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Modernizing Human Capital Management in the Face of Natural Resource Depletion Risks within Sustainable Development in the Green Economy Landscape

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Abstract

Recently, the discourse of scholarly discussions within the field of sustainability and effective use of national resources has been significantly expanded and complicated. However, a range of important components for a comprehensive understanding of the 'state-of-the-art' is not integrated sufficiently. In particular, this refers to the issues of the role of human capital management and appropriate policies in the landscape of the green economy. The current research represents an attempt to fill this gap, outlining the existing patterns. The methodology implies a mixture of grounded theory and content analysis. The study indicates that a combination of poor governance quality and natural resource rents could have a negligible influence on economic growth and may have a negative impact on the economy in both the long and short run. The results also show that there is unidirectional causality from the interaction term to growth. This implies that natural resource rents and institutional quality may both influence the growth trajectory. The implications of green human capital are described, and the expediency of broader acceptance of a category of sustainable human capital is emphasized. In particular, it is demonstrated that green growth, which seeks to promote economic development while reducing environmental impact, is dependent on sustainable human capital. Systematization of domains of human capital management within the landscape of green economy, and covering the category of sustainable human capital, represents the core utility of this article.

Keywords

Green human capital; Quality of institutions; Resource rent; Environmentally sustainable practices; Ecological quality

Introduction

Human capital, defined by a workforce's skills, knowledge, and experience, is a crucial element of a green economy. Enhancing resource efficiency, encouraging innovation in sustainable practices, and developing and implementing green technology are all made possible by investing in human capital through healthcare, education, and training. Thus, sustainable growth is encouraged, and green economic efficiency is increased. The concepts of a green economy, natural resources, and human capital are interrelated. A green economy relies on the sustainable management of natural resources, necessitating human capital, which encompasses knowledge, skills, and health (Mia *et al*., 2022; Semenets-Orlova *et al*., 2022). In turn, the growth and long-term viability of a green economy depend on both natural resources and human capital.

Radulescu *et al*. (2025) investigate how the productivity of natural resources and human capital affect the EU's attempts to attain Sustainable Cities and Society (SDG-11), with a focus on the effect of renewable energy. The analysis determined that 1.867 is the optimal threshold value for the human capital index (HCI) score across European Union countries. This threshold figure represents a vital point at which human capital's impact on achieving SDG-11, which aims to make cities and human settlements more inclusive, safe, resilient, and sustainable, shifts substantially. The impact of renewable energy on SDG-11 is nonlinear. There is a negative connection at lower levels of renewable energy adoption (less than a certain threshold), with renewable energy having a 1% negative impact on SDG-11 progress. However, once renewable energy use rises above this threshold, the link becomes even more advantageous. The studies also reveal that natural resource productivity rises before and after exceeding a specific threshold; however, the magnitude of this effect varies. This compelling evidence emphasizes the need for focused policies in the European Union to strengthen human capital, expand renewable energy uptake, and boost natural resource productivity, hence ensuring long-term funding mechanisms for SDG-11.

People are empowered to contribute to a sustainable future when their education and talents are invested in. According to Šlaus and Jacobs (2011), the best way to ensure a sustainable future is to cultivate a more conscious and aware populace, where people have a better awareness of who they are and how they affect the environment. A population that is well-educated and competent encourages creativity, propels technological developments in sustainable practices and clean energy, and raises awareness of environmental issues (Voronina, Lopushynskyi and Grechanyk, 2024; Zilinska, Avedyan and Kyrychenko, 2022). Enhanced resource management and problem-solving for a sustainable future can result from a high HCI. The expanding significance of competent human resources for the development of contemporary cities must be emphasized. Atikul and Olanrewaju (2022) explored the four variables - green opportunities, green savings, green talent, and green places - in order to outline an HCI-based strategy for enforcing sustainable communities. Enhancing HCI management systems is essential, particularly when it comes to encouraging innovation in urban areas. Ivaldi *et al*. (2020) showed a direct correlation between the development of a creative and sustainable urban environment and a city's knowledge-based economy. Furthermore, the two most important elements for creating smart sustainable cities (SSCs) are local transportation and sustainable social services.

