UNEQUAL IMPACTS OF ICT AND HUMAN CAPITAL ON ECONOMIC GROWTH: A QUANTILE REGRESSION APPROACH TOWARD PROVINCIALLY DIFFERENTIATED STRATEGIES IN VIETNAM'S CENTRAL COASTAL REGION

TÁC ĐỘNG KHÔNG ĐỒNG ĐỀU CỦA ICT VÀ VỐN CON NGƯỜI TỚI TĂNG TRƯỞNG KINH TẾ: NGHIÊN CỨU HỒI QUY PHÂN VỊ HƯỚNG ĐẾN CHIẾN LƯỢC CẤP TỈNH PHÂN HÓA TẠI VÙNG TRUNG TRUNG BỘ CỦA VIỆT NAM

Vo Cao Thi Mong Hoai[1,2]*

[1]PhD student Development Economics, The University of Danang - University of Economics, Vietnam
[2]The Department of Science and Technology of Gia Lai Province, Vietnam

*Corresponding author: monghoaicedasit@gmail.com

(Received: April 08, 2025; Revised: June 13, 2025; Accepted: August 29, 2025)

DOI: 10.31130/ud-jst.2025.23(10A).197

Abstract - This study examines the role of information and communication technology (ICT) and human capital in driving regional economic growth, while testing for heterogeneity and asymmetric effects across provincial growth levels. The objective is to provide an empirical basis for stratified development policies tailored to local conditions. The model employs log (GRDP) as the dependent variable, with explanatory variables including ICT index, trained labor ratio, PCI, physical capital, and employment. Panel data from five provinces in the Central Coastal region of Vietnam (2010–2024) are analyzed using quantile regression (QR) and compared with OLS estimates. Results indicate that both ICT and human capital positively influence growth, but their marginal effects diminish at higher GRDP quantiles, reflecting regional disparities in absorptive capacity and diminishing returns. The findings highlight the need for region-specific digital and human capital policies to promote more balanced and sustainable economic development.

Key words - Economic growth; Human capital; ICT; Quantile regression; Central Coastal Region.

Tóm tắt - Nghiên cứu này đánh giá vai trò của công nghệ thông tin (ICT) và vốn con người đối với tăng trưởng kinh tế vùng, đồng thời kiểm định tính không đồng đều và hiệu ứng bất đối xứng của hai yếu tố này giữa các nhóm tỉnh. Mục tiêu là cung cấp cơ sở khoa học cho chính sách phát triển phân tầng, phù hợp với điều kiện của từng địa phương. Mô hình sử dụng GRDP (log) làm biến phụ thuộc, cùng các biến độc lập gồm ICT, tỷ lệ lao động qua đào tạo, PCI, vốn vật chất và lao động. Dữ liệu bảng của 5 tỉnh Trung Trung Bộ (2010–2024) được phân tích bằng hồi quy phân vị (QR) và so sánh với OLS. Kết quả cho thấy, ICT và vốn con người đều tác động tích cực đến tăng trưởng, song hiệu ứng giảm dần ở các phân vị GRDP cao, phản ánh sự khác biệt về năng lực hấp thụ và hiệu suất cận biên giữa các nhóm tỉnh, qua đó gợi mở định hướng phát triển cân bằng vùng.

Từ khóa - Tăng trưởng kinh tế; Vốn con người; Chuyển đổi số (ICT); Hồi quy phân vị; Trung Trung Bộ.

1. Introduction

In the context of transforming growth models, digital transformation (ICT) and human capital are increasingly becoming two strategic pillars driving productivity and economic growth. However, practical realities in the Central Coastal Region of Vietnam reveal pronounced disparities in development levels, access to technology, and labor quality among provinces. Da Nang, with an ICT index consistently above 0.9 since 2016 and the number of trained workers rising from 129,000 (2010) to over 321,000 (2024), has emerged as a hub for technology and high-quality human resources. In contrast, provinces such as Quang Ngai and Binh Dinh exhibit ICT indices ranging from 0.3 to 0.7; although labor productivity has improved, it remains low, and the ability to translate investment capital into growth remains limited.

