

UTILISATION OF TECHNOLOGY INFORMATION AND COMMUNICATION TO IMPROVE SUSTAINABLE REGION'S COMPETITIVENESS

JEFFRY WOWILING¹, STANSS L.H.V.J. LAPIAN², GREIS M. SENDOW³ and HEINCE RUDY NICKY WOKAS⁴

¹Student, Doctoral Program of Management Science, Sam Ratulangi University Manado.
Lecturer, Bitung College of Business and Management, North Sulawesi. Email: jeffryw69@gmail.com,
ORCID: 0000-0003-3783-9726

²Professor, Faculty and Economics and Business, Sam Ratulangi University Manado, Indonesia.
Email: lapianjoyce@unsrat.ac.id, ORCID: 0000-0001-5421-0722

^{3,4}Lecturer, Faculty and Economics and Business, Sam Ratulangi University Manado, Indonesia.
Email: ³greis5sendow@gmail.com, ⁴heincewokas@unsrat.ac.id
ORCID: ³0009-0009-2429-246X, ⁴0000-0002-2999-9028

Abstract

Purpose: This research examines the impact of technology information and communication on sustainable regional competitiveness, with a focus on key dimensions including connectivity, human capital, technology integration, internet usage, public digital services, operational efficiency, global market access, and the promotion of local innovation. **Methodology/Approach:** This research employed a quantitative design with a purposive sample of 385 respondents, comprising educators, bureaucrats, community leaders, private sector employees, entrepreneurs, and members of the Regional People's Representative Council. Data were collected using a structured questionnaire and analyzed using structural equation modeling with Smart PLS version 3.2.9. **Findings:** Research indicates that technology information and communication positively and significantly influence regional competitiveness. Furthermore, it mediates the relationship between the variables of Quality of Education, Quality of Human Resources, and innovation capability to sustainable regional competitiveness. **Research Limitation/Implication:** This study only focuses on several main dimensions, while other factors such as political and cultural stability are not analyzed. Further research can consider these variables for a more comprehensive study. **Originality/Value of paper:** This study identifies the strategic role of determinants of regional competitiveness and highlights the significance of utilising technology information and communication in enhancing sustainable regional competitiveness.

Keywords: Technology Information and Communication; Quality of Education; Quality of Human Resources; Innovation Capability; Sustainable Region's Competitiveness.

Research Areas: Management of Technology and Innovation; Quality by Sustainability.

INTRODUCTION

Sustainable regional competitiveness refers to a region's capacity to enhance living standards and community welfare while prioritising environmental sustainability (Kouskoura et al., 2024). It encompasses the interplay between a company's superiority and economic performance, measured through welfare comparisons with more advanced regions (Kovács, Bodnár, and Lengyel, 2023). To maintain and improve societal welfare in an environmentally sustainable manner, it is essential to develop individuals with adequate education and

innovative capabilities (Uğurluay and Kirikkaleli, 2022). In pursuit of enhanced economic growth, governments have implemented various policies aimed at improving educational quality, increasing the capacity and competency of human resources to contribute effectively to national economic development.

Regions or business organisations with an adequate education level are likely to achieve higher incomes and more sustainable jobs (Charatsari, Michailidis, and Lioutas, 2024). Furthermore, reliable human resources within these organisations are expected to drive innovations and breakthroughs, enhancing their competitive positioning and contributing to sustainable national development. Therefore, investing and developing a skilled workforce has become an urgent organisational priority. The advancement of information technology (IT) serves as a key driver of global economic and social transformation, underscoring the need to explore the relationship between Technology Information and economic growth tailored to each country's development level (Daher, Ashour, and Hamdan, 2022). Information technology facilitates the creation of new products and services that respond to market demands, enhance organisational adaptability, increase digital literacy, and ensure the availability of necessary infrastructure and resources (Rahoveanu et al., 2022). Thus, integrating quality education and effective IT utilisation is vital for fostering innovation and achieving sustainable regional competitiveness.

However, there is still a knowledge gap regarding how Information Technology can be effectively integrated with other factors influencing regional competitiveness, such as education quality, human resources (HR), and innovation capabilities. The quality of education plays a role in providing a skilled and knowledgeable workforce. In contrast, the quality of human resources reflects the individual's ability to apply their knowledge and skills professionally. Innovation capability includes the region's ability to create and implement new solutions to increase productivity and competitiveness.

Not all individuals or organisations have equal access to technology applications, leading to a digital divide that encompasses not only ownership of devices like smartphones and laptops but also a low understanding of information technology among vulnerable groups, including the homeless, impoverished, elderly, and rural communities. This issue extends beyond physical access, including gaps in digital skills, technology use, infrastructure quality, access to digital content, and various socioeconomic factors. Thus, the digital divide is a multifaceted problem involving disparities in access, capability, and socioeconomic influences on the use of digital technology (Lythreatis, Singh, and El-Kassar, 2022).

This research is essential because the use of information and communication technology in the current era of globalisation can create efficiency and productivity. For several decades, developments in information technology (IT) and knowledge management that can create competitive advantages have been one of the main concerns of managers and academics (Liu et al., 2019).

Technology information and communication in education and training can improve human resource skills, which in turn can encourage innovation and increase regional competitiveness. This is explained by human capital theory, which views each individual's knowledge and skills

as valuable in increasing regional production and economic growth. By utilising information and communication technology, regional competitiveness will be managed effectively and efficiently, and it will be able to adapt to the times. Technology information and Communication investments have helped companies reduce communication and coordination costs.

This research aims to identify information and communication technology use in increasing sustainable regional competitiveness. For this reason, this research contributes to the development of comprehensive literature. It provides practical implications to help policymakers understand how to maintain and increase regional competitiveness through a more integrative and holistic approach. This research can also help public and private organisations maximise the management of reliable human resources through technology information and communication.