Asghar *et al*. (2024) found that sustainable energy and HCI improve environmental quality, but economic globalization degrades it. These scholars stressed the role of natural capital in economic growth and sustainable development programs. The study examined data from 53 developing nations (2011-2022) to determine the effects of human, natural, and produced capital on sustainable development. The regression study results revealed that HCI, innovation, green energy, political stability, and a lack of violence, among other variables, are positively connected to sustainable development. Both natural and generated capital have negative repercussions, underlining the need for more investment in HCI, innovation, renewable energy, and the modernization of produced capital in order to attain sustainability.

The dynamic interrelationships among economic growth, natural resources, and human capital imply the attainment of sustainable development goals. Given the threats of natural resource depletion, this environment calls for in-depth research on modernizing human capital management, particularly about sustainable development and the green economy. This study investigates the relationship between human capital development policies, environmental risk management, and demographic factors in the context of a green economy. Accordingly, the tasks of analyzing the 'state-of-the-art' in human capital role in green growth and sustainable development, as well as outlining the green human capital concept's practical implementation, are set.

Materials and Methods

The present study employs qualitative methodology, based on a combination of content analysis and grounded theory. While grounded theory seeks to generate new theories from the data, content analysis concentrates on finding and classifying patterns within the data. In a research project, these two qualitative approaches are typically integrated, with content analysis possibly acting as an initial stage to pinpoint important themes and ideas that can subsequently be investigated further and developed into a grounded theory. But we applied a reverse approach - at the first stage, we used grounded theory for revealing categories to be further employed for searching literature sources for content analysis.

We used the MAXQDA application (*The #1 qualitative data analysis software*, 2025)[1] (based on AI-powered features) such as automated coding, thematic analysis, and cross-segment comparisons. This allowed revealing and accepting categories (from 537 founded sources) for the next stage of research: green human capital; sustainable human capital; innovative human capital; resource curse/blessing; human capital index; green jobs; green technologies; quality of institutions. The adoption of the MAXQDA application over manual methods facilitates quicker and more precise analysis of large datasets, enabling the identification of patterns that may be overlooked in manual processing.

On the next stage of research, we used the above categories for searching literature entries for content analysis. The search was done first with the use of the SciSpace (https://scispace.com/) application, then from the 149 found items, we conducted manual selection, based on the topic and abstracts. Overall, 45 entries were included in the final

[1] *The #1 qualitative data analysis software with the best AI integration* (2025). MAXQDA. https://www.maxqda.com/

analysis based on the content analysis method, for revealing patterns and provisions and formulating conclusions.

Content analysis was aimed at identifying themes, ideas, symbolic meanings, and contextual dependencies, meanings, and interpretations. Using this method, we went from the text to the non-textual reality (social reality) of the green economy in the context of the functioning of human capital and the level of efficiency of natural resource use. Thus, based on the foundation of categories identified at the first stage of searching for literary sources and compiling the sample, with the help of content analysis, we identified patterns of relationships between the studied components of the green economy landscape. The logic of the content analysis application was based on revealing and analysis of the pattern illustrated in figure 1. Human activity ↔ climate change; human capital ↔ energy efficiency; human capital ↔ ecological footprint; natural resources management ↔ resource curse; green human capital ↔ SDGs; green human capital ↔ sustainable human capital; sustainable economy ↔ green human capital paradigm. The overall logic (sequence) of research is presented in figure 1.

