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Green Technology Innovation: Moderating Role of Environmental Dynamism

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Fanesha Fazriyani[1*], Moh Mukhsin[2]

[1,2]Master of Management, Faculty of Economics and Business,
University Sultan Ageng Tirtayasa, Serang, Indonesia

Corresponding Email: *faneshafy98@gmail.com

Abstract

This study aimed to determine how green human capital, green knowledge management, and environmental dynamism moderation affect green technology innovation. Increasing ecological damage is also caused by industrial waste from the batik-making process, which is carried out using wax or batik dye and wax. Attaching batik wax produces waste in gas from heating smoke and wax vapor. Therefore, green technology is essential for environmental prevention, economic compliance, and increasing effectiveness. The research method uses quantitative data by distributing questionnaires to 190 respondents at Batik XYZ. The data is processed using SEM PLS to test the hypothesis. These findings reveal that green human capital significantly affects green technology innovation. The study found that green knowledge management significantly affects green technology innovation. Environmental dynamism can moderate the relationship between green knowledge management and technology innovation. Improving the quality of green human capital and knowledge management at Batik XYZ can affect the company's ability to innovate green technology. The level of environmental dynamism can affect how much green knowledge management impacts green technology innovation.

Keywords: Green Technology, Batik, Moderating Role, Environmental Dynamism

INTRODUCTION

Indonesia has a world-famous industrial product, namely batik products. Batik is one of the world's cultural heritages recognized by UNESCO, including traditional weaving techniques, and has developed into a modern industry. The intellectual traditional batik of the nation's children and the community's proud cultural heritage is one component of the creative industry that must be developed (Sutjipto *et al*., 2021).

The batik industry plays an important role in national economic growth. This sector, which mostly consists of small and medium businesses, is capable of making a large contribution to the country's foreign exchange through exports. One of them is the export of Indonesian batik to America, which has been going on since 1999. Especially after UNESCO recognized it, batik exports to America have increased (Siswanto *et al*., 2022). According to the Indonesian Ministry of Industry, export report data for May 2024 shows the export value based on the non-oil and gas processing industry was US$ 313.59 million for textiles and US$ 656.98 million for ready-made clothing.

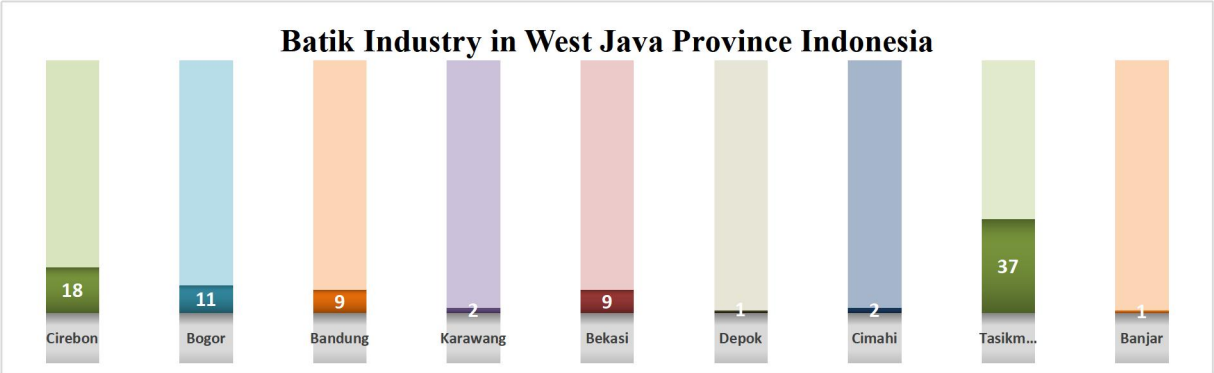

Figure 1. Batik Industry in West Java Province Indonesia
Source: Processed by the Author based on CBS-Indonesian Ministry of Industry data

Based on the picture above, it can be concluded that the number of batik industries in West Java province in Indonesia is 90 batik industries, namely in Cirebon as many as 18 batik industries, Bogor has 11 batik industries, Bandung has 9 batik industries, Karawang has 2 batik industries, Bekasi has 9 batik industries, Depok has 1 batik industry, Cimahi has 2 batik industries, Tasikmalaya has 37 batik industries and Banjar has 1 batik industry.