LITERATURE REVIEW AND HYPOTHESIS DEVELOPMENT

Grounded in Resource-Based Theory (RBT), the framework posits that regions can attain sustainable competitive advantage by effectively utilising valuable, rare, and inimitable resources. Education quality, human resources, innovation capacity, and Technology information and Communication are key strategic resources that enhance regional capabilities. RBT highlights the importance of strong internal capabilities, such as an effective education system, in fostering innovation and economic growth. By prioritising human resource development and cultivating a culture of innovation, regions can secure lasting competitive advantages, with Technology information and Communication acting as a dynamic mediator that supports these initiatives and facilitates continuous learning in a rapidly changing global environment.

The Influence of Education Quality on Human Resource Quality

Education is a fundamental determinant of human resource quality, as an individual's knowledge, skills, and abilities are directly influenced by their educational attainment, impacting their workplace performance. Given its critical role in human resource development, policymakers must investigate the relationship between education quality and human resource effectiveness (Prout et al., 2023). Adequate education equips individuals with essential knowledge, practical skills, and critical thinking abilities for job success. Numerous studies have established a correlation between the cognitive skills of a nation's workforce and economic growth, positing that a more educated population enhances productivity, innovation, and overall economic prosperity (Wang, Liu, and Yin, 2024).

Access to high-quality education is vital for addressing social inequality and enhancing social mobility, as it empowers individuals to overcome barriers and escape the cycle of poverty. Research shows that providing quality education to disadvantaged children leads to favourable long-term economic outcomes, such as increased income, lower incarceration rates, and improved social mobility (Sheehan et al., 2022). Moreover, education is essential for human development and enhancing the quality of human resources, with adequate education linked to

regional economic growth (Krstić, Filipe, and Chavaglia, 2020; Chentukov et al., 2021). Therefore, the author proposes the following hypothesis:

H1: Quality of education positively and significantly affects the quality of human resources

The Influence of Education Quality on the Technology Information and Communication Technology Human Resources

Integrating information technology and communication in education has transformed teaching and learning models, offering new ways to access information, collaborate, and engage with content. Platforms such as online courses and educational apps enable personalised learning experiences tailored to individual needs and styles. Furthermore, technology facilitates distance learning, overcoming geographic barriers and improving access for remote or underserved communities. This advancement fosters a more inclusive and equitable educational environment, empowering students from diverse backgrounds to achieve their goals without geographical constraints.

Technology information and communication are crucial in enhancing education quality by providing educators with innovative tools and resources. It utilises digital platforms and interactive technologies to foster a dynamic and engaging learning environment, promoting active participation and critical thinking among students. Additionally, it enables educators to access various educational resources, such as multimedia content, simulations, and online assessments, enriching the teaching and learning process and facilitating a deeper understanding of concepts. By effectively utilising these technologies, educational institutions can improve learning outcomes, increase student engagement, and better prepare students for success in the digital era (Wirajing and Nchofoung, 2023). Based on these insights, the author formulates the following hypothesis.:

H2: Quality of education is positively and significantly affect Technology Information and Communication

The Influence of Education Quality on Regional Competitiveness

The quality of education is closely linked to a nation's competitiveness on the global stage, as a high-quality education system equips individuals with critical thinking skills, innovative abilities, and advanced knowledge, thereby fostering economic growth (Adolfo van Ronzelen Enríquez et al., 2023). Countries with strong education systems excel in innovation-driven economies, producing an adaptable and skilled workforce in new technologies and complex problem-solving. Furthermore, quality education enhances a nation's ability to attract investment by creating a highly qualified workforce that meets modern industry demands, ultimately boosting competitiveness. Research indicates that nations with higher education and training rankings generally exhibit stronger economic performance and greater resilience to global challenges (Montrimas et al., 2024).

Additionally, a robust education system promotes a culture of lifelong learning and continuous improvement, which is essential for maintaining competitiveness in a rapidly evolving world. Lifelong learning initiatives ensure that the workforce remains current with industry trends and

technological advancements, enhancing employability and productivity. Fernández-Portillo, Almodóvar-González, and Hernández-Mogollón (2020) highlight that ongoing skills development is crucial for sustaining regional economic competitiveness. Based on these observations, the author formulates the following hypothesis.

H3: Quality of education positively and significantly affects sustainable regional competitiveness

The Influence of Human Resource Quality on Innovation Capability

Human resources (HR) quality is related to a nation's ability to innovate. Highly skilled and educated individuals drive the creative process that leads to new technologies, products, and services. Countries with higher education and training demonstrate more robust innovation performance, as their workforce is better equipped with the skills necessary to engage in complex problem-solving and creative thinking (Lo and Tian, 2020). Human resource development through continuing education and professional development is essential for sustaining innovation, as lifelong learning initiatives and workplace training enhance employees' adaptability to new technologies and methodologies, fostering an innovative environment (Gajdzik and Wolniak, 2022).

Organisational investments in employee skills significantly influence a company's innovative output; those prioritising training and development are more likely to achieve innovation (Rubio-Andrés, del Mar Ramos-González, and Sastre-Castillo, 2022). This investment enhances technical capabilities and boosts creative potential, facilitating more effective contributions to the innovation process. Furthermore, the synergy between high-quality human resources and a supportive institutional framework maximises innovation potential, as policies that promote education, skills development, and research create an ecosystem conducive to high levels of innovation (Charina et al., 2022). This highlights the necessity of an integrated approach to human resource development to foster sustainable innovation. Based on this, the author formulates the following hypothesis.

H4: HR Quality positively and significantly affects Innovation Capability

The Influence of Human Resource Quality on Technology Information and Communication

High-quality human resources, which include skills, knowledge, and competencies, are essential in exploiting the full potential of technology information and communication. Individuals trained and knowledgeable in the field of technology information and communication can develop and implement effective technological solutions and optimise the use of information devices and systems to increase productivity and efficiency (Su, Wang, and Tang, 2023).

Information and communication technology significantly enhances the quality of human resources by providing broader access to educational and training resources, with e-learning, webinars, and online courses offering flexible and sustainable opportunities for skill and knowledge development in line with technological advancements and market demands

(Alenezi, Wardat, and Akour, 2023). Moreover, technology facilitates effective collaboration and communication in the workplace through online platforms, such as project management applications and real-time communication tools, enabling teams to work more efficiently regardless of geographic location. Based on the things above, the author builds the following Hypothesis:

H5: HR Quality positively and significantly affects Technology Information and Communication

The Influence of Human Resource Quality on Sustainable Regional Competitiveness

Human resources (HR) quality is essential for fostering sustainable regional competitiveness. Skilled and knowledgeable human resources drive innovation, efficiency, and productivity, enhancing regional competitiveness. In an era of rapid technological change, regions that cultivate and retain high-quality HR will achieve a more significant and sustainable competitive advantage (Chen, 2023; Chu, Wang, and Wang, 2023).