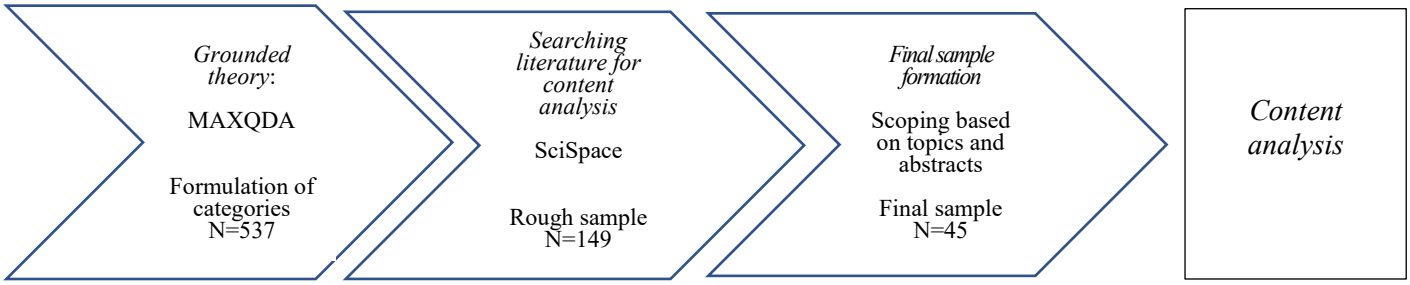

Figure 1: The overall logic (sequence) of research

Green human capital is a "set of knowledge, skills, and abilities of employees related to environmental protection and green innovation" (Marco-Lajara, Zaragoza-Saez and Martinez-Falco, 2022). "The definition of sustainable human capital, at its most fundamental level, signifies the long-term preservation and enhancement of individuals' capabilities and well-being within an organizational or societal context" (Lanza and Simone, 2020). Innovative human capital is defined as "a kind of heterogeneous capital that always possesses cutting-edge knowledge and skills in a specific professional field, continuously carries out innovative activities, and obtains innovative output, so that the marginal income can continue to increase" (Lin *et al.,* 2021).

Results and Discussion

Despite growing evidence linking human activities to environmental degradation and climate change, ecological issues continue to arise. It is now more crucial than ever to think creatively and consider other elements like awareness and education in order to halt atmospheric damage. Ecological sustainability may be impacted by human capital focused on education and return on education, since prior research suggests a connection between education, ecological consciousness, and pro-environmental actions. For instance, Chankrajang and Muttarak (2017) argue that human capital influences people's behavior toward the adoption of renewable energy products. Furthermore, it is undeniable that education is necessary to help people understand the underlying causes of global

climate change and its grave consequences. Researchers demonstrate that education positively affects recycling initiatives (Krysovatyy *et al.,* 2025; Liubchych *et al.,* 2023). Although there is evidence that education reduces the loss of forests, Desha, Robinson and Sproul (2015) found that education influences people's decisions to follow environmental laws. Energy efficiency is one method in which human capital makes a substantial contribution to lowering CO_2 emissions, according to Bano *et al.* (2018). Increasing human capital can significantly reduce pollution, according to Ahmed *et al.* (2020).

On the other hand, natural resources affect the climate in two ways. First of all, natural resources are used for production and consumption; nevertheless, their careless usage, such as extraction, agriculture, and deforestation, affects the country's atmosphere. When natural resources are used, waste and pollutants are discharged into the air and water (Hassan *et al*., 2019). Redevelopment of natural resources is made possible by the use of sustainable production and consumption methods (Ulucak and Ozcan, 2020). On the other side, environmental quality is impacted by economic growth derived from natural resources. Growing economic growth speeds up the exploitation of natural resources, which raises pollution levels. In many countries, the expansion of GDP is driven by natural resources (Hailu and Kipgen, 2017). Economic development encourages waste, ecological deficits, industrialization, and the utilization of natural resources (Sarkodie and Strezov, 2018). Climate change, water shortages, and forest loss increase the use of natural resources and cause environmental problems in both industrialized and developing countries (Baloch, Mahmood and Zhang, 2019).

Chen, Lee and Chen (2022) used panel data from 110 economies between 1990 and 2016 to investigate the relationship between ecological footprint, urbanization, and human capital. The findings show that, mainly from a global perspective, human capital increases first, followed by a decrease in environmental effect. Additionally, Ahmed, Zafar and Ali (2020) examined the relationship between EF, human capital, and suburbanization in G7 economies. From 1971 to 2014, the study excluded the rising level of panel data. Research shows that while human capital hurts ecological footprint, urbanization, GDP per capita, imports, and energy have a favorable link.

