dependent is Net Export; (ii) Standard errors in parentheses; (iii) ***), **), and *) indicate statistical significance at the 1%, 5%, and 10% levels, respectively.
Table 6. Quantile Regression Estimation for Net Export Model
Source: Author's data processing results

Discussion

The findings of this suggest indicate that digital techhatraisignificant impact onntly to improving export performance across provinces in Indonesia. This positive effect becomes stronger when combined with higher levels of human capital, suggesting a complementary relationship between technological capacity and the quality of the workforce. This result aligns with those of Dong et al. (2024), Vasilyeva et al. (2022), Wang et al. (2023), and Zhao and Li (2024).

Digital Technology Significantly Positive to Export

Several studies highlight that when firms effectively harness their human capital alongside digital transformation initiatives, exports are likely to experience a boost due to improved organizational capabilities, enhanced productivity, and greater adaptability in international markets. Digital advancements help reduce operational costs and improve human resource processes, enhancing overall productivity. There are several reasons why digitalization has a significant impact, such as: 1) enhancing communication and market access; 2) reduction of transaction costs; 3) increased productivity and efficiency; 4) improvement in export quality; 5) enhancing access to global markets.

Li et al. (2022) discuss how the digital economy facilitates the circulation of market information and production factors, enhancing overall technical levels and production efficiency. The ability to access real-time information allows businesses to better understand market demands and customer preferences, thereby improving their competitiveness in exports. This improved communication infrastructure is particularly critical for firms in developing countries where market conditions may be less transparent.

According to Jiang et al. (2022) notes that digital trade innovations, including e-commerce platforms and digital logistics, significantly reduce the transaction costs associated with exporting. By streamlining processes such as customs clearance and documentation, digitalization enhances the efficiency of matching supply with demand. This reduction in operational costs allows firms, particularly SMEs, to compete more effectively in global markets, thus boosting their export activities.

The study by Erdey et al. (2024) highlights that digital affordances, such as automation and data analytics, contribute to firm-level productivity gains that positively influence export performance. By leveraging these technologies, firms can allocate resources more efficiently and enhance their production processes, resulting in higher-quality and greater quantities of export goods. These advancements enable companies to adapt quickly to changing market conditions, further facilitating export growth.

Research by Zhang and Duan (2023) indicates that digitalization can promote the quality upgrading of export products through enhanced management practices and innovation capability. By adopting digital tools, businesses can improve quality control and product development, resulting in exported products that meet or exceed international standards. Higher-quality products are crucial for gaining competitive advantages in foreign markets, thereby contributing to increased export volumes.

Boccia et al. (2022) argue that the adoption of ICT allows firms to penetrate new markets more easily. Digital platforms enable businesses to showcase their products to a global audience, overcoming geographical barriers and localized competition. This accessibility amplifies the reach of firms' exports and helps diversify export markets, which is particularly valuable in volatile economic conditions.

Human Capital Boosting the Effect of Digital Technology on Export

Human resource quality, defined by education, skills, and experience, directly influences a firm's competitive edge in export markets. This result can be understood through various mechanisms, such as: 1) quality of human capital; 2) technological adaptation and innovation; 3) digital communication and market responsiveness; 4) reduction of transaction costs; 5) strategic employment of digital tools; 6) support of organizational learning and development; and 7) facilitating knowledge transfers.

Well-designed human resource management practices significantly enhance export performance. Rodríguez & Orellana (2020) argue that High-Performance Work Systems (HPWS) elevate employee skills and commitment, thereby improving innovation and responsiveness in export activities. Firms with high-quality human resources can manage digital technologies more effectively, enhancing productivity and the quality of products offered for export. This relationship highlights the necessity of investing in human capital as a precursor for successful digital transformations and exporting capabilities (Tazliqoh, 2023).

Research by Wang and Shuquan (2024) underscores the significance of human resources in leveraging digital technologies to improve export product quality. The skilled workforce resulting from strategic human capital investments is capable of producing high-quality goods that meet international standards. This correlation implies that human capital is a critical driver in achieving export quality and successful international trade (C. Wang & XiaoweiZhou, 2023).