Investment in a robust education system—from primary to higher education, alongside vocational training relevant to industry needs—produces a workforce capable of addressing future challenges, with regions prioritising educational quality demonstrating more significant innovation and adaptability, thus maintaining long-term competitiveness (Bak, Wawrzyniak, and Oesterreich, 2022). Furthermore, quality education fosters entrepreneurship and creativity, essential for sustainable economic development. The health and welfare of human resources also significantly influence regional competitiveness, as a healthy and prosperous workforce is more productive and better able to contribute to economic growth (Adegoke, Mbonigaba, and George, 2023; Korshøj et al., 2023). Consequently, investment in health services and community welfare programs is integral to sustainable development strategies, as a safe and healthy work environment enhances quality of life, motivation, and performance. Ultimately, the quality of human resources plays a crucial role in attracting investment and improving a region's image among investors, with skilled human resources making regions more appealing to companies seeking expansion opportunities (Ma et al., 2023). Based on this, the author proposes the following hypothesis:

H6: HR Quality positively and significantly affects Sustainable Regional Competitiveness

The Influence of Innovation Capability on Technology Information and Communication

Innovation capability includes the ability of an organisation or region to create, adopt, and disseminate new ideas that can increase efficiency, productivity, and competitiveness (Mehmood et al., 2023). On the other hand, technology information and communication provide the infrastructure and tools that enable the innovation process to run more quickly and efficiently. Effective use of technology information and communication can strengthen innovation capabilities by speeding up the flow of information, facilitating collaboration, and providing the data needed for better decision-making.

Integrating information and communication technology in innovation fosters sophisticated, scalable solutions (Elstner et al., 2022; Tigre Moura, 2023). For instance, big data and analytics

enhance market understanding, driving relevant product and service innovations. Moreover, artificial intelligence and the Internet of Things (IoT) facilitate process automation and operational efficiency, strengthening innovation capabilities. Thus, information and communication technology is a crucial enabler in innovation.

Collaboration facilitated by technology information and communication also plays a vital role in enhancing innovation capabilities. Digital collaboration platforms, such as online project management tools and communications applications, enable geographically dispersed teams to work together effectively (Li, 2023; Maloca et al., 2023). This allows a faster and broader exchange of ideas and knowledge and promotes a cross-disciplinary approach to innovation. Additionally, professional networks and online communities can inspire and inform individuals and organisations seeking to improve innovation capabilities.

Integrating information and communication technology in the innovation process supports sustainable development goals. TIC-driven innovation fosters environmentally friendly solutions that optimise resource use. For instance, smart grid technology and TIC-based energy management can lower energy consumption and carbon emissions. Additionally, TIC solutions enable environmental conservation through real-time monitoring of air and water quality (Sakiyama et al., 2023). Therefore, innovation capabilities enhanced by TIC boost economic competitiveness and promote environmental and social sustainability. Based on this, the author proposes the following hypothesis:

H7: Innovation Capability positively and significantly affects Technology Information and Communication

The Influence of Innovation Capability on Sustainable Regional Competitiveness

Innovation capabilities are crucial for enhancing regional competitiveness, encompassing the ability to generate new ideas, develop innovative products and services, and apply new technologies to improve efficiency. Regions with strong innovation capabilities are more adaptable to market and technological changes, creating significant added value and thus becoming more competitive than less innovative areas (Kim and Jin, 2022; Lei et al., 2023).

One of the main factors supporting innovation capability is investment in research and development (R&D). Regions that consistently allocate resources to R&D can produce more sustainable innovation. This innovation may be a new product, a more efficient production process, or a more effective management method. Thus, investment in R&D increases productivity and efficiency and strengthens the region's competitive position in the global market. Collaboration among government, academia, media, and the private sector fosters innovation capabilities (Daradkeh, 2023). This synergy creates a dynamic and sustainable innovation ecosystem where governments provide incentives and regulations, academics contribute to research and knowledge, and the private sector commercialises innovations. Such collaboration enhances the exchange of ideas and resources, ultimately boosting regional competitiveness. Furthermore, innovation capability is closely linked to developing quality human resources. Education and training focused on innovative and entrepreneurial skills equip regional residents to participate actively in the innovation ecosystem (Russo et al., 2022; Zeng

et al., 2023). Regions with a skilled workforce can create and implement relevant innovations, attracting investment and talent and strengthening their competitive position globally. Based on the things above, the author builds the following hypothesis:

H8: Innovation Capability positively and significantly affects Sustainable Regional Competitiveness

The Influence of Information Technology on Sustainable Regional Competitiveness

Technology Information (IT) is critical in changing society, government, and business operations. Effective IT implementation can increase efficiency, reduce operational costs, and speed up the dissemination of Information (Vigodny et al., 2023). Regions that optimise information technology (IT) experience enhanced economic productivity and improved public service quality, elevating their national and global competitiveness. A key benefit of IT is its capacity to enhance connectivity and access to information; regions with robust IT infrastructure are better positioned to engage with global markets and respond to economic shifts. This connectivity allows local entrepreneurs to tap into broader markets, utilise more efficient resources, and collaborate with international partners, conferring a significant competitive advantage over less connected areas. Additionally, IT plays a vital role in human resource development and innovation. IT-based education and training enable residents to acquire skills aligned with the modern job market while integrating IT into the educational process, enhancing quality and accessibility. Consequently, a more skilled and knowledgeable workforce positions the region to generate innovations that drive economic growth and further bolster competitiveness.