Using panel data spanning from 1975 to 2021, Tariq, Ali and Usman's (2024) recent study investigates the impact of natural resources and human capital on environmental quality in South Asia. The long-term relationships between natural resources, human capital, urban population, economic growth, economic growth squared, industrial value added, and ecological footprint are established by advanced cointegration techniques. This research study was conducted with a panel of five South Asian states (Pakistan, India, Sri Lanka, Nepal, and Bangladesh), with the exception of Afghanistan, Bhutan, and the Maldives due to data availability issues. The current study will incorporate ecological footprint, human capital, natural resource rents, GDP, GDP squared, urban population, and industrial value added. South Asian countries are economically and geographically related to one another. As a result, a shock in one country might have a ripple effect on the economies of neighboring republics. As a result, it is critical to examine the cross-sectional dependence (CSD) of variables prior to doing the primary analysis calculation. As a result, models in this study are evaluated using the CSD test.

This study used the panel autoregressive distributed lags (ARDL) model.[2] to investigate the short- and long-term relationships between these variables. The results validate the existence of the environmental Kuznets curve (EKC) theory[3] by showing that human capital has a negative and substantial relationship with environmental quality, whereas economic growth and economic growth square have both positive and negative effects on environmental quality. While industrial value-added raises pollution levels in South Asia, urban population growth and natural resources have strong negative correlations with environmental pollution. Finally, there is a notable beneficial impact on the ecological footprint as a result of the relationship between human capital and natural resource rent. In order to encourage industrial modernization, the spread of green technologies, and energy-efficient practices, the author advises South Asian countries to enhance their human capital. Making use of natural resources also aids South Asian countries in keeping their ecosystems clean. South Asian countries should also keep a close eye on the detrimental effects of industrialization on the environment. Therefore, both natural resources and human capital are necessary for ecological sustainability.

The impact of natural resources, human capital, and foreign direct investment on the ecological footprint is examined in the Zafar *et al*. (2019) study. The United States of America is the subject of a study conducted between 1970 and 2015. The long- and short-run elasticities are examined using the ARDL technique. It was discovered that while economic expansion and energy use raise the ecological footprint, human capital and the richness of natural resources decrease it. The impact of natural resources on the ecological footprint is one of the questions the study attempts to answer. Natural resources such as forests, croplands, fishing grounds, grazing pastures, and developed lands supply capital for energy production and offset human-caused CO_2 emissions, according to the Global Footprint Network. However, some natural resources, like coal and petroleum, harm the ecosystem. The income level of an economy is largely related to its natural resources. During the early stages of economic development, societies often prioritize the rapid consumption of natural resources, frequently overlooking environmental impacts. As living standards rise, there is a shift toward a greater demand for cleaner environments, energy-efficient products, and sustainable resource management, reflecting an increasing awareness of ecological sustainability. As a result, environmental quality begins to improve, demonstrating the existence of the Environmental Kuznets Curve (EKC) in the connection between ecological footprint and energy use.

The Zhang *et al.* (2021) study used the same methodology. The authors wanted to show how Pakistan's environmental degradation is influenced by economic growth, natural resources, and human capital. The dynamic ARDL method was used. It was shown that

[2] Autoregressive Distributed Lag (ARDL) model is a single-equation time series model used to analyze the long-run and short-run relationships between variables, even if they have different orders of integration. It combines autoregressive (AR) and distributed lag (DL) components. The AR component captures the influence of past values of the dependent variable on its current value, while the distributed lag component captures the influence of past values of independent variables on the current value of the dependent variable.

[3] The Environmental Kuznets Curve (EKC) theory suggests an inverted U-shaped relationship between per capita income and environmental degradation. Initially, as a country develops, environmental degradation increases. However, after a certain point (the "turning point"), further economic growth leads to a decrease in environmental degradation. This suggests that economic growth can eventually lead to environmental improvement.

there is a negative correlation between carbon emissions and natural resources, and human capital. However, human capital has a positive relationship with ecological footprint, while natural resources have a negative one.

The overall logic of such studies can be schematically depicted as follows (see figure 2).