This gap raises an urgent question: Do ICT and human capital yield equivalent effectiveness across different localities, or is there asymmetry and heterogeneity in their impacts on economic growth? Based on endogenous growth theory and the principle of diminishing marginal returns, such disparities may arise due to differences in production foundations, institutional capacity, and technology absorption capabilities.

Therefore, this study adopts the Quantile Regression (QR) approach not only to examine the impacts of ICT and human capital on GRDP growth, but also to clarify the extent of heterogeneity in these effects across provincial groups and growth levels. This stratified policy approach aims to provide scientific and practical evidence for developing strategies tailored to local conditions, especially in the context of nationwide digital transformation and human resource development policies.

2. Theoretical framework and research methods

2.1. Theoretical foundations and empirical evidence

2.1.1. Relevant theories

In modern economic growth theories, ICT and human capital are considered two crucial pillars that promote growth by enhancing productivity, fostering innovation, and enabling technology absorption. However, the impacts of these factors are not uniform across localities or

countries; they may vary depending on development levels, current growth rates, institutional capacity, or readiness to adopt technology. According to endogenous growth theory, human capital plays a central role in sustaining long-term growth through the creation of new knowledge and technology absorption [1], [2]. However, the effectiveness of human capital investment often depends on the economic foundation - regions with low productivity tend to see more pronounced effects from skill improvement. Similarly, in the context of digital transformation, the "digital divide" theory posits that disparities in infrastructure, skills, and management capabilities across economic regions lead to uneven benefits from ICT [3]. Some studies emphasize that ICT only generates significant effects when coupled with good institutions and appropriate human resource levels [4], [5]. This explains why identical ICT investment may yield different impacts across provinces with varying development levels. The theory of diminishing marginal returns also shows that once a locality reaches high levels of ICT and human capital, the incremental impact of these factors on growth diminishes. Conversely, in regions with lower baselines, the impact is stronger due to greater room for improvement. Therefore, quantitative models such as Quantile Regression are highly suitable for capturing this asymmetry in empirical analysis.

2.1.2. Overview of empirical studies

In recent years, numerous empirical studies have focused on clarifying the uneven impacts of ICT and human capital on economic growth, particularly through flexible quantitative methods like quantile regression (QR) on panel data. Adeleye et al. [6] employed quantile regression combined with the method of moments (MMQR) to analyze the relationship between ICT and growth in SAARC countries. Their findings indicate that ICT exerts a more pronounced positive effect in countries with low growth rates, highlighting the potential for "leapfrogging" through digital technology in less developed economies. In the ASEAN region, Haini [7] analyzed the impact of ICT and export diversification on income inequality, showing that the effect of ICT is stronger in countries with high GINI coefficients - implying uneven benefits from technology across population groups. Chen and Ye [8] applied spatial quantile regression to assess the role of ICT in GRDP growth across 280 Chinese cities. The results reveal that the effect of ICT diminishes across quantiles, being stronger in localities with low GRDP, and also record spatial spillover effects, where ICT in developed cities can positively influence neighboring areas. In Vietnam, Tam et al. [9] used QR to analyze the influence of human capital and ICT index on provincial economic growth, finding that these two factors have different impacts across quantiles: human capital exerts a greater effect in low-GRDP provinces, while ICT is more effective in high-GRDP groups. Nguyen and Pham [10] evaluated the impact of public spending on science and technology on growth across 63 Vietnamese provinces/cities, and found that policy effectiveness is more evident in provinces with medium and low growth - reflecting the asymmetry according to absorption capacity. Recent studies have continued to expand the QR approach. Shi and Wang [11] applied Bayesian quantile regression to test the role of human capital in industrial restructuring in China, discovering the strongest effect at median quantiles - corresponding to the production restructuring phase. Jiang et al. [12] compared the impacts of human and physical capital on economic growth and green growth (Green GDP) using QR, concluding that human capital plays a stable and prominent role at higher quantiles. Additionally, Sun et al. [13] showed that green ICT, human capital, and urbanization have stronger effects on sustainable growth in developing countries, emphasizing the role of foundational conditions and transformation capacity. Collectively, these findings demonstrate that quantile regression is a suitable tool for elucidating the asymmetry in the impacts of ICT and human capital, especially when analyzing groups of localities with differing development characteristics. This supports the design of more appropriately stratified policies, rather than applying a uniform policy model for all.

