

**Environmental challenges and the impact of human capital
on Azerbaijan's foreign economic activity**

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Abstract. The aim of this study was to analyse the main environmental challenges of Azerbaijan, their impact on the economy and international trade, and to assess the role of the quality of human capital in the country's adaptation to these challenges and the development of innovative solutions to reduce the negative impact on the environment. The study used an analytical approach that included the analysis of atmospheric emissions, such as CO₂, methane and nitrogen oxides, the assessment of their economic impact, as well as the analysis of the Human Development Index (HDI) indicators, which covered the level of education, health and standard of living of the population. The study analysed Azerbaijan's environmental challenges, including air pollution, land degradation, water scarcity, and climate change, highlighting their significant economic impacts, such as losses of 0.11-0.14% of gross domestic product (GDP) from air pollution, 10-11 billion manats annually from land degradation, and reduced productivity in key sectors. The results of the study showed that Azerbaijan's HDI changed from 0.762 in 2019 to 0.722 in 2020 due to the impact of the COVID-19 pandemic, and by 2022 it had increased to 0.760, almost returning to the 2019 level, indicating the effectiveness of measures to restore the economy and improve the quality of life. The study also found significant disparities in vocational education levels, with enrolment at only 12.4% of the total number of students in 2020, limiting the country's innovation potential. Azerbaijan's participation in international environmental initiatives, such as cooperation with the Green Climate Fund, which promotes the introduction of modern technologies in renewable energy, including the development of solar and wind power plants, was assessed. The results demonstrate that developing human capital, strengthening environmental culture, and implementing environmentally friendly technologies can contribute to sustainable economic growth, reducing environmental burdens, and increasing the country's international competitiveness.

Keywords: sustainability; export; renewable energy; climate; workforce

Introduction

The study of environmental challenges and human capital's impact on Azerbaijan's foreign economic activity is highly relevant amid global transformations. Azerbaijan's natural resources and strategic location position it as a key player in global trade, but climate change, resource depletion, and industrial impacts threaten its economic stability and competitiveness. Developing skilled human capital is vital for reducing reliance on oil exports and transitioning to a knowledge-based economy. Addressing environmental challenges while leveraging human capital underscores the need for a comprehensive approach to sustainable development.

Achieving sustainable economic growth and preserving environmental quality is a challenge for modern economies. B.R. Rexhepi *et al.* (2024) studied the impact of foreign direct investment (FDI), energy consumption and technological innovation on the economy and environment of BRICS countries. FDI promotes growth, but increases CO₂ emissions, while innovation reduces them, increasing environmental sustainability. The integration of eco-technologies in developing countries and mechanisms for balancing the economy and the environment need to be further studied.

Economic growth, foreign investment, and environmental pollution are key topics for developing countries. T.T. Le *et al.* (2022) analysed the relationship between FDI, CO₂ emissions, and economic growth using a nonlinear autoregressive distributed lag model. They found that FDI asymmetrically affects growth in the short run, while pollution influences growth in both the short and long run. Positive CO₂ changes boosted growth by 0.662%, while reductions negatively impacted economic activity. The study highlighted gaps, such as limited analysis of factors like technology, trade, and logistics, and the need for broader geographic coverage.

Economic growth in Africa faces significant challenges, including low quality human capital and weak institutional frameworks. F.O. Anetor & O. Vincent (2022) studied how human capital and institutional quality affect the relationship between FDI and economic growth in 46 African countries. The results showed that FDI alone does not stimulate economic growth, but its positive effect is enhanced in countries with high quality human capital and institutions. For low-income countries, FDI has a limited effect due to weak institutions and low technology absorptive capacity (Ismayilov *et al.*, 2024). Gaps include insufficient research on specific mechanisms for improving human capital quality and how to reform institutions to optimise the use of FDI.