In the government context, exemplary IT implementation can improve the quality and transparency of public services. Local governments utilising IT for administration and public services can increase operational efficiency and provide services that are more responsive to community needs. A transparent information system also helps reduce corruption and increase public trust. All these factors contribute to an environment conducive to economic growth and higher regional competitiveness. Based on the things above, the author builds the following hypothesis:

H9: Technology Information and Communication positively and significantly affect Sustainable Regional Competitiveness

Technology Information and Communication as a mediating variable on the Influence of Education Quality on Sustainable Regional Competitiveness

Education Quality is fundamental for developing competent and competitive human resources, and the role of technology information and communication (TIC) as a mediator is essential. TIC enhances educational access, allowing students from various regions, including remote areas, to obtain high-quality learning materials globally (Saif et al., 2022). This reduces educational disparities, improves academic standards, and facilitates more effective teaching and learning processes. Additionally, TIC promotes interactive and engaging methods, increasing student motivation and involvement. Thus, TIC is crucial for enhancing educational

quality, directly influencing regional competitiveness, and equipping individuals with digital skills relevant to the modern job market. In addition to improving access and quality, TIC facilitates the development of essential skills for today's workforce. Digital skills like programming and data analysis are increasingly demanded across various industries. Through ICT-based education, students can acquire these skills early, preparing them to be competent and innovative professionals. Regions with a skilled workforce are better positioned to attract investment, create jobs, and achieve sustainable economic growth (Niedzwiedz et al., 2020). Based on the things above, the author builds the following hypothesis:

H10: Technology Information and Communication mediates the relationship between Education Quality and sustainable regional competitiveness

Information and Communication Technology as a mediating variable on the Influence of Human Resource Quality on Sustainable Regional Competitiveness

Information and communication technology (ICT) enhances access to information and knowledge, significantly improving human resource quality (Bhattacharyya et al., 2020). Online learning platforms, webinars, and digital courses enable individuals, particularly in remote or underdeveloped areas, to pursue quality education regardless of geographic limitations, fostering equitable improvement in human resource quality and promoting inclusive competitiveness. Furthermore, ICT boosts productivity and efficiency through digital tools and management applications, allowing the workforce to operate more swiftly and accurately and enhancing adaptability and innovation (Vazhenina, Magaril, and Mayburov, 2023). ICT cultivates a dynamic innovation ecosystem by facilitating collaboration among government, academia, and the private sector, creating environments conducive to new ideas and solutions (Zhou et al., 2022; Naughton, Dopson, and Iakovleva, 2023). Consequently, the quality of human resources, mediated by ICT, not only strengthens regional competitiveness in the short term but also ensures sustainable economic growth. Based on the things above, the author builds the following Hypothesis:

H11: Technology Information and Communication mediates the relationship between HR Quality and sustainable regional competitiveness

Information and Communication Technology as a mediating variable on the Influence of Innovation Capability on Sustainable Regional Competitiveness

Innovation capability includes the ability of a region to create, adopt, and disseminate new ideas that can increase efficiency, productivity, and competitiveness. On the other hand, technology, information, and communication are significant enablers that enable the innovation process to take place more quickly and effectively, thereby sustaining the impact of innovation capabilities on regional competitiveness. The integration of technology information and communication in innovation capabilities facilitates broader and faster access to information and knowledge needed for innovation (Liu and Wang, 2023). Individuals and organisations can identify market trends, consumer needs, and innovation opportunities more accurately through big data, analytics, and knowledge-sharing platforms. This enables the creation of more relevant and timely solutions, increasing regional competitiveness. Regions that can utilise

technology information and communication to strengthen their innovation capabilities will have a sustainable competitive advantage amidst intense global competition.

Moreover, technology information and communication technology (TIC) enhance collaboration among various stakeholders within the innovation ecosystem. Digital collaboration platforms, such as project management applications and online communication tools, facilitate efficient teamwork across geographically dispersed teams, fostering the exchange of ideas and knowledge across disciplines, which is crucial for holistic and impactful innovation. Consequently, TIC cultivates an environment conducive to open innovation, allowing diverse economic actors to enhance regional competitiveness synergistically.

Furthermore, the ongoing integration of TIC in innovation capabilities aligns with sustainable development goals by producing resource-efficient, environmentally friendly, and socially sustainable solutions. For instance, smart city technologies leveraging the Internet of Things (IoT) for energy and transportation management can reduce carbon emissions and improve citizens' quality of life. Thus, TIC -mediated innovation capabilities bolster regional economic competitiveness and promote inclusive and sustainable growth through global development objectives. Based on the things above, the author builds the following Hypothesis:

H12: Technology Information and Communication mediates the relationship between Innovation Capability and sustainable regional competitiveness

The relationship between the studied variables and the hypothesis framework is illustrated in Figure 1.

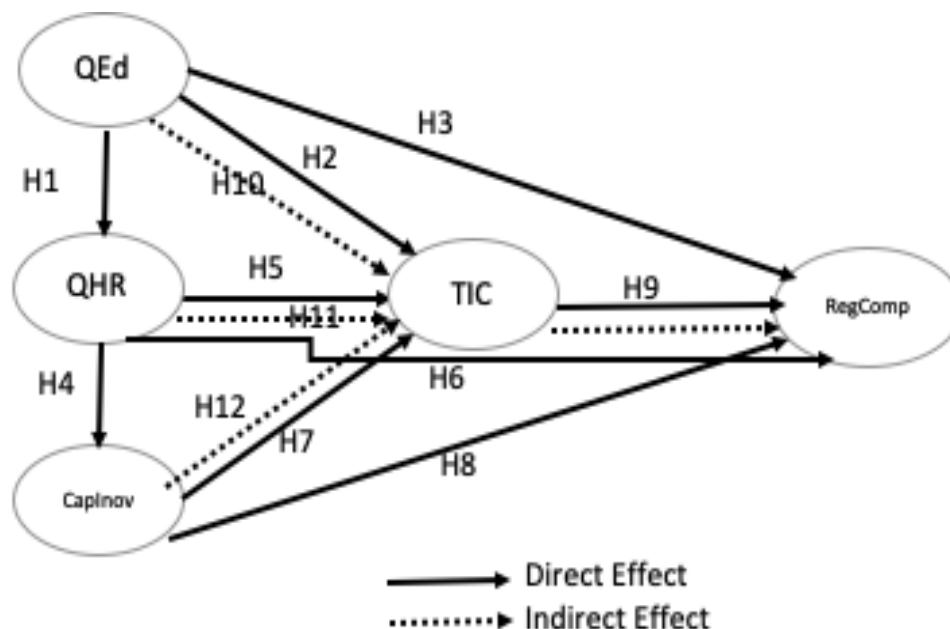


Figure 1: The conceptual framework illustrating the relationships among the variables
 (Source: Author's explanation)