2.2. Research methods

Analytical framework and proposed research model

The analytical framework and theoretical model of this study are constructed based on modern theories of economic growth and technology. According to endogenous growth theory [1], [2], human capital is a key factor driving long-term growth through the creation of new knowledge, skill improvement, and technology absorption. The digital divide theory [3] points out that the impact of ICT is uneven across regions, due to differences in digital infrastructure, institutional capacity, and digital skills of the workforce. Combined with the principle of diminishing marginal returns, ICT and human capital tend to have greater impacts in less developed localities and diminish in more developed ones. Moreover, the model incorporates three control variables: institutional quality (PCI), physical capital (K), and labor (L) to ensure completeness and theoretical relevance. According to modern institutional theory, institutions strongly influence resource allocation and operational efficiency [14]. Physical capital and labor are foundational factors in classical and endogenous growth models, providing the basis for ICT and human capital to be effective [15]. Recent studies also reinforce this assumption. Chen and Ye [8] found that ICT's impact diminishes according to GRDP, while Jiang et al. [12] and Shi & Wang [11] highlight the distinct roles of human capital across development quantiles. Therefore, this study chooses quantile regression (QR) to capture asymmetry, thereby guiding policy according to provincial groups within the region. The theoretical model for the study posits that economic growth is a function of human capital (H), digital transformation (ICT), and other control variables Xi, as shown in equation (1):

$$TTKT = f(H, ICT, X_i) \quad (1)$$

From (1), the empirical analytical model can be constructed as follows (2):

$$Lny_{it} = \beta_0 + \beta_1 lnlquadt_{it} + + \beta_2\, ICT1_{it} + \beta_3\, pci_{it} + \beta_4 lnk_{it} + \beta_5\, lnl_{it} + \varepsilon_{it} \quad (2)$$

Where: The dependent variable is Lny – economic growth; independent variables include Lnlquadt – representing

human capital, ict – digital transformation; and control variables including pci – institutional quality, lnk – physical capital, and lnl – labor.

Data: Provincial-level data of the Central Coastal Region of Vietnam from the Provincial Statistical Offices (now regional branches), the Ministry of Information & Communications (now the Ministry of Science and Technology), and the Vietnam Chamber of Commerce and Industry for the period 2010–2024. The availability of provincial and time-series data allows for the construction of panel data for analysis.

Estimation methods

This study employs a combination of two methods: ordinary least squares (OLS) regression and quantile regression (QR). While OLS only provides information on the average impact of input factors on economic growth, QR enables analysis of impacts at each quantile level, thereby more fully reflecting the heterogeneity and asymmetry of economic relationships among provincial groups with different development levels.

The choice of QR is grounded in both theoretical foundations and recent empirical evidence. According to endogenous growth theory [1], [2], human capital is a core factor in knowledge creation and technology absorption, but its effectiveness depends on institutional foundations and the development level of the locality. The digital divide theory [3] also shows that disparities in technical infrastructure and digital skills lead to varying access and utilization of ICT across regions. Furthermore, the principle of diminishing marginal returns implies that the marginal impact of ICT or educational investment tends to be stronger in areas with lower baselines, where there is more room for improvement.