Provinces with high HDI typically possess a well-educated and skilled workforce, which is vital for enhancing innovation and productivity. Research by Edeh et al. (2020) suggests that a competent labor force facilitates effective implementation of strategies required for export success, as higher educational attainment and training allow workers to leverage technology effectively and adapt to market demands. This contrasts sharply with low HDI provinces, where insufficient educational and training opportunities hinder the development of human capital. As a result, firms in low HDI regions often struggle to maintain competitiveness in the international market, facing challenges related to productivity, quality, and innovation. Furthermore, high HDI provinces are generally more capable of utilizing digital technologies that enhance communication, reduce transaction costs, and streamline operations, leading to improved responsiveness in export activities. Liu et al. (2023) corroborate that provinces with skilled human resources can better navigate the complexities of digital trade, optimizing their production capabilities and aligning with global market requirements. Conversely, low HDI provinces may lack the necessary technological infrastructure and human capital, leading to missed export opportunities. Consequently, the disparity in human resource quality directly contributes to differing levels of export performance across provinces, emphasizing the need for targeted investments in education and workforce development to uplift low HDI areas and enhance their export capabilities. By bridging the gap in human resource quality between regions, countries

can foster a more inclusive and competitive export economy, ultimately driving economic growth and development.

Fernandes et al. (2019) emphasize that sectors producing differentiated products can significantly benefit from digital technologies due to their communication-intensive nature. High-quality human resources facilitate better communication and coordination within firms, allowing for quicker responses to market changes and consumer demands. This responsiveness is crucial for optimizing exports and making strategic decisions based on real-time data from digital channels.

The interplay of human resources and digital technologies can lead to reduced transaction costs associated with exporting. Nham et al. (2023) highlight that digitalization reduces export costs by streamlining documentation and compliance processes, while skilled human resources ensure that firms navigate these processes effectively. High-quality human resources exploit digital tools efficiently to manage these costs, improving overall export performance.

Liu et al. (2023) indicate that digital trade enhances the accumulation of capital, including human resources, and optimizes production allocation. Firms with competent human capital are better positioned to utilize digital technologies for strategic purposes, such as entering new markets or improving product quality. The moderation effect occurs as skilled employees drive the firm's digital capabilities, ensuring that technological investments translate into concrete export outcomes.

Ekananda & Dion (2017) discuss how an established human resource foundation enables firms to engage in organizational learning and adapt strategies to effectively leverage digital technologies. Their capacity to learn and innovate is crucial for remaining competitive in export markets, demonstrating how human resources can influence the impact of digitalization on export performance.

Abeliansky & Hilbert (2017) emphasize the importance of quality data and infrastructure in supporting international trade. High-quality human resources are crucial for effectively utilizing digital tools to manage and analyze data, thereby facilitating knowledge transfers that are vital for strategic decision-making in export activities. This competency improves the overall effectiveness of digital technologies in promoting export growth.

4. Conclusion

The findings of this study indicate that digital technology contributes significantly to improving export performance across provinces in Indonesia. This positive effect becomes stronger when combined with higher levels of human capital, suggesting a complementary relationship between technological capacity and the quality of the workforce. The analysis also shows that the benefits of digitalization are not evenly distributed. Provinces with higher export performance are more likely to gain from advancements in digital technology, while regions with weaker export outcomes appear less responsive. These results highlight that the effectiveness of both digital and human capital is shaped by broader economic and institutional contexts that influence how well regions can utilize these resources.

The results provide valuable insights for policymakers seeking to enhance regional trade competitiveness. Efforts to accelerate digital transformation should be accompanied by parallel investments in human capital development, particularly in education, health, and skills training. In addition, addressing structural limitations in less developed provinces, such as inadequate infrastructure, weak institutional support, and limited market access, is critical to ensuring that all regions can benefit from technological progress. A regionally tailored approach that integrates digital readiness with human capacity building and economic preparedness is essential for promoting inclusive and sustainable export growth across Indonesia.

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