RESEARCH METHOD

This research uses quantitative research methods. The population in this study are residents domiciled in Bitung City, while the unit of analysis is community groups whose status is: Lecturers/teachers/education administrators, bureaucrats, community/religious figures, BUMN/bank employees, entrepreneurs, and members of the Regional People's Representative Council, with a total sample of 385 people. The procedure for taking samples or respondents is carried out using purposive sampling, namely, determining samples or respondents who represent segments of community groups that are considered to have influence or feel a significant impact regarding regional economic competitiveness. Data collection techniques in this research used a questionnaire. Data analysis used structural equation modelling using Smart PLS version 3.2.9

RESULT AND DISCUSSION

This research uses the variables Quality of education (QEd), quality of human resources (QHR), and innovation capability (CapInov) as well as information and communication technology (TIC) as exogenous variables and sustainable regional competitiveness (RegComp) as an endogenous variable. To analyse data using SmartPLS software, it is carried out in two stages, namely:

Measurement Model or Outer Model

a. Validity Test

The validity test in PLS-SEM employs the PLS Algorithm to calculate the Outer Loading measure, which indicates the extent to which indicators reflect variable measurements, with recommended values ranging from 0.60 to 0.70. In this study, several indicators for each variable did not meet this criterion, resulting in removing those with values below 0.60 before further testing with the PLS algorithm.

b. Reliability Test

The reliability test in SEM PLS utilises Cronbach Alpha and Composite Reliability, with a minimum accepted composite reliability value of 0.7. The results for the variables in this study are presented in Table 2.

Table 2: Results of measurement model

	Reliability Test			Convergent Validity Test	Discriminant Validity Test (Fornel Larker Criterion value)				
	Cronbach's Alpha	Rho_A	Composite Reliability	Average Variance Extracted (AVE)	CapInov	QEd	QHR	RegComp	TIC
CapInov	0,863	0,873	0,902	0,649	0,806				
QEd	0,874	0,879	0,903	0,572	0,793	0,757			
QHR	0,812	0,825	0,863	0,514	0,705	0,609	0,717		
RegComp	0,789	0,796	0,855	0,542	0,652	0,661	0,543	0,736	
TIC	0,784	0,797	0,861	0,608	0,767	0,686	0,681	0,597	0,78

Source: Output SmartPLS AAlgorithm (2024)

Based on Table 2, the Cronbach Alpha, rho A, and Composite Reliability values for each variable have met the requirements with values > 0.7 . Likewise, the Average Variance Extracted (AVE) value for each variable also meets the requirement of ≥ 0.50 , indicating a positive correlation between indicators in the same construct. Likewise, the Fornel Larker Criterion value shows that the $\sqrt{\text{AVE}}$ value for the CapInov variable is 0.806, higher than other variables, which also applies to the $\sqrt{\text{AVE}}$ QEd (0.757), QHR (0.717), RegComp (0.736), and TIC (0.780) values.

Structural Model / Structural Model (Inner Model)

Hypothesis Testing

Hypothesis testing was carried out using the PLS method, with the findings in Table 3.

Table 3: Direct Effect and Indirect Effect Value

	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T Statistic (O/STDEV)	P Values	Result
Direct Effect						
CapInov→RegComp	0,207	0,206	0,09	2,306	0,011	Supported
CapInov→TIC	0,445	0,448	0,056	7,909	0	Supported
QEd→QHR	0,609	0,611	0,037	16,409	0	Supported
QEd→RegComp	0,347	0,345	0,068	5,085	0	Supported
QEd→TIC	0,174	0,172	0,055	3,135	0,001	Supported
QHR →CapInov	0,705	0,708	0,034	20,754	0	Supported
QHR→RegComp	0,093	0,099	0,062	1,505	0,066	Not Supported
QHR→TIC	0,261	0,262	0,056	4,71	0	Supported
TIC→RegComp	0,136	0,136	0,066	2,079	0,019	Supported
Indirect Effect						
CapInov→TIC →RegComp	0,061	0,060	0,030	2,046	0,020	Partial Mediation
QEd→TIC →RegComp	0,024	0,023	0,014	1,652	0,049	Partial Mediation
QHR→TIC →RegComp	0,036	0,035	0,018	1,975	0,024	Full Mediation

Source: Output SmartPLS Algorithm (2024)

As presented in Table 10, of the nine hypotheses tested, only one variable shows a positive relationship—specifically, the relationship between Quality of Human Resources (QHR) and Regional Competitiveness (RegComp), with an Original Sample value of 0.093; however, this relationship is not significant (P-Value > 0.05). Additionally, the information technology variable significantly mediates the relationships between Quality of Education (QEd) and Sustainable Regional Competitiveness (RegComp), Quality of Human Resources (QHR) and Regional Competitiveness (RegComp), and Innovation Capability (CapInov) and Sustainable Regional Competitiveness (RegComp), with P values for each relationship being less than 0.05.

Discussion

The development of quality human resources is very dependent on good education and training and is supported by adequate access to technology. Education that utilises information technology can provide more interactive and dynamic learning materials to make teaching and learning more effective and exciting for students.

In addition, internet access allows students and teachers to access the latest information and follow developments in their scientific fields. Thus, technology enriches learning material and broadens insight and knowledge.

Furthermore, technology-based training enables the development of specialised skills according to the needs of modern industry. Training programs that use digital simulations, special software, and e-learning platforms can provide practical experience relevant to the world of work, thereby helping trainees be better prepared and competent when entering the job market. Technology also enables distance learning, allowing those in remote areas to improve their skills without moving. Thus, the combination of education and training supported by adequate access to technology will produce superior human resources ready to compete in the global era (Zhang and Chen, 2021).