Recent empirical studies have reinforced the rationale for QR. Adeleye et al. [6] found that ICT exerts a stronger effect in countries with low growth. Chen and Ye [8] used spatial quantile regression to reveal that ICT's impact diminishes across GRDP quantiles in Chinese cities. Similarly, Tam et al. [9] in Vietnam found that human capital has a stronger influence in provinces with low GRDP, while ICT is more effective in high-GRDP groups. Additionally, Shi and Wang [11] applied Bayesian QR to identify the phase of industrial restructuring as the period when human capital is most effective, while Jiang et al. [12] used QR to clarify the prominent role of human capital in green growth at higher quantiles. These findings demonstrate that QR is a superior tool compared to OLS in quantifying stratified and asymmetric effects, making it particularly suitable for the intra-regional disparities observed in Vietnam's Central Coastal Region.

3. Research findings

3.1. Overview of economic growth, digital transformation (ICT), human capital, physical capital, and labor in Vietnam's Central Coastal Region

Economic growth in the provinces shows a clear upward trend over time, with Da Nang possessing the largest GRDP scale and maintaining stable growth rates, far surpassing other provinces in the region. Da Nang's GRDP increased from approximately VND 34,763 billion in 2010 to over VND 79,200 billion in 2024 (2010 constant prices). Quang Nam and Quang Ngai also recorded strong GRDP growth, especially in the period before the COVID-19 pandemic. Meanwhile, Thua Thien Hue and Binh Dinh experienced stable growth but have smaller GRDP scales, partly reflecting constraints in production bases and urban scale.

In terms of digital transformation, Da Nang continues to affirm its position as the leading ICT center in the region, maintaining a high and stable ICT index (above 0.9 since 2016). The remaining provinces have lower ICT levels, ranging from 0.3 to 0.7, but all show improvement trends after 2020, especially Binh Dinh and Quang Ngai. Da Nang's high ICT development is closely linked to GRDP growth and labor productivity, highlighting the positive relationship between digital transformation and economic growth, particularly in central urban areas.

Human capital, measured by the number of trained workers, has increased continuously across all localities. Da Nang leads absolutely, rising from 129,000 people in 2010 to over 321,000 in 2024. Quang Nam and Quang Ngai also recorded significant increases, reflecting the expansion of vocational training and higher education in these provinces. Notably, labor productivity has also risen sharply in provinces with substantial improvements in labor quality, especially Da Nang and Quang Ngai. This reinforces the positive impact of human capital on productivity and GRDP, particularly when combined with ICT.

Regarding physical capital, all provinces have increased investment, albeit at different levels. Quang Nam and Da Nang have seen substantial increases in total physical capital, reflecting rapid industrialization and urbanization. Meanwhile, Quang Ngai and Binh Dinh, despite increased capital investment, have not seen corresponding rises in labor productivity, indicating limitations in the absorption and transformation of capital into production efficiency.

Changes in labor and population across provinces have occurred relatively steadily, but labor productivity is the key indicator reflecting development effectiveness. Da Nang has the highest and steadily increasing labor productivity, reaching VND 119 million per person in 2024. Quang Ngai stands out with strong productivity growth after 2020, while Thua Thien Hue and Binh Dinh, despite substantial investment in ICT and training, still maintain lower productivity levels, suggesting the need to improve organizational efficiency and innovation.

From the above analysis, it is evident that the relationship between ICT, human capital, and economic growth is synergistic and conditional. In localities like Da Nang, where high ICT foundations, quality labor, and abundant physical capital converge, the combined impact of these factors on GRDP and productivity is very pronounced. Conversely, in provinces such as Binh Dinh or Thua Thien Hue, fragmented development prevents ICT or human capital from fully promoting growth. This indicates that economic growth does not depend on a single factor, but requires synchronization among digital infrastructure

investment, education and training development, and an efficient production-business environment.

4. Analytical results

4.1. Statistical data

Table 1, descriptive statistics of the variables used in the study.