Apart from that, increasing environmental damage is also caused by industrial waste from the batik-making process, which is carried out using wax or batik dye and wax. Attaching batik wax produces waste in gas from heating fumes and wax vapor. Therefore, green technology is essential for environmental prevention, economic compliance, and increased effectiveness. Innovation drives the achievement of competitive business advantages and increases environmental efficiency (Shahzad et al., 2022). In recent years, the impact of ecological damage and global warming has increased along with human life. Environmentally friendly technology in recycling products benefits the environment (Alam et al., 2024).

Innovation in environmentally friendly technology is influenced by a region's human resources. Economic growth is also significantly influenced by human capital, which increases productivity and lowers energy consumption through the use of new technology. They create new economic value and serve as the main source of encouragement and impetus for the development of environmentally friendly technologies (Zhang & Li, 2023).

Human resources are essential for organizational innovation because employee knowledge is essential to maintain the organization in today's rapidly developing technological context (Khan et al., 2024). Human capital refers to the knowledge, skills, competencies, and other qualities that individuals or groups possess, acquire throughout their lives, and use to produce goods, services, or ideas in the marketplace (Adeleye et al.).Training

and scientific exploration play a vital role in facilitating the transformation of externally helpful human resources into newly available energy; the ability of individuals to facilitate the transfer of knowledge and technology is critical to successfully implementing new energy solutions (Strielkowski et al., 2024).

An important operational asset is knowledge. Green knowledge management, or GKM, has emerged as a crucial strategic component for numerous companies, giving them a competitive edge. The basis for an organization's capacity to innovate and perform its duties is knowledge (Khan et al., 2024).

Environmental dynamism informs the business world about its environmental impact, which can help ecological sustainability. If an organization neglects environmental changes, the organization may experience losses. Environmental instability requires continuous improvement in responding to environmental changes (Yu et al., 2022).

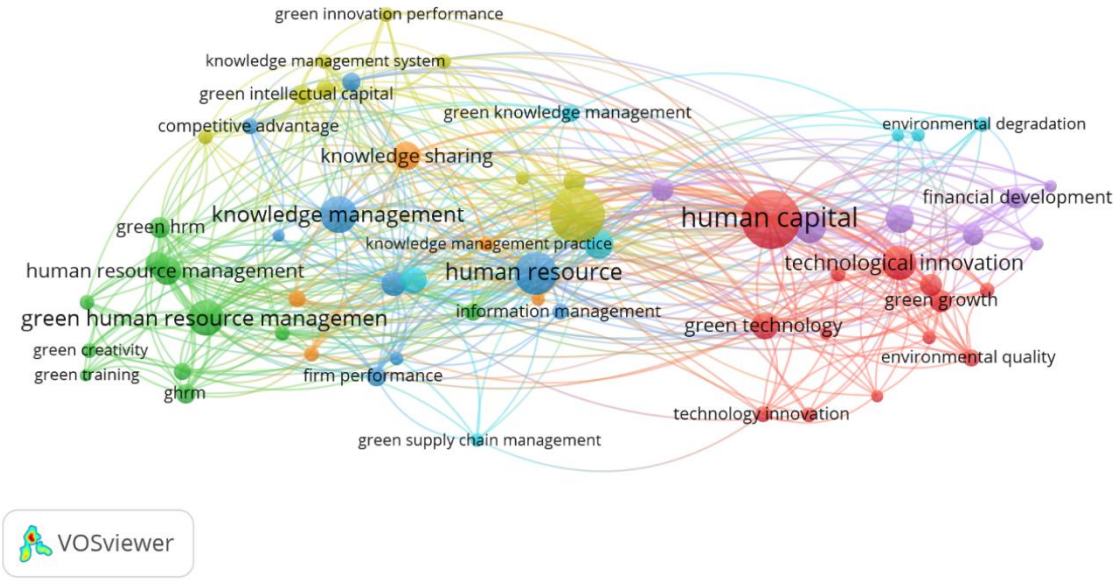

Figure 2. Network Visualization
Source: Author's Data Processing Based on the VOSviewer program

This analysis is based on articles indexed on Scopus and Google Scholar during the last five-year period from 2020 to 2024. The database was searched using keywords such as "Green Technology Innovation, "Green Human Capital," and "Green Knowledge Management. These phrases are included in the article's title, abstract, and keywords. Analysis of the appearance of these words contained 61 items, 496 links, 7 clusters, and a total link strength of 1027.