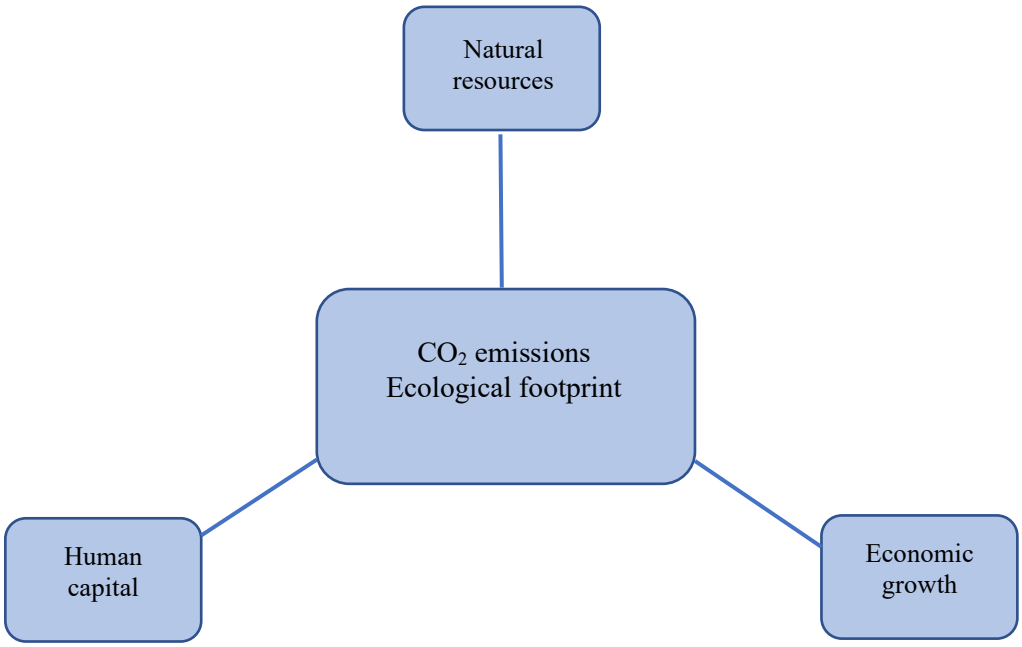

Figure 2: The logic of researching the relation between ecological footprint, natural resources, human capital, and economic growth [*Source*: Zhang *et al*. (2021)]

Rahim *et al.* (2021) examine the influence of natural resources, human capital, financial development, industrialization, technical advancement, and international trade on the Next Eleven countries' economic growth between 1990 and 2019. The econometric approaches used are reliable in accounting for cross-sectional dependence and slope heterogeneity problems in the data. The findings support the resource curse concept, as higher natural resource rents are observed to slow economic growth in the Next Eleven countries. Human capital development, financial development, industrialization, technical innovation, and international trade participation, on the other hand, have been shown to contribute to economic growth. Another intriguing finding in this study is that human capital and natural resources have a beneficial impact on economic growth. As a result, human capital development contributes to mitigating the effects of the resource curse in the Next Eleven countries. As a result, these findings highlight the importance of increasing investments in human capital development, strengthening the financial sector, accelerating industrialization, facilitating technological innovation, and increasing international trade volumes to achieve higher economic growth in the Next Eleven countries. More importantly, human capital development should be focused on in order to turn the curse of natural resources into a blessing for these nations.

Many elements influence a country's economic growth, including natural resource rent, human capital, financial development, industrialization, and technical innovation, which are recognized to play critical roles in determining economic growth (Lozo and Onishchenko, 2021). Furthermore, it is thought that low human capital development is one of the primary reasons for the resource curse in natural resource-rich developing countries (Butkiewicz and Yanikkaya, 2010). However, investing in human capital can turn this resource curse into a blessing, as human capital development can boost economic growth (Hu and Xiao, 2007). However, it is worth noting that the relative weight of mineral rents might hurt human capital development. Green human capital, or the knowledge and skills required for ecologically sustainable practices, is critical for managing natural resources and avoiding negative repercussions. A well-educated and environmentally conscious populace is more likely to engage in sustainable practices, which leads to enhanced environmental quality. However, the link is complex, as natural resources can have both good and negative effects on environmental quality, depending on how they are handled.