Table 1. *Descriptive Statistics*

Variable Name	Mean	Std. Dev.	Min	Max
lny	10.65	0.36	9.78	11.28
lnlquadt	5.04	0.34	4.24	5.82
ict	0.49	0.11	0.32	0.77
pci	64.27	4.10	52.21	70.42
lnk	9.92	0.41	9.23	11.59
lnl	6.55	0.19	6.08	6.80

(Source: Compiled from data of Provincial Statistical Offices in the Central Coastal Region, Ministry of Information and Communications (now Ministry of Science and Technology), Vietnam Chamber of Commerce and Industry during the period 2010–2024)

Table 1 shows that the variables in the model exhibit reasonable fluctuations and clearly reflect differences among localities. Economic growth (lny) is stably distributed, while digital transformation (ICT), human capital (lnlquadt), and institutional quality (PCI) display moderate dispersion, suitable for testing the roles of independent variables. Physical capital (lnk) fluctuates strongly, indicating investment disparities among provinces, whereas labor (lnl) is relatively uniform, suggesting that labor quality is the noteworthy distinguishing factor. Overall, the data is well-dispersed, with no abnormal signs, suitable for quantitative analyses such as linear regression, quantile regression, and simultaneous models to examine the relationships among ICT, human capital, and economic growth.

4.1.1. Analytical results

Model comparison and selection: Estimation results show that both OLS and quantile regression (QR) models confirm the statistically significant, positive roles of human capital, digital transformation (ICT), institutional quality, physical capital, and labor in economic growth. However, the QR model provides deeper insights by analyzing the variation in the impact of these factors across different growth levels. Specifically, the coefficients of human capital and ICT tend to decrease as the quantile increases, indicating that these two factors exert stronger impacts in provinces with low growth and decline in provinces with higher growth. This reflects the asymmetric effect of input factors, which the OLS model - reflecting only overall averages - cannot capture. While OLS coefficients and fit are comparable to QR at the median quantile (Q50), QR allows for the identification of differences among provincial groups, thereby better supporting stratified policy formulation. Therefore, in terms of analytical depth and suitability for research objectives, quantile regression (QR) is considered a superior choice over OLS in this context.

Differential impacts across growth levels: According to endogenous growth theory [1], [2], human capital plays a central role in sustaining long-term growth through knowledge creation and technology absorption. QR results in Figure 1 and Table 1 show that the impacts of human capital and ICT on economic growth decrease as quantiles increase. Specifically, in provinces with low GRDP, the regression coefficients of these two variables are significantly higher, while in provinces with high GRDP, the coefficients decrease markedly. This aligns with the theory of diminishing marginal returns, i.e., in provinces with lower development levels, investment in education or digital infrastructure yields greater effects due to more room for improvement. Conversely, in developed provinces like Da Nang, the incremental benefits from ICT and training diminish. This finding is also supported by recent studies such as [6], which assert that ICT plays a stronger role in slow-growing economies; or the study by [8] in Vietnam, indicating that human capital has a stronger impact in localities with low growth.

Detection of asymmetric effects: Figure 1 clearly illustrates the asymmetric effects in the impacts of ICT and human capital, as the coefficients of these two variables fluctuate strongly across quantiles, while other variables such as institutional quality (PCI), physical capital (lnk), or labor (lnl) remain relatively stable. This indicates that the impacts of ICT and human capital differ not only by economic scale but also by nature, depending on each locality's development level. In the context of digital transformation, the "digital divide" theory [3] suggests that disparities in infrastructure, skills, and management capacity lead to differences in the ability to reap benefits from ICT across regions. Empirical studies such as [4] and [5] also emphasize that ICT only generates significant effects when accompanied by good institutions and suitable human resource levels. Therefore, identical investments in ICT or education/training may yield very different results among provinces, depending on their initial foundations and absorption capacity.