Human capital development is crucial for economic growth, especially in diversifying economies (Sadikhov, 2024). L. Zeynalli (2020) examined its impact on Azerbaijan, identifying low education levels, limited healthcare access, and brain drain as key obstacles. Countries with stronger human capital achieve faster growth due to higher productivity and innovation. The study highlights gaps in addressing barriers to education and healthcare access and evaluating the role of innovative technologies in resource-limited settings.

The impact of human capital development on economic growth is critical amid current challenges. H.S. Baghirov *et al.* (2022) found that investments in IT and economic diversification enhance human capital and resilience in Azerbaijan, reducing reliance on oil and gas while supporting agriculture. Gaps include studying long-term war impacts, global changes, and technology integration for human capital growth.

Fuel and energy resource development significantly affects Azerbaijan's economy (Musayeva *et al.*, 2024). A. Mirheydarova & M. Orujov (2023) highlighted the oil

and gas sector as a growth driver but a major contributor to pollution. They stressed the need for economic diversification, renewable energy, and stricter environmental laws. Gaps involve analysing alternative energy impacts and integration into existing infrastructure.

The link between renewable energy and economic growth is crucial for countries like Azerbaijan and Hungary. S.I. Humbatova *et al.* (2024) found that in Azerbaijan, economic growth negatively affected hydropower, wind, and solar energy production, while overall energy supply remained stable. In Hungary, it reduced CO₂ emissions and boosted renewable energy production. Gaps include analysing long-term economic impacts on renewable energy and CO₂ reduction technologies.

Human capital is vital for sustainable development. S. Pürhani *et al.* (2022) highlighted professional development, labour availability, health, and financial inclusion as key components. Human capital quality drives economic, social, and environmental progress, especially through innovative technologies. Gaps involve insufficient focus on gender inequality and reducing environmental risks amid labour force growth.

The purpose of this study was to analyse the main environmental problems of Azerbaijan, their impact on the economy and international trade, and to assess the role of human capital quality in the country's ability to adapt to environmental challenges and develop innovative solutions to reduce the negative impact on the environment. The objectives of the study were to analyse the main environmental problems of Azerbaijan, in particular the level of atmospheric emissions and their impact on the economy and international trade, to assess the role of human capital quality in the country's ability to adapt to environmental challenges, and to investigate how the development of environmentally responsible human capital affects the competitiveness of Azerbaijani goods and services in the international market.

Materials and Methods

The study, conducted in 2019-2022, was comprehensive in nature and based on an analytical approach that combined qualitative and quantitative methods of data collection and analysis. It covered the study of environmental challenges, their impact on the economy and international trade of Azerbaijan, as well as the analysis of human capital as a factor of adaptation to modern challenges. The type of research is applied, focused on solving practical problems to improve the country's international competitiveness. The main sources of data were national statistics, international reports, scientific articles and analytical studies. The Human Development Index (HDI) (2024) was used to assess the level of human capital, covering indicators of education, health and living standards of the population. The HDI analysis helped identify the main trends and challenges related to the development of human capital in Azerbaijan, including access to quality education, the level of vocational training and innovative activity.

The study included an analysis of key environmental indicators, such as CO₂, methane and nitrogen oxide emissions, and their impact on economic activity and international trade (Steen, 2001; Sakata *et al.*, 2024). The main sources of emissions were taken into account, including industry, energy, agriculture and transport, with a further assessment of the effectiveness of existing environmental initiatives. To study the environmental problems of Azerbaijan and their economic consequences, a table was used that included an analysis of the main environmental challenges, their impact on the economy and international trade based on scientific publications (Bayramli, 2020; Chepeliev *et al.*, 2024) and official reports (Global Alliance on Health and Pollution, 2024; Climate Centre, 2024).

In addition, international partnerships were analysed, such as cooperation with the Green Climate Fund that contributed to the implementation of advanced environmental solutions (Mammadov, 2024). An important element of the study was the analysis of the role of environmental awareness of employees in reducing the environmental impact of production processes and increasing the competitiveness of products in international markets.