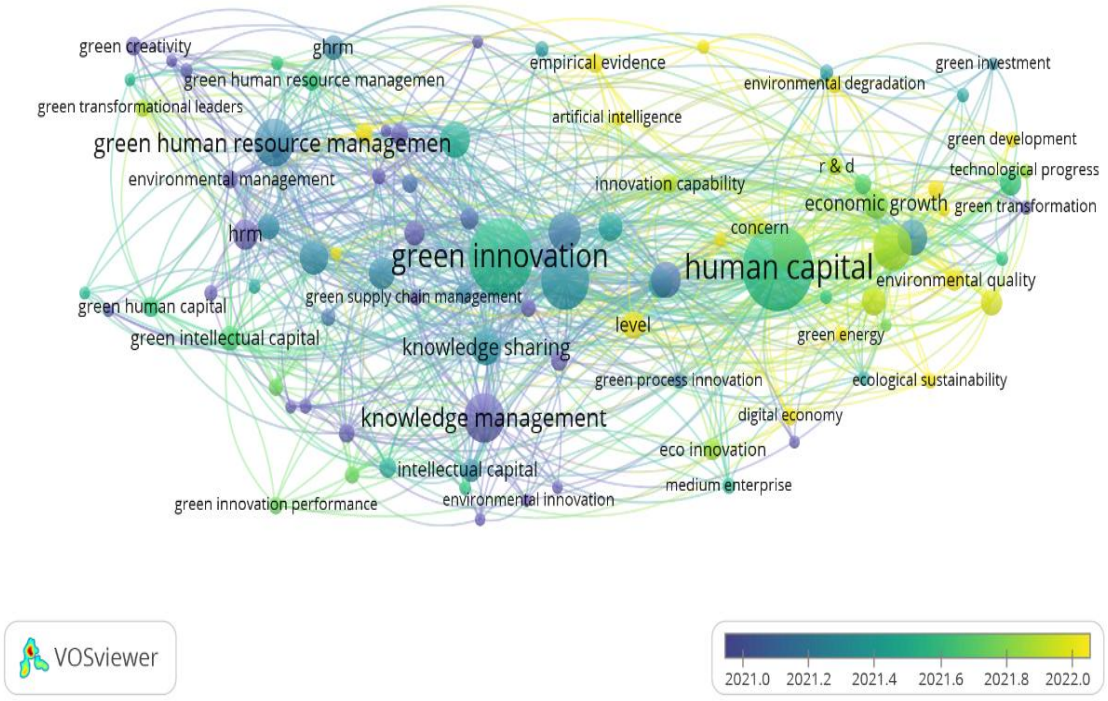

Figure 3. Overlay Visualization
Source: Author's Data Processing Based on the VOSviewer program

Based on the VOSviewer analysis, there is research novelty, namely the green technology innovation and green knowledge management variables, each of which is colored yellow, which means the brighter the color of the items, the newer the research conducted. The author was able to identify four variables; from the results of 496 links, the author took four links that can be used as research variables, namely environmental dynamism variables (links 35), green human capital (links 17), green technology innovation (links 29) and green knowledge management (links 19).

Research Purposes

1. To determine the influence of green human capital on green technology innovation.
2. To determine the influence of green knowledge management on green technology innovation.
3. To determine how environmental dynamism moderates the relationship between green knowledge management and green technology innovation.

Green Technology Innovation

Innovation as an organizational capacity to overcome ongoing problems and meet stakeholder needs (Sahoo *et al*., 2023). Environmentally friendly technology and innovation aimed at resource efficiency are the core of environmental sustainability. This technology emphasizes reducing negative impacts on the environment by utilizing natural processes (Zhao & Huang, 2022). Environmental innovation helps organizations avoid environmental

damage and waste of resources, creating strategic and business opportunities for organizations to meet environmentally friendly demands from stakeholders without causing damage to the environment (Yu *et al*., 2022). GTI is characterized by the company's ability to implement new ideas in the service of development. It refines existing processes and products and creates new functional products through an approach more oriented towards environmental benefits. The primary strategy is to enable the organization to comprehensively evaluate technologies that contribute to energy conservation, emissions reduction, sustainable production, and sustainable development (Sahoo *et al*., 2023).