Applying information technology to maintain and increase regional competitiveness requires reliable human resources. The use of information and communication technology is crucial for regional development because it can increase the competitiveness of the local and national economies as well as increase efficiency, transparency, and innovation (Wang et al., 2022).

The relationship between information technology and management is solid and one-way, where information technology positively impacts performance and increases competitive advantage and overall organisational performance (García-Muñiz, Vicente and Billon, 2022).

Maximum technology information and communication can increase regional competitiveness through environmentally friendly innovation. The rapid development of technology information and communication has resulted in many literature studies examining the contribution of technology information and communication to economic growth. This is based on the benefits that technology information and communication can provide for growth, especially for developing countries (Appiah-Otoo and Song, 2021).

Information technology is fundamental in supporting regional economic growth, especially in efforts to maintain and increase competitiveness. Information technology allows more accessible and faster access to global markets. With e-commerce and digital marketing, local products can be sold to international markets without going through traditional distribution channels, which require a lot of time and effort. Information technology also facilitates the exchange of information and knowledge more efficiently for business actors so that business actors in the region can continue to follow the latest trends and innovations, thereby continuously improving the quality of their products and services. As well as the information technology contributes to increasing productivity and efficiency in operations. Companies can optimise their business processes through an IT-based management system, from inventory

management to customer service. Big data and analytics enable more precise and data-based decision-making to minimise business risks. Thus, regions that adopt information technology well will be better able to compete in the digital era, create new jobs, and attract investment, ultimately contributing to sustainable economic growth.

Quality education management can increase the number of reliable human resources utilising information technology to create competitiveness. Human resource management is an important activity and cannot be separated from efforts to develop and improve the quality of human resources themselves.

Management of human resources in development requires awareness without coercion, and this is the essence of the role of human resources, which is always expected in development. One important thing in education management is related to the human resources involved in the education management process, both from teachers and other educational staff, such as administrative (Rajeswaran, Kengatharan and Rasanayagam, 2023)

CONCLUSION

The conclusion of this research shows that information technology has a positive and significant effect on the quality of education and human resources and increases regional competitiveness. The results of this research can be helpful for policymakers to increase insight into formulating effective strategies for utilising digital infrastructure. Policies based on information technology analysis can ensure policies can be accessed by all and equally. This encourages the equal distribution of educational opportunities and the development of quality human resources throughout the region, thus strengthening national competitiveness.

For academics, information and communication technology analysis offers a strong foundation for developing teaching methods relevant to the needs of the industrial era 4.0. Academics can use the results of this analysis to research the latest trends in the technology field so that they can adapt to study programs and provide graduates with skills according to the demands of the global job market. Additionally, research is proper and helps identify innovative ways to improve the quality of education through technology-based learning.

For students, understanding analysis related to information technology opens up opportunities to develop digital skills necessary in the modern era. Students skilled in information and communications technology are better prepared to enter the world of work and can innovate and adapt quickly to technological changes. This knowledge also allows them to actively participate in research and projects to improve the quality of education and human resources.

Acknowledgements

We express our deepest gratitude to Sam Ratulangi University Manado for the support and facilities during this research process. We also greatly appreciate the Bitung City Government for providing precious data and information. We do not forget to respect those who have provided constructive input and the respondents who were the samples in this research. Without their participation, this research would not have been carried out well.

References

- 1) Adegoke, Y.O., Mbonigaba, J. and George, G. (2023) 'Health and total factor productivity nexus in selected sub-Saharan African countries: quadratic and threshold modelling,' *BMJ Open*, 13(5). Available at: <https://doi.org/10.1136/bmjopen-2022-066970>.
- 2) Adolfo van Ronzelen Enríquez et al. (2023) 'Quality management and international accreditation processes for the development of student competencies', *Journal of Namibian Studies: History Politics Culture*, 33, pp. 3412–3421. Available at: <https://doi.org/10.59670/jns.v33i.983>.
- 3) Alenezi, M., Wardat, S. and Akour, M. (2023) 'The Need of Integrating Digital Education in Higher Education: Challenges and Opportunities', *Sustainability (Switzerland)*, 15(6). Available at: <https://doi.org/10.3390/su15064782>.
- 4) Appiah-Otoo, I. and Song, N. (2021) 'The impact of ICT on economic growth-Comparing rich and poor countries', *Telecommunications Policy*, 45(2), p. 102082. Available at: <https://doi.org/10.1016/j.telpol.2020.102082>.
- 5) Bak, I., Wawrzyniak, K. and Oesterreich, M. (2022) 'Competitiveness of the Regions of the European Union in a Sustainable Knowledge-Based Economy', *Sustainability (Switzerland)*, 14(7). Available at: <https://doi.org/10.3390/su14073788>.
- 6) Bhattacharyya, D.S. et al. (2020) 'Challenges and facilitators of implementation of an information communication and technology (ICT)-based human resources management tool in the government health sector in Bangladesh: Protocol for an exploratory qualitative research study', *BMJ Open*, 10(12). Available at: <https://doi.org/10.1136/bmjopen-2020-043939>.
- 7) Charatsari, C., Michailidis, A. and Lioutas, E.D. (2024) 'Do farm advisory organisations promote sustainability? A study in Greece', *Agricultural Systems*, 218, p. 104003. Available at: <https://doi.org/10.1016/j.agsy.2024.104003>.
- 8) Charina, A. et al. (2022) 'Sustainable Education and Open Innovation for Small Industry Sustainability Post COVID-19 Pandemic in Indonesia', *Journal of Open Innovation: Technology, Market, and Complexity*, 8(4). Available at: <https://doi.org/10.3390/joitmc8040215>.
- 9) Chen, J. (2023) 'Correlation analysis between talent training quality and regional economic development based on multivariate statistical analysis model', *Applied Mathematics and Nonlinear Sciences* [Preprint]. Available at: <https://doi.org/10.2478/amns.2023.1.00224>.
- 10) Chentukov, Y. et al. (2021) 'Assessing the impact of higher education competitiveness on the level of socioeconomic development of a country', *Problems and Perspectives in Management*, 19(2), pp. 370–383. Available at: [https://doi.org/10.21511/ppm.19\(2\).2021.30](https://doi.org/10.21511/ppm.19(2).2021.30).
- 11) Chu, H., Wang, H. and Wang, Z. (2023) 'Impact of Innovation Quality on the Growth Performance of Entrepreneurial Enterprises: The Role of Knowledge Capital', *Sustainability (Switzerland)*, 15(10). Available at: <https://doi.org/10.3390/su15108207>.
- 12) Daher, W., Ashour, W. and Hamdan, R. (2022) 'The Role of ICT Centers in the Management of Distance Education in Palestinian Universities during Emergency Education', *Education Sciences*, 12(8). Available at: <https://doi.org/10.3390/educsci12080542>.
- 13) Daradkeh, M. (2023) 'Exploring the Curvilinear Relationship between Academic-Industry Collaboration Environment and Innovation Performance: A Multilevel Perspective', *Sustainability (Switzerland)*, 15(10). Available at: <https://doi.org/10.3390/su15108349>.
- 14) Elstner, S. et al. (2022) 'The diffusion of technological progress in ICT', *European Economic Review*, 149, p. 104277. Available at: <https://doi.org/10.1016/j.eurocorev.2022.104277>.