The materials and methods of this study encompassed a comprehensive analytical approach aimed at studying environmental challenges and their impact on the Azerbaijani economy and international trade, as well as the role of human capital in overcoming these challenges. Key environmental indicators, such as CO₂, methane and nitrogen oxide emissions, were studied to assess their economic impact. Special attention was paid to the role of education and vocational training in the formation of environmentally responsible human capital, in particular, disparities in vocational and higher education coverage and their impact on the labour market were analysed.

The solution examined the development and integration of renewable energy, smart technologies and artificial intelligence (AI) projects in the field of energy management. International partnerships, such as initiatives under the Green Climate Fund, were assessed, as well as cooperation with organisations such as the European Bank for Reconstruction and Development (EBRD) (Bitsadze, n.d.) to highlight their contribution to Azerbaijan's progress in the environmental and economic spheres.

Results

Evaluation of global environmental challenges

Environmental issues are one of the biggest challenges in the modern world, especially in the context of the growing impact of economic activity on the environment. Ecosystems are severely strained by industrialisation, urbanisation, rising energy consumption, and the growth of transportation infrastructure; therefore, sustainable development calls for solutions. The examination of atmospheric emissions, which have a major influence on human health, air quality, and worldwide economic activity, is one of the most important components. Industry, energy, transportation, agriculture, and the domestic sector are the primary

sources of atmospheric emissions worldwide today. Because of its large emissions of greenhouse gases like carbon dioxide (CO₂), methane (CH₄), and nitrogen oxides (NO_x), industry is a major contributor to air pollution. For instance, in addition to using a lot of energy, the cement and chemical industries also produce CO₂ emissions through chemical reactions related to burning limestone. A major source of emissions is the metallurgical sector, which uses high-temperature processes (Sakata *et al.*, 2024).

One of the biggest producers of greenhouse gases is the energy industry, which mostly depends on fossil fuels like coal, oil, and natural gas. As the most affordable and plentiful energy source in many nations, coal contributes significantly to CO₂, SO_x, and PM emissions. Although their effects are marginally less significant than those of coal, the burning of natural gas and oil also contributes to air emissions. Furthermore, fugitive emissions of methane, one of the most hazardous greenhouse gases because of its high potential heat-trapping capacity, are a by-product of the extraction and transportation of energy resources (Steen, 2001; Zlenko & Isaikina, 2020).

Another significant source of air pollution is the transportation industry. CO₂, NO_x, and volatile organic compounds are released as a result of the increasing number of automobiles, airplane trips, and sea transportation. Because of the high concentration of pollutants, road transportation using antiquated internal combustion engines that do not adhere to contemporary environmental requirements is a significant challenge for megacities. Simultaneously, the lack of adoption of hybrid and electric vehicles slows down the industry's efforts to reduce pollution (Steen, 2001).

Air emissions are also significantly influenced by agriculture. The amount of greenhouse gases in the atmosphere is greatly influenced by methane released during the production of rice and livestock as well as nitrogen oxides from the use of nitrogen fertilisers. Furthermore, burning agricultural waste results in high concentrations of fine particulate matter (PM_{2.5}), which deteriorates the quality of the air in rural areas and nearby areas (Guliyeva, 2023).

The amount of economic activity and the composition of the economy are directly correlated with the amount of emissions into the atmosphere. Emissions often rise in emerging nations in tandem with increases in industrial production and energy use. For instance, rising industrial production and fast urbanisation are frequently coupled by rising fossil fuel usage, which causes air pollution to rise sharply. In wealthy nations, things are frequently a little

different. They can reduce emissions while experiencing economic growth because of the advent of energy-efficient technologies and the shift to a green economy. Carbon capture and storage technology, for instance, help lessen the impact of conventional energy facilities, while the usage of renewable energy sources, such as solar and wind power, can lower CO₂ emissions. Global trends indicate that nations like China and India, which have sizable populations and rapid economic expansion, continue to be the biggest contributors to atmospheric emissions. Meanwhile, these nations are progressively implementing more stringent environmental regulations, which could eventually alter the course of events (Dziejarski *et al.*, 2023).