Green Human Capital

Human Capital can control or influence something to encourage technological development, ultimately resulting in an improved economy and higher efficiency. Human capital, as an intellectual resource, drives organizational innovation. Education and health are the most critical human resources. However, while studying human-innovation relationships, most scholars focus on human capital management through education (Zhang & Li, 2023).

Green Knowledge Management

Knowledge management (KM) is often considered an essential prerequisite for companies to develop, survive, and grow in a challenging environment. KM is a crucial driver of solid growth. Creating and using knowledge can not only prevent failure but also increase profits. Knowledge serves as a fundamental resource for improving performance and ensuring long-term survival. Knowledge is also the basis of innovation. Consistent innovation is the result of continuous knowledge production (Khan *et al*., 2024).

Environmental Dynamism

Environmental dynamics is defined as the rate of change and environmental instability. Environmental dynamism is a condition that influences the current environment. There is no pattern or instability forcing organizations to quickly adapt to their environment to continue exploring and utilizing external resources. Factors that influence environmental dynamism include politics, economics, society, technology, law and the environment (Achmad *et al*., 2023).

HYPOTHESIS

GHC and GTI

Employees are initiated by environmental awareness when they receive training programs designed to promote organizational culture and goals. This, in turn, improves their ability to address environmental issues. Active employee participation in formulating

environmental issues will increase cognitive and emotional awareness of organizational values and principles (Ababneh, 2021).

H1: Green Human Capital has a significant influence on Green Technology Innovation

GKM and GTI

GKM has a positive impact on GTI and sustainable performance. Companies with a strong focus on GKM can increase their GTI capacity and thereby improve performance, demonstrating the impact of GKM on GTI and sustainable performance, thereby generating valuable findings (Khan *et al*., 2024). Research (Sahoo *et al*., 2023), Suggests that manufacturers have an effective Green Knowledge Management (GKM) process to improve their ability to innovate in creating green products and new environmentally friendly processes.

H2: Green Knowledge Management has a significant influence on Green Technology Innovation.

ED moderates the GKM dan GTI

Dynamic environments, where change occurs very quickly, the causes of change may need to be clarified, and operational metrics cannot be used to predict a stable response. The business world is increasingly faced with more complex and dynamic environments, and individuals who are unprepared for change may experience the need to adapt and influence the operation of these environments. Competitive, national, and international pressures and government policies emphasize the need for the business world to adapt to environmental changes (Azadegan *et al*., 2013). Environmental dynamics are critical to the development of environmentally friendly innovation in Pakistan and Malaysia and to the three pillars of sustainability: social, economic, and environmental (Yu *et al*., 2022).

H3: Environmental Dynamism moderates the relationship between Green Knowledge Management and Green Technology Innovation.