The findings of Ni *et al*. (2023) suggest that green human capital has a favorable impact on green innovation, green industry upgrading, and sustainable development. Environmental restrictions have a beneficial impact on green industry upgrading, but no effect on green innovation or sustainable development was discovered. Green innovation and green industry upgrading both benefit sustainable development (Kovalko, Eutukhova and Novoseltsev, 2022). The study finds that politicians and organizations should prioritize green human capital in their efforts to promote sustainable development, green innovation, and green sector upgrading. At the same time, politicians and organizations need to understand why environmental legislation is ineffective in these countries. The findings aid policymakers, sustainable development research groups, and governments, particularly in achieving SGD 7, SGD 9, and SGD 12.

In light of Poland's shifting labor market, Kozera-Kowalska (2024) sought to evaluate the market availability of human capital for the demands of the green economy. Based on desk research and a critical evaluation of the available factual data, it is a theoretical and analytical study. A significant labor supply deficit was discovered after quantitative data characterizing the age distribution and educational attainment of Poles over three successive decades were analyzed. It also suggests that the skills required to green the economy may be lacking. The necessity of supplementing the labor shortfall with external resources, such as labor migration, was underlined due to the state's preventative policies' limited success in halting the escalating demographic catastrophe. The job markets in other European nations are becoming more competitive, though, so this could potentially be challenging. Delaying employee departures, increasing female economic activity, and improving the efficiency of the educational system are some suggested ways to promote labor market sustainability for the green economy.

Meanwhile, a policy of green human capital formation faces demographic and ecological risks. These hazards include potential labor market upheavals, increasing inequality, and poor environmental effects from unsustainable activities. Addressing these threats necessitates meticulous development and execution of policies that promote both environmental sustainability and social equality.

"Green jobs" is a term that is naturally associated with green human capital. At first, "green" jobs were closely associated with the mining, energy, and agricultural industries. But as time went on, the term expanded to encompass intermediate sectors that are crucial to sustainable economic and social development, as well as jobs that contribute to the preservation of ecosystems and biodiversity, the decarbonization of the economy, the reduction of energy, material, and water consumption through high-efficiency strategies, and the reduction or elimination of all waste and pollution (Shalamai, 2024). Green jobs, according to the International Trade Union Confederation (ITUC), lessen the negative effects that businesses and economic sectors have on the environment while guaranteeing respect for workers' rights and good living and working conditions for all those involved in the production process (Petrukha *et al.,* 2025). The International Labor Organization's (ILO) terminology uses more artificial language, stating that "green jobs" include direct employment that lowers environmental consequences to sustainable levels. Therefore, every work helps to reduce the amount of energy and resources used, decarbonize the economy, preserve and restore ecosystems and biodiversity, and reduce waste and pollution. Therefore, any new position in a certain industry that lowers its environmental impact to below-average levels and even marginally increases overall efficiency is considered a "green" job (Sulich and Rutkowska, 2021).

Since every new product, service, or technology may eventually become a more efficient equivalent in terms of emissions, material or energy usage, etc., the creation of green jobs is not just a technological challenge (Grudziński and Sulich, 2018), but also a social one (e.g., social awareness, staff training). This suggests that investments must be made in both the development of human capital and the green economy's producing sectors. While economic factors play a major role in determining technological development, it is far more difficult to identify and change the factors that determine the development of human capital (habits, customs, perceptions of work, and its role in human life, such as Generation Z, which is already present in the labor market) (Ahakwa and Tackie, 2024).