- 15) Fernández-Portillo, A., Almodóvar-González, M. and Hernández-Mogollón, R. (2020) 'Impact of ICT development on economic growth. A study of OECD European union countries', *Technology in Society*, 63(September), p. 101420. Available at: <https://doi.org/10.1016/j.techsoc.2020.101420>.
- 16) Gajdzik, B. and Wolniak, R. (2022) 'Smart Production Workers in Terms of Creativity and Innovation: The Implication for Open Innovation', *Journal of Open Innovation: Technology, Market, and Complexity*, 8(2). Available at: <https://doi.org/10.3390/joitmc8020068>.
- 17) García-Muñiz, A.S., Vicente, M.R. and Billon, M. (2022) 'ICT Research networks and regional competitiveness: an analysis of the 7th Framework Program', *European Planning Studies*, 30(10), pp. 2063–2083. Available at: <https://doi.org/10.1080/09654313.2021.2021505>.
- 18) Kim, D. and Jin, S. (2022) 'Innovation Capabilities and Business Performance in the Smart Farm Sector of South Korea', *Journal of Open Innovation: Technology, Market, and Complexity*, 8(4). Available at: <https://doi.org/10.3390/joitmc8040204>.
- 19) Korshøj, M. et al. (2023) 'An integrated approach to health, wellbeing, and productivity at work: a design of a stepped wedge worksite intervention study', *BMC Public Health*, 23(1). Available at: <https://doi.org/10.1186/s12889-023-16014-x>.
- 20) Kouskoura, A. et al. (2024) 'Assessing the Key Factors Measuring Regional Competitiveness', *Sustainability (Switzerland)*, 16(6). Available at: <https://doi.org/10.3390/su16062574>.
- 21) Kovács, P., Bodnár, G. and Lengyel, I. (2023) 'Relationships between factors of regional competitiveness in Central and Eastern Europe', *Journal of International Studies*, 16(3), pp. 78–95. Available at: <https://doi.org/10.14254/2071-8330.2023/16-3/4>.
- 22) Krstić, M., Filipe, J.A. and Chavaglia, J. (2020) 'Higher education as a determinant of the competitiveness and sustainable development of an economy', *Sustainability (Switzerland)*, 12(16). Available at: <https://doi.org/10.3390/su12166607>.
- 23) Lei, Y. et al. (2023) 'Multidimensional Evaluation of Urban Land-Use Efficiency and Innovation Capability Analysis: A Case Study in the Pearl River Delta Region, China', *Sustainability (Switzerland)*, 15(8). Available at: <https://doi.org/10.3390/su15086387>.
- 24) Li, J. (2023) 'Digital technologies for mental health improvements in the COVID-19 pandemic: a scoping review', *BMC Public Health*, 23(1). Available at: <https://doi.org/10.1186/s12889-023-15302-w>.
- 25) Liu, C.C. and Wang, Y.L. (2023) 'Does ICT Usage Have a Positive or Negative Effect on Taiwanese Older Adults' Emotional Experiences? The Moderating Role of Basic Psychological Needs Satisfaction', *Journal of Intelligence*, 11(3). Available at: <https://doi.org/10.3390/jintelligence11030046>.
- 26) Liu, X. et al. (2019) 'Cohort Profile: The Henan Rural Cohort: a prospective study of chronic non-communicable diseases', *International journal ...* [Preprint]. Available at: <https://academic.oup.com/ije/article-abstract/48/6/1756/5420306>.
- 27) Lo, M.F. and Tian, F. (2020) 'Enhancing competitive advantage in Hong Kong higher education: Linking knowledge sharing, absorptive capacity and innovation capability', *Higher Education Quarterly*, 74(4), pp. 426–441. Available at: <https://doi.org/10.1111/hequ.12244>.
- 28) Lythreath, S., Singh, S.K. and El-Kassar, A.-N. (2022) 'The digital divide: A review and future research agenda', *Technological Forecasting and Social Change*, 175, p. 121359. Available at: <https://doi.org/10.1016/j.techfore.2021.121359>.
- 29) Ma, Y. et al. (2023) 'Exploration of the Role of Human Capital in China's High-Quality Economic Development and Analysis of Its Spatial Characteristics', *Sustainability (Switzerland)*, 15(5). Available at: <https://doi.org/10.3390/su15053900>.