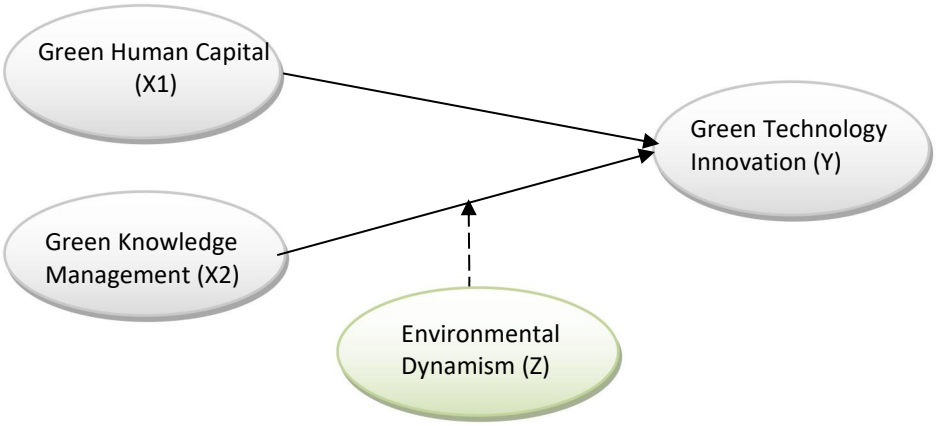

Figure 4. Research Model

Table 1. Measurement

Variable & Researcher	Code	Indicator
Green Technology Innovation (Sahoo *et al*., 2023).	**GTI 1**	Our organization continues to optimize production processes by using environmentally friendly technological methods to make savings.
	GTI 2	Development Department ensures the latest technological advancements are implemented to develop innovative ecosystems.
	GTI 3	Our organisation is actively engaged in "eco-labeling" to ensure that our clients are aware of our management practices.
Green Human Capital (Ababneh, 2021). and (Khan *et al*., 2024).	**GHC 1**	The company develops training programs in environmental management to increase environmental awareness, skills and expertise of employees.
	GHC 2	Employees are involved in improving quality and solving problems related to environmentally friendly issues.
	GHC 3	The level of cooperative teamwork in environmental protection in the company is higher than that of its main competitors.
Green Knowledge Management (Khan *et al*., 2024).	**GKM 1**	Employees and partners in our organization have easy access to information about best-in-class environmental practices.
	GKM 2	Our organization has procedures for obtaining knowledge about the environmental practices of our competitors, suppliers, clients and strategic partners.
	GKM 3	Our organization has a structured mechanism for exchanging best practices across various disciplines of business operations.
	GKM 4	Our organization develops initiatives (such as seminars, regular meetings and collaborative projects) that promote the exchange of environmentally friendly information across divisions.
Environmental Dynamism (Yu *et al*., 2022).	**ED 1**	Our company adopts a high level of innovation.
	ED 2	Our company frequently makes major and major changes in government regulations.
	ED 3	Our company adopted major changes in the way of production.
	ED 4	Our company is embracing major changes in consumer demographics.

METHOD

This research uses quantitative methods; the author conducted a direct survey to collect research data by distributing questionnaires to employees at Batik XYZ. The total population at Batik XYZ is 200 employees. The indicators studied were 14 indicators, namely: Green Technology Innovation (Y) of 3 indicators, Green Human Capital (X1) of 3 indicators, Green Knowledge Management (X2) of 4 indicators, and Environmental Dynamism (Z) of 4 indicators. Sampling using the method (Ferdinand, 2014). Explains that between 100 to 200 respondents is the ideal sample size. The number of study indicators multiplied by five to ten

yields the optimal and representative number of samples. As previously explained, there are 190 samples in the study.

Data Analysis

The Likert Scale is used to summarize the statements in the questionnaire. A measurement instrument called the Likert scale is used to evaluate how people or a group of people feel about social issues. Strong disagreement is indicated by a score closer to 1, and strong agreement is indicated by a score closer to 5, on the scale that is employed (Sugiyono, 2020). Data processing uses PLS-SEM. The testing method uses the Measurement Model Test, Structural Model Test, and Hypothesis Test.

RESULTS AND DISCUSSION

Outer Model Test

1. Convergent Validity and Reliability Test

Convergence validity refers to the extent to which a construct converges to explain the variance of its indicators. The minimum acceptable AVE is 0.50 - AVE of 0.50 or above. A higher value indicates a higher level of reliability. For example, reliability values between 0.60 and 0.70 are considered "acceptable in exploratory research," whereas values between 0.70 and 0.90 range from "satisfactory to good." A value above 0.90 (and definitely above 0.95) indicates a problem (Hair *et al*, 2021).

Table 2. Validity Test and Reability Test

Variable	Cronbach's Alpha	rho_A	Composite Reliability	Average Variance Extracted (AVE)
ED (Z)	0.874	0.916	0.913	0.724
GHC (X1)_	0.922	0.925	0.950	0.865
GKM (X2)	0.966	0.969	0.975	0.907
GTI (Y)	0.912	0.912	0.945	0.851
X2*Z	0.969	1.000	0.971	0.679

Source: Smart PLS Data Processing, 2024.

The calculation results, as stated in the table above, show that the AVE value for each variable is above 0.50 and meets the criteria for convergent validity. The results of the Cronbach's alpha reliability test and the composite reliability of all variables are above 0.70, meaning all variables are reliable or pass the reliability test.

2. Discriminant Validity

Discriminant validity is assessed using the Average Variance Extracted (AVE) each construct should be compared with the correlation between the squared constructs (as a measure of shared variance) of the same construct and all other constructs measured

reflectively in the shared variance structural model. The model should not have a more considerable AVE value for all constructs (Hair *et al*., 2019).