It is imperative to shift from traditional skills to those that enable green technology, sustainable agriculture, renewable energy, and efficient waste management as environmental concerns increase. According to Ahakwa *et al.* (2023), achieving the SDGs and other international accords depends on building green human capital. Numerous studies agree that a population with higher levels of education and awareness of environmental issues is more likely to adopt sustainable practices, which improves ecological quality (Zheng *et al.,* 2024). Green human capital is necessary to shift from the conventional model of natural resource exploitation to a more sustainable one. According to Khan *et al.* (2023), maximizing environmental benefits and encouraging resource regeneration require green human capital. Green human capital also lessens reliance on natural resources, according to Li *et al.* (2023).

In the meantime, demographic processes, specifically green human capital, have a significant impact on the quantity and composition of human resources. The main demographic risks associated with green human capital are the possibility of skill shortages in a rapidly changing green economy, the necessity of upskilling and retraining to meet shifting job demands, and the effect of an aging workforce on productivity and innovation in green industries. Additionally, the shift to a green economy may result in employment losses in carbon-intensive sectors, necessitating cautious workforce

transition management. Specialized skills in fields like renewable energy, sustainable agriculture, and green building are becoming more and more in demand as the green economy grows. The advancement of green projects may be hampered by a skills gap that develops if the educational and training systems do not change swiftly enough. In some areas, this mismatch may also result in underemployment or unemployment if workers are not qualified for new green jobs. The aging of the workforce, especially in developed nations, poses a serious demographic risk. The new technology and work patterns needed for a green economy may be harder for older workers to adopt. Additionally, an aging workforce may result in higher labor and pension costs, which might take funds away from green technology research and development.

Long-term negative effects of natural resources are lessened by green human capital and environmental restrictions. It is imperative to shift from traditional skills to those that enable green technology, sustainable agriculture, renewable energy, and efficient waste management as environmental concerns increase. According to Ahakwa, Xu and Tackie (2023), achieving the SDGs and other international accords depends on building green human capital. Numerous studies agree that a population with higher levels of education and awareness of environmental issues is more likely to adopt sustainable practices, which improves ecological quality. Ahakwa, Xu and Tackie (2023) showed, using Ghana as an example, that although green human capital short-term deteriorates environmental quality, it eventually enhances it. In order to address the negative effects of environmental degradation brought on by inadequate human capital, the authors suggested that more robust programs and regulations be put in place. They also suggested that lifelong green education be consistently strengthened to keep human knowledge and skills up to date with zero-emission milestones.

In general, higher levels of human capital are connected with increased, rather than decreased, adoption of renewable energy sources. Meanwhile, some writers contend that, while there is no clear, uniformly negative association between human capital and renewable energy, the relationship is complex and subtle (Akram *et al*., 2023). Yao *et al*. (2020) investigate whether human capital accumulation lowers CO_2 emissions. The authors looked at 20 OECD nations from 1870 to 2014. Parametric results reveal that advanced human capital is associated with lower CO_2 emissions. Non-parametric results, on the other hand, reveal that the link between CO_2 emissions and human capital changes with time. The findings support the social benefits of investing in advanced human capital. Oanh and Ha (2023) use different regression estimators on balanced panel data to assess the impact of human capital and wealth inequality on climate change in Asian nations from 2007 to 2020. The Generalized method of moments (GMM) estimator's results demonstrate that wealth disparity and human capital investments promote environmental degradation in Asian countries.

Meanwhile, green human capital is necessary to shift from the conventional model of natural resource exploitation to a more sustainable one. According to Khan *et al.* (2023), maximizing environmental benefits and encouraging resource regeneration require green human capital. According to research, green human capital also lessens reliance on natural resources (Avedyan and Belyavtseva, 2023; Ferdman *et al*., 2025). The authors concluded that green human capital and environmental regulations reduce the negative

effects of natural resources over time, and that environmental regulation has a positive short- and long-term influence on ecological quality.

Demographic factors like population growth, age distribution, and migration trends have a big impact on both green growth and human capital development. The workforce's size and makeup are influenced by these factors, which also have an effect on resource consumption, productivity, and innovation. Additionally, human capital, especially when it comes to environmental consciousness, can spur innovation in green technologies and sustainable consumption, which could result in a more sustainable economy (Ostapenko *et al.,* 2024). Sydorchuk, Kharechko and Khomenko (2024) also noted the impact of innovative human capital (IHC) on the convergence of regional green growth. Within this domain, a concept of sustainable human capital arose. According to Ahakwa and Tackie (2024), sustainable human capital refers to the combined ability of people and societies to create long-lasting value and well-being in the areas of the environment, society, and economy. It represents the vital interconnectedness of ecological integrity, societal equality, and human capability, which is consistent with international goals for sustainable development and long-term planetary health.