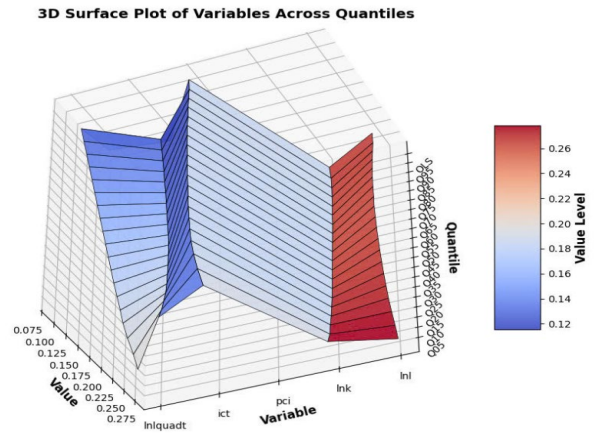

Figure 1. *Variation of Regression Coefficients across Quantiles*

(Source: Author's calculations based on data from the Provincial Statistical Offices in the Central Key Economic Region, the Ministry of Information and Communications (now the Ministry of Science and Technology), and the Vietnam Chamber of Commerce and Industry during the period 2010–2024)

Identification of Provincial Groups Requiring Differentiated Policies: Based on these findings, it is possible to clearly identify provincial groups requiring different policy priorities. For provinces with low growth such as Quang Ngai and Binh Dinh, policy should focus on improving digital skills, expanding basic ICT infrastructure, and promoting vocational training - since these areas have significant room for improvement. For medium-growth provinces like Thua Thien Hue and Quang Nam, policies should aim to enhance local institutional quality and promote digital applications in production and public services. For Da Nang - an advanced, high-growth province - policy should shift toward in-depth investment, such as developing green ICT, research and innovation, improving management skills, and research capacity. Quantile regression results are crucial tools for specifically identifying provincial groups by their responsiveness to policy, thereby supporting the design of more differentiated and effective development strategies, rather than applying a uniform policy across the region. This approach aligns with the research directions of Sun et al. [10], Haini [7], and Nguyen & Pham [9], which emphasize the multidimensional and stratified nature of technology and education policy effects.

Table 2. *Estimation Results of Variables in the Model*

Variable, Quantile	Dependent variable – lny - TTKT						
	lnlquadt	**ict**	**pci**	**lnk**	**lnl**	**Constant**	**Pseudo R^2**
Dependent Variable – lny – Economic Growth							
Q05	0.242 *** (0.054)	0.155 *** (0.038)	0.117 *** (0.040)	0.267 *** (0.046)	0.290 *** (0.060)	5.431 *** (0.531)	0.471
Q10	0.231 *** (0.050)	0.161 *** (0.036)	0.104 *** (0.038)	0.273 *** (0.043)	0.283 *** (0.056)	5.472 *** (0.502)	0.480
Q15	0.217 *** (0.048)	0.165 *** (0.035)	0.095 *** (0.036)	0.275 *** (0.042)	0.275 *** (0.054)	5.489 *** (0.481)	0.487
Q20	0.206 *** (0.046)	0.169 *** (0.034)	0.089 *** (0.035)	0.278 *** (0.041)	0.268 *** (0.053)	5.505 *** (0.467)	0.492
Q25	0.199 *** (0.044)	0.171 *** (0.033)	0.086 *** (0.034)	0.280 *** (0.040)	0.263 *** (0.051)	5.515 *** (0.452)	0.495
Q30	0.191 *** (0.043)	0.172 *** (0.032)	0.084 *** (0.033)	0.282 *** (0.039)	0.258 *** (0.050)	5.525 *** (0.441)	0.498
Q35	0.183 *** (0.042)	0.173 *** (0.032)	0.082 *** (0.033)	0.283 *** (0.039)	0.254 *** (0.049)	5.533 *** (0.433)	0.501
Q40	0.176 *** (0.041)	0.173 *** (0.032)	0.081 *** (0.032)	0.284 *** (0.039)	0.250 *** (0.048)	5.540 *** (0.426)	0.503
Q45	0.169 *** (0.041)	0.173 *** (0.032)	0.080 *** (0.032)	0.285 *** (0.039)	0.247 *** (0.048)	5.547 *** (0.420)	0.505
Q50	0.162 *** (0.041)	0.172 *** (0.032)	0.079 *** (0.032)	0.286 *** (0.039)	0.244 *** (0.048)	5.553 *** (0.414)	0.506
Q55	0.155 *** (0.042)	0.170 *** (0.032)	0.078 *** (0.032)	0.287 *** (0.039)	0.242 *** (0.048)	5.558 *** (0.409)	0.507
Q60	0.148 *** (0.043)	0.168 *** (0.033)	0.078 *** (0.033)	0.288 *** (0.040)	0.241 *** (0.049)	5.563 *** (0.404)	0.507
Q65	0.141 *** (0.045)	0.166 *** (0.034)	0.077 *** (0.034)	0.289 *** (0.041)	0.240 *** (0.050)	5.567 *** (0.400)	0.506
Q70	0.134 *** (0.047)	0.164 *** (0.035)	0.077 *** (0.035)	0.290 *** (0.042)	0.239 *** (0.051)	5.570 *** (0.396)	0.504
Q75	0.127 *** (0.050)	0.161 *** (0.037)	0.077 *** (0.036)	0.291 *** (0.044)	0.239 *** (0.053)	5.572 *** (0.392)	0.502
Q80	0.120 *** (0.053)	0.159 *** (0.038)	0.078 *** (0.037)	0.291 *** (0.046)	0.240 *** (0.055)	5.573 *** (0.389)	0.499
Q85	0.113 *** (0.057)	0.156 *** (0.040)	0.078 *** (0.038)	0.291 *** (0.048)	0.241 *** (0.057)	5.573 *** (0.386)	0.495
Q90	0.106 *** (0.061)	0.153 *** (0.042)	0.079 *** (0.040)	0.291 *** (0.050)	0.243 *** (0.060)	5.572 *** (0.383)	0.490
Q95	0.099 *** (0.066)	0.150 *** (0.044)	0.080 *** (0.041)	0.290 *** (0.052)	0.245 *** (0.063)	5.570 *** (0.380)	0.484
OLS	0.162 *** (0.041)	0.172 *** (0.032)	0.079 *** (0.032)	0.286 *** (0.039)	0.244 *** (0.048)	5.553 *** (0.414)	0.506