Table 3. Discriminant Validity Fornell-Larcker Criterion

Variable	ED (Z)	GHC (X1)_	GKM (X2)	GTI (Y)	X2*Z
ED (Z)	0.851				
GHC (X1)_	0.073	0.930			
GKM (X2)	0.222	-0.503	0.953		
GTI (Y)	0.141	0.846	-0.589	0.922	
X2*Z	-0.544	-0.234	-0.068	-0.277	0.824

Source: Smart PLS Data Processing, 2024.

Based on the results of discriminant validity, it can be concluded that all discriminant validity at the variable level can be accepted because each variable has a higher AVE root compared to its correlation with other variables.

Inner Model Test

The following is a picture of the structural model:

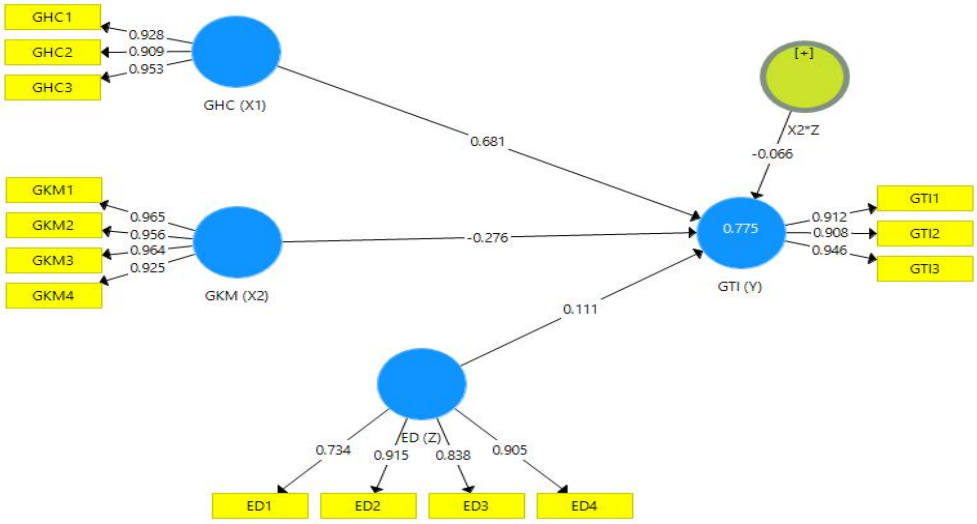

Figure 5. Structural Model

Source: Data Processed by the Author, 2024

1. Coefficient of Determination (R2)

R2 represents the variance explained within each endogenous construct and measures the model's explanatory power. An R2 value of 0.75 is considered substantial, 0.50 is moderate, and 0.25 is weak (Hair *et al.*, 2021).

Table 4. Coefficient of Determination

Variable	R Square	R Square Adjusted
GTI (Y)	0.775	0.770

Source: Smart PLS Data Processing, 2024.

The results in the table above show an R-squared value of 0.775, meaning that green technology innovation is 77.5 percent influenced by green human capital, green knowledge

management and environmental dynamism, while the remaining 22,5 percent is influenced by other variables not included in this study.

2. Effect Size (f2)

An f^2 value of 0.02 indicates a small effect, 0.15 indicates a medium effect, and 0.35 indicates a large effect. An effect size below 0.02 indicates no effect. The effect size f^2 allows for analysis of construct relevance in explaining the selected endogenous construct (Hair *et al*., 2019).

Table 5. F-Square

Variable	GTI (Y)
ED (Z)	0.037
GHC (X1)_	1.383
GKM (X2)	0.229
GTI (Y)	
X2*Z	0.017

Source: Smart PLS Data Processing, 2024

Based on table 5, the f square value can be expressed as follows:

a. The effect of GHC on GTI has an f-square value of 1.383, meaning it has a large effect size.
b. The effect of the GKM variable on GTI has an f-square value of 0.229, meaning it has a medium effect size.
c. The effect of ED moderating GKM on GTI has an f-square value of 0.017, meaning it has no effect.

Hypothesis Test

Hypothesis testing is done by comparing the t-statistics that have been determined. The t-value obtained from the bootstrapping test must exceed the one tile 1.65 for a standard error rate of 5% or a p-value below 0.05 (Hair *et al*., 2017).