The long-term investment in and maintenance of people's abilities and well-being within a company or society is referred to as sustainable human capital. It highlights a change in perspective from considering workers as disposable commodities to appreciating them as precious resources that should be fostered for long-term contributions. With an emphasis on long-term organizational success and the holistic well-being of employees, this strategy incorporates sustainability concepts into human resource management while taking into account wider societal and environmental effects.

Green growth, which seeks to promote economic development while reducing environmental impact, depends on sustainable human capital. In order to create a workforce capable of driving green technology, promoting resource efficiency, and supporting sustainable business models, it is imperative to invest in human capital, which includes education, skills, and environmental awareness. Similar to how a green economy leads to a sustainable economy, the green human capital paradigm ought to serve as the cornerstone of a more comprehensive idea known as sustainable human capital. This would enable the effective management of natural resources and the consideration of all the intricate relationships and patterns found in the context of sustainable development. Thus, sustainability education to improve the quality of human capital can be seen as one of the primary directions of enhancing the revealed positive correlations.

Conclusions

The content analysis revealed, in particular, a negative correlation between human capital and CO_2 emissions. Long-term negative consequences of natural resources are mitigated by green human capital and environmental regulations. The research showed that the development of green capital helps to overcome the "resource curse", whereas institutional governance and human capital hinder the rent from natural resources. The substantial and adverse impact of natural resource rent on human development suggests that resource booms have not resulted in a rise in human development. In actuality, stronger governance not only increases economic transparency and holds the

government accountable, but it also improves resource management by preventing resource waste and misuse. The quality of institutions and policy aimed at green human capital development is a key factor in turning the resource curse into a blessing.

A new comprehensive intervention model should be devised to address the identified interrelated patterns at the same time. These initiatives can directly contribute to the Sustainable Development Goals (SDGs), particularly SDG 3 (Good Health and Well-being) and SDG 4 (Quality Education), by tackling significant impediments to equal access to important health and education services in underserved populations. These strategies should be based on theories that emphasize the importance of investing in education and health for human and economic development, as well as evidence showing investments in these sectors increase productivity, income, well-being, and equality. The study finishes with practical and applicable recommendations for public policymakers, highlighting the significance of tailoring them to the local situation and guaranteeing active participation from recipient communities.

The empirical findings presented in this research have the following policy implications. First, the government should raise fiscal spending on green R&D investment and implement policies such as tax breaks to encourage businesses to embrace green innovation. Second, the elder population's knowledge, skills, and experience should be recognized, while the younger population's innovative capacity should be encouraged by "combining the old with the new". Third, focus on cultivating the green innovation market. Developing economies should prioritize education investment and talent development in the green transformation. Decision makers should review human capital stock on a frequent and dynamic basis, appropriately estimate human capital, and categorize diverse talent development levels across geographies. They can then design complementary talent development plans and industrial policies to boost human capital development and promote green growth. Nevertheless, further studies are needed to investigate the effects of human capital within all the elements of the sustainable development landscape and taking into account the features of environmental dynamics (political, educational, and other effects).

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Authors' Declarations and Essential Ethical Compliances

Authors' Contributions (in accordance with ICMJE criteria for authorship)

Contribution	*Author 1*	*Author 2*	*Author 3*	*Author 4*	*Author 5*	*Author 6*
Conceived and designed the research or analysis	Yes	No	Yes	Yes	No	No
Collected the data	No	No	Yes	Yes	Yes	Yes
Contributed to data analysis and interpretation	Yes	Yes	No	No	No	No
Wrote the article/paper	Yes	Yes	No	No	No	No
Critical revision of the article/paper	No	Yes	No	Yes	No	No
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