***Note: Standard errors are in parentheses. *** and * denote statistical significance at the 1%, 5%, and 10% levels, respectively*

(Source: Author's calculations based on data from the Provincial Statistical Offices in the Central Key Economic Region, the Ministry of Information and Communications (now the Ministry of Science and Technology), and the Vietnam Chamber of Commerce and Industry during the period 2010–2024).

5. Conclusions and policy implications

5.1. Conclusions

The research results affirm that the impacts of human capital and digital transformation (ICT) on economic growth in the Central Coastal Region are uneven and depend on the current development level of each locality. Based on the quantile regression model, ICT and human capital exhibit larger marginal effects in provinces with low growth, while in more developed provinces, the additional impact tends to diminish. This finding clearly reflects the asymmetry in policy effectiveness and underscores the need for more appropriate group-based approaches in development planning.

5.2. Policy implications

Accordingly, the following policy implications can be proposed for the Central Coastal Region:

For Da Nang: As the regional leader in GRDP scale, ICT index, trained labor force, and labor productivity, Da Nang demonstrates a clear synergistic effect between ICT and human capital on growth. With its advanced foundation, the marginal returns from further investment in ICT and education tend to decrease. Therefore, policy should shift focus to in-depth investment, concentrating on R&D, green ICT, innovation, advanced education, and core technology development, to maintain its role as a central hub for technology and knowledge diffusion throughout the region.

For Quang Nam and Quang Ngai: These provinces have made clear progress in GRDP and human capital, especially after 2020. However, the effectiveness of ICT and capital investment in productivity remains limited, particularly in Quang Ngai. Thus, these provinces need to strengthen synchronized investment in ICT infrastructure, human resource training, and production management capacity. It is especially important to promote regional linkages with Da Nang in sharing digital platforms, modern vocational training programs, and technology transfer in industrial parks and satellite urban areas.