Table 6. Hypothesis Results

Variable	Sample Mean (M)	Standard Deviation (STDEV)	T Statistics (|O/STDEV|)	P Values
GHC (X1)_ -> GTI (Y)	0.676	0.073	9.315	0.000
GKM (X2) -> GTI (Y)	-0.275	0.060	4.605	0.000
X2*Z -> GTI (Y)	-0.074	0.037	1.761	0.039

Source: Smart PLS Data Processing, 2024

This study uses a one-tail hypothesis so that the significant number can be known with a t-statistic value above 1.65 for a significance of 5%. Based on these criteria, three hypotheses

are accepted because they show a t-statistic value > 1.65. Hypothesis testing can be done as follows:

a. **H1** is accepted: The results of this study indicate that GHC has a significant effect on GTI with a t-statistic value of 9.315 > 1.65 and a p-value of 0.000 < 0.05.
b. **H2** is accepted: the research results show that GKM has a significant effect on GTI with a t-statistic value of 4.605 > 1.65 and a p-value of 0.000 < 0.05.
c. **H3** is accepted: the results of the study on the relationship between GKM and GTI moderated by ED show a significant influence, with a t-statistic value of 1.761 > 1.65 and a p-value of 0.039 < 0.05.

GHC has a significant effect on GTI

GHC has a significant effect on GTI. The higher the quality of green human capital in Batik XYZ, the greater the company can implement green technology innovation. This finding is in line with research conducted by (Zhang & Li, 2023), human resources in education, with a gap of three periods, significantly promote green technology innovation; healthy human resources significantly affect regional green technology innovation. Healthy human resources can provide a healthy work environment for employees, thereby improving the quality of employees, improving their ability to use technology, and encouraging environmentally friendly technology innovation.

GKM has a significant effect on GTI

GKM has a significant effect on GTI. In Batik XYZ, green knowledge management is critical to encourage green technology innovation by introducing new environmentally friendly ideas in producing batik. Companies can accelerate the development of green technology to achieve better innovation results. This finding is consistent with the research (Khan *et al*., 2024), the implementation of GKM and GTI is very beneficial for companies that want to do so to promote a cooperative green mindset across their various team organizations and business ally ecosystems.

ED moderates the relationship between GKM and GTI

The study's results indicate that ED can moderate the relationship between GKM and GTI. When environmental conditions are dynamic, the relationship between GKM and GTI becomes stronger. When environmental dynamics are high, companies rely more on the green knowledge they have to respond to changes with more effective green technology innovations. The study (Acosta *et al*., 2018), found that environmental dynamics strengthen the relationship between knowledge management and innovation, especially in the context of small and medium enterprises.

CONCLUSION

This study focuses on green human capital, green knowledge management, the role of environmental dynamism, and green technology innovation. The study results indicate that improving the quality of green human capital at Batik XYZ can significantly affect the company's ability to develop green technology innovation. Knowledge management that focuses on the environment at Batik XYZ has a significant influence on green technology innovation, and the level of environmental dynamism can affect how much green knowledge management impacts green technology innovation at Batik XYZ.

SUGGESTIONS

This study's limitation is that it only uses three variables. Future research suggestions need to add other variables. Future research can also collect and manage data based on respondent identity, such as age, education, and work experience.

REFERENCES

Ababneh, O. M. A. (2021). How do green HRM practices affect employees' green behaviors? The role of employee engagement and personality attributes. *Journal of Environmental Planning and Management*, *64*(7), 1204–1226. https://doi.org/10.1080/09640568.2020.1814708

Achmad, F., Prambudia, Y., & Rumanti, A. A. (2023). Improving Tourism Industry Performance through Support System Facilities and Stakeholders: The Role of Environmental Dynamism. *Sustainability (Switzerland)*, *15*(5). https://doi.org/10.3390/su15054103

Alam, S., Zhang, J., Shehzad, M. U., Boamah, F. A., & Wang, B. (2024). The inclusive analysis of green technology implementation impacts on employees age, job experience, and size in manufacturing firms: empirical assessment. *Environment, Development and Sustainability*, *26*(2), 4467–4486. https://doi.org/10.1007/s10668-022-02891-6

Azadegan, A., Patel, P. C., Zangoueinezhad, A., & Linderman, K. (2013). The effect of environmental complexity and environmental dynamism on lean practices. *Journal of Operations Management*, *31*(4), 193–212. https://doi.org/10.1016/j.jom.2013.03.002

Eko Sutjipto, B., Suman, A., & Wahyono, H. (2021). *SWOT Analysis: Utilization of Technology and Innovation in the Sustainability of Trusmi Batik Business in Cirebon Regency, West Java*.