- 30) Maloca, P.M. et al. (2023) 'Validation of collaborative cyberspace virtual reality oculometry enhanced with near real-time spatial audio', *Scientific Reports*, 13(1). Available at: <https://doi.org/10.1038/s41598-023-37267-x>.
- 31) Mehmood, U. et al. (2023) 'Evaluating the impact of digitalisation, renewable energy use, and technological innovation on load capacity factor in G8 nations', *Scientific Reports*, 13(1). Available at: <https://doi.org/10.1038/s41598-023-36373-0>.
- 32) Montrimas, A. et al. (2024) 'Measuring national economic resilience through industrial portfolios', *Journal of International Studies*, 17(1), pp. 124–154. Available at: <https://doi.org/10.14254/2071-8330.2024/17-1/8>.
- 33) Naughton, B., Dopson, S. and Iakovleva, T. (2023) 'Responsible impact and the reinforcement of responsible innovation in the public sector ecosystem: cases of digital health innovation', *Journal of Responsible Innovation*, 10(1). Available at: <https://doi.org/10.1080/23299460.2023.2211870>.
- 34) Niedzwiedz, C.L. et al. (2020) 'Regional employment and individual worklessness during the Great Recession and the health of the working-age population: Cross-national analysis of 16 European countries', *Social Science and Medicine*, 267. Available at: <https://doi.org/10.1016/j.socscimed.2019.112377>.
- 35) Prout, J.T. et al. (2023) 'Application of a Model of Workforce Resilience to the Education Workforce: Expanding Opportunities for Support', *School Mental Health*, 15(2), pp. 456–469. Available at: <https://doi.org/10.1007/s12310-022-09560-z>.
- 36) Rahoveanu, M.M.T. et al. (2022) 'Perspectives on Smart Villages from a Bibliometric Approach', *Sustainability (Switzerland)*, 14(17). Available at: <https://doi.org/10.3390/su141710723>.
- 37) Q3Rajeswaran, P., Kengatharan, N. and Rasanayagam, J.X. (2023) 'Teacher Job Satisfaction: Do Human Resource Management Practices Matter? Evidence from Secondary Level Education', *Educational Administration: Theory and Practice*, 29(3), pp. 238–256. Available at: <https://doi.org/10.52152/kuey.v29i3.653>.
- 38) Rubio-Andrés, M., del Mar Ramos-González, M. and Sastre-Castillo, M.Á. (2022) 'Driving innovation management to create shared value and sustainable growth', *Review of Managerial Science*, 16(7), pp. 2181–2211. Available at: <https://doi.org/10.1007/s11846-022-00520-0>.
- 39) Russo, M. et al. (2022) 'Mapping regional strengths in a key enabling technology: The distribution of Internet of Things competencies across European regions', *Papers in Regional Science*, 101(4), pp. 875–900. Available at: <https://doi.org/10.1111/pirs.12679>.
- 40) Saif, S.M. et al. (2022) 'Impact of ICT in Modernising the Global Education Industry to Yield Better Academic Outreach', *Sustainability (Switzerland)*, 14(11). Available at: <https://doi.org/10.3390/su14116884>.
- 41) Sakiyama, R.Z. et al. (2023) 'Development of a Platform for Monitoring the Levels of Dispersed Oxygen in River Components of a Water Supply Micro Basin Using Programmable Microcontrollers', *Water (Switzerland)*, 15(13). Available at: <https://doi.org/10.3390/w15132316>.
- 42) Sheehan, K. et al. (2022) 'Long-term effects of a community-based positive youth development program for Black youth: health, education, and financial well-being in adulthood', *BMC Public Health*, 22(1). Available at: <https://doi.org/10.1186/s12889-022-13016-z>.
- 43) Su, J., Wang, W. and Tang, S. (2023) 'The spatial spillover effect of ICT development level on regional CO2 emissions', *Scientific Reports*, 13(1). Available at: <https://doi.org/10.1038/s41598-023-34573-2>.
- 44) Tigre Moura, F. (2023) 'Artificial Intelligence, Creativity, and Intentionality: The Need for a Paradigm Shift', *Journal of Creative Behavior*. John Wiley and Sons Inc, pp. 336–338. Available at: <https://doi.org/10.1002/jocb.585>.

- 45) Uğurluay, K. and Kirikkaleli, D. (2022) 'Sustainable Technology in High-Income Economies: The Role of Innovation', *Sustainability* (Switzerland), 14(6). Available at: <https://doi.org/10.3390/su14063320>.
- 46) Vazhenina, L., Magaril, E. and Mayburov, I. (2023) 'Digital Management of Resource Efficiency of Fuel and Energy Companies in a Circular Economy', *Energies*, 16(8). Available at: <https://doi.org/10.3390/en16083498>.
- 47) Vigodny, A. et al. (2023) 'Digitally managed larviciding as a cost-effective intervention for urban malaria: operational lessons from a pilot in São Tomé and Príncipe guided by the Zzapp system', *Malaria Journal*, 22(1). Available at: <https://doi.org/10.1186/s12936-023-04543-0>.
- 48) Wang, C., Liu, Y. and Yin, H. (2024) 'Research on Curriculum Construction and Capacity Cultivation of Innovation and Entrepreneurship Education in Colleges and Universities in the Context of Digital Curriculum Civics and Politics', *Applied Mathematics and Nonlinear Sciences*, 9(1). Available at: <https://doi.org/10.2478/amns.2023.2.01518>.
- 49) Wang, Y., Dai, Y., & Wang, Z. (2022). The Influence of the Internet on Regional Economic Development—An Empirical Study Based on China's Provincial Panel Data. *Sustainability*, 14(19), 12894. <https://doi.org/10.3390/su141912894>
- 50) Wirajing, M.A.K. and Nchofoung, T.N. (2023) The role of education in modulating the effect of ICT on governance in Africa, *Education and Information Technologies*. Springer US. Available at: <https://doi.org/10.1007/s10639-023-11631-w>.
- 51) Zeng, Y. et al. (2023) 'Regional innovation effect of smart city construction in China', *PLoS ONE*, 18(2 February). Available at: <https://doi.org/10.1371/journal.pone.0281862>.
- 52) Zhang, G. and Chen, C. (2021) 'A Study on the Relationship Between Learning Motivation and Learning Effectiveness of Personnel Based on Innovation Capability', *Frontiers in Psychology*, 12. Available at: <https://doi.org/10.3389/fpsyg.2021.772904>.
- 53) Zhou, X. et al. (2022) 'Carbon-economic inequality in global ICT trade', *iScience*, 25(12). Available at: <https://doi.org/10.1016/j.isci.2022.105604>.