For Thua Thien Hue and Binh Dinh: These provinces have stable growth rates, but ICT foundations, productivity, and labor quality remain below their investment potential. Targeted support policies are needed, such as data infrastructure development, promoting digitalization among small and medium-sized enterprises, and integrating digital skills training with practical business needs. Additionally, there should be a reassessment of public investment effectiveness and improvements in local institutional quality to ensure that ICT and human capital are not "fragmented" in development.

REFERENCES

[1] R. E. Lucas, "On the mechanics of economic development", *Journal of Monetary Economics*, vol. 22, no. 1, pp. 3–42, 1988.

[2] P. M. Romer, "Endogenous technological change", *Journal of Political Economy*, vol. 98, no. 5, Part 2, pp. S71–S102, 1990.

[3] J. van Dijk, *The Deepening Divide: Inequality in the Information Society*, SAGE Publications, 2005.

[4] T. Niebel, "ICT and economic growth – Comparing developing, emerging and developed countries", *World Development*, vol. 104, pp. 197–211, 2018.

[5] P. Koutroumpis, "The economic impact of broadband on growth: A simultaneous approach", *Telecommunications Policy*, vol. 33, no. 9, pp. 471–485, 2009.

[6] B. N. Adeleye, A. Jamal, L. S. Adam, and T. Oyedepo, "ICT leapfrogging and economic growth among SAARC economies: Evidence from method of moments quantile regression", *Environment, Development and Sustainability*, vol. 26, no. 34, pp. 1–16, 2022.

[7] H. Haini, "The Impact of the ICT and Export Diversification on Income Inequality", *Springer Lecture Notes in Networks and Systems*, vol. 426, pp. 303–318, 2021. [Online]. Available: https://doi.org/10.1007/978-3-031-60997-8_30

[8] Z. Chen and X. Ye, "Heterogeneous Effects of ICT across Multiple Economic Development in Chinese Cities: A Spatial Quantile Regression Model", *Sustainability*, vol. 13, no. 4, p. 2041, 2021. [Online]. Available: https://doi.org/10.3390/su13042041

[9] C. M. Tam, N. A. Phong, and L. V. Chinh, "The Impact of Human Capital and ICT Index on Local Economic Growth in Vietnam", *International Journal of Religion*, vol. 5, no. 7, pp. 431–440, 2024. [Online]. Available: https://www.researchgate.net/publication/380499707

[10] T. A. Nguyen and H. T. Pham, "The impact of public science spending on economic growth in Vietnam", *Applied Economics Letters*, 2025. [Online]. Available: https://doi.org/10.1080/13504851.2025.2462724 (Accessed: Mar. 5, 2025).

[11] H. Shi and Y. Wang, "Analysis of Human Capital Effects Introducing Bayesian Quantile Regression in the Process of Industrial Structural Upgrading", *PLOS ONE*, vol. 19, no. 1, pp. 1–18, 2024. [Online]. Available: https://doi.org/10.1371/journal.pone.0289123

[12] J. Jiang, M. Wu, and Y. Zhang, "A Comparative Study of the Impacts of Human Capital and Physical Capital to Economic Growth: Evidence from China Based on Quantile Regression", *Energies*, vol. 13, no. 22, p. 5963, 2020. [Online]. Available: https://doi.org/10.3390/en13225963

[13] Y. Sun, Q. Bao, S.-Y. Wu, and A. Razzaq, "Influence of green ICT and socioeconomic factors on sustainable growth", *Journal of Environmental Management*, vol. 351, p. 120139, 2024. [Online]. Available: https://doi.org/10.1016/j.jenvman.2024.120139.

[14] D. Acemoglu and J. A. Robinson, *Why Nations Fail: The Origins of Power, Prosperity, and Poverty*, Crown Publishers, 2012.

[15] R. M. Solow, "A Contribution to the Theory of Economic Growth", *Quarterly Journal of Economics*, vol. 70, no. 1, pp. 65–94, 1956.