Ferdinand, A. (2014). Metode Penelitian Manajemen. Universitas Diponegoro.

Hair, J. F. ., Hult, G. T. M. ., Ringle, C. M. ., & Sarstedt, Marko. (2017). *A primer on partial least squares structural equation modeling (PLS-SEM)*. Sage.

Hair, J. F., Risher, J. J., Sarstedt, M., & Ringle, C. M. (2019). When to use and how to report the results of PLS-SEM. In *European Business Review* (Vol. 31, Issue 1, pp. 2–24). Emerald Group Publishing Ltd. https://doi.org/10.1108/EBR-11-2018-0203

Khan, A. N., Mehmood, K., & Kwan, H. K. (2024a). Green knowledge management: A key driver of green technology innovation and sustainable performance in the construction organizations. *Journal of Innovation and Knowledge*, *9*(1). https://doi.org/10.1016/j.jik.2023.100455

Khan, A. N., Mehmood, K., & Kwan, H. K. (2024b). Green knowledge management: A key driver of green technology innovation and sustainable performance in the construction organizations. *Journal of Innovation and Knowledge*, *9*(1). https://doi.org/10.1016/j.jik.2023.100455

Oluwatofunmi Adeleye, G., Joshua Afolabi, A., & Funmilayo Asebiode, M. (n.d.). *Human Capital Development And Sustainable Economic Development In Nigeria*.

Sahoo, S., Kumar, A., & Upadhyay, A. (2023). How do green knowledge management and green technology innovation impact corporate environmental performance? Understanding the role of green knowledge acquisition. *Business Strategy and the Environment*, *32*(1), 551–569. https://doi.org/10.1002/bse.3160

Shahzad, M., Qu, Y., Rehman, S. U., & Zafar, A. U. (2022). Adoption of green innovation technology to accelerate sustainable development among manufacturing industry. *Journal of Innovation and Knowledge*, *7*(4). https://doi.org/10.1016/j.jik.2022.100231

Siswanto, D. J., Dewi, E. S., Wahyudi, I., & Syah, T. Y. R. (2022). Analysis of Factors Affecting the Export of Batik in Indonesia. *Journal of Social Science*, *3*(6), 2081–2089. https://doi.org/10.46799/jss.v3i6.483.

Soto-Acosta, P., Popa, S., & Martinez-Conesa, I. (2018). Information technology, knowledge management and environmental dynamism as drivers of innovation ambidexterity: a study in SMEs. *Journal of Knowledge Management*, *22*(4), 824–849. https://doi.org/10.1108/JKM-10-2017-0448.

Strielkowski, W., Kuzmin, E., & Vlasov, M. (2024). Integrative approaches across green energy technologies: the role of innovations in human capital. *Academia Green Energy*. https://doi.org/10.20935/acadenergy6244.

Sugiyono. (2020). Metode Penelitian Kuantitatif, Kualitatif Dan R&D . Alfabeta, CV.

TomassMHultt, G. (n.d.). *Classroom Companion: Business Partial Least Squares Structural Equation Modeling (PLS-SEM) Using R AAWorkbook*. http://www.

Yu, D., Tao, S., Hanan, A., Ong, T. S., Latif, B., & Ali, M. (2022). Fostering Green Innovation Adoption through Green Dynamic Capability: The Moderating Role of Environmental Dynamism and Big Data Analytic Capability. *International Journal of Environmental Research and Public Health*, *19*(16). https://doi.org/10.3390/ijerph191610336.

Zhang, J., & Li, S. (2023). The Impact of Human Capital on Green Technology Innovation—Moderating Role of Environmental Regulations. *International Journal of Environmental Research and Public Health*, *20*(6). https://doi.org/10.3390/ijerph20064803.

Zhang, J., & Li, S. (2023). The Impact of Human Capital on Green Technology Innovation—Moderating Role of Environmental Regulations. *International Journal of Environmental Research and Public Health*, *20*(6). https://doi.org/10.3390/ijerph20064803.

Zhao, W., & Huang, L. (2022). The impact of green transformational leadership, green HRM, green innovation and organizational support on the sustainable business performance: evidence from China. *Economic Research-Ekonomska Istrazivanja* , *35*(1), 6121–6141. https://doi.org/10.1080/1331677X.2022.2047086.