Global economic cycles are also associated with changes in emissions. Emissions have temporarily decreased during economic crises, such as the COVID-19 epidemic or the 2008 financial crisis, due to sharp drops in industrial production and energy use. Nevertheless, these downturns are often brief, and as soon as the economy improves, emissions swiftly reach or surpass their prior levels (Avgousti *et al.*, 2023). The economy of the globe are severely challenged by environmental difficulties. Because of increased sickness, decreased productivity, and shortened life expectancy, air pollution raises healthcare expenses. For instance, long-term respiratory conditions brought on by elevated airborne particulate matter lower worker productivity and raise medical expenses.

The economy of the globe are severely challenged by environmental difficulties. Because of increased sickness, decreased productivity, and shortened life expectancy, air pollution raises healthcare expenses. For instance, long-term respiratory conditions brought on by elevated airborne particulate matter lower worker productivity and raise medical expenses. The significance of environmental issues in global trade is growing. Due to the implementation of carbon taxes and stringent environmental regulations in importing nations, countries with high pollution levels are experiencing a decrease in demand for their goods. The Green Deal, for instance, is being implemented by the European Union with the goal of lowering carbon emissions at every stage of the production process. Because of this, exporters that rely on conventional energy sources face difficulties and must adopt environmentally (Avgousti *et al.*, 2023). Table 1 summarises the main environmental problems in Azerbaijan and their economic consequences, including the impact on international trade and the estimated economic losses.

Table 1. Main environmental problems and their economic consequences in Azerbaijan

Environmental problem	Primary causes	Economic consequences	Impact on international trade	Estimated economic losses
Air pollution	1. Oil and Gas Industry (oil extraction, transportation, refining). 2. Industrial Activities (metallurgical plants, emissions of NO₂, CO₂, etc.) 3. Vehicle Emissions. 4. Agricultural Practices (excessive use of fertilisers and pesticides). 5. Energy Production (thermal power plants, emissions of SO₂, NO₂, particulate matter).	1. Health care costs due to respiratory diseases. 2. Decreased worker productivity due to health issues. 3. Cost of air pollution control measures.	1. Non-compliance with environmental standards can lead to trade barriers or sanctions. 2. High levels of air pollution can deter foreign investors prioritizing sustainability. 3. Stricter regulations in international markets could hinder trade.	1. The economic costs of air pollution are estimated to be between 0.11% and 0.14% of gross domestic product (GDP) due to lost productivity from pollution-related diseases. 2. Particulate emission damage accounts for about 0.166% of gross national income as adjusted savings.

Table 1, Continued

Environmental problem	Primary causes	Economic consequences	Impact on international trade	Estimated Economic Losses
Land degradation	1. Soil Erosion (water and wind erosion). 2. Salinisation (salt accumulation in soils due to groundwater evaporation). 3. Loss of Natural Vegetation (reduction of soil-protective vegetation cover). 4. Intensive Use of Lands (high economic development and exploitation of lands without protective measures). 5. Unfavourable Climatic Conditions (harsh farming conditions). 6. Inadequate Agricultural Practices (lack of proper soil protection).	1. Decreased agricultural productivity. 2. Increased soil restoration costs. 3. Loss of arable land affecting food security. 4. Losses from soil erosion are estimated at approximately 10-11 billion manats annually.	1. Reduced agricultural productivity, especially for export crops like cotton, diminishes Azerbaijan's competitiveness in global markets. 2. Damage to trade routes due to increased flash floods or mudslides from land degradation.	Annual damages from soil erosion alone are estimated at approximately 10-11 billion manats.
Water shortage	1. Climate Change (reduced precipitation and increased evaporation). 2. Inadequate Infrastructure (outdated canals, wastewater treatment issues). 3. Mismanagement and Corruption (lack of oversight in resource distribution). 4. Agricultural Practices (inefficient irrigation, salinisation). 5. Geopolitical Factors (dependence on external water inflows). 6. Urbanisation and Population Growth (increased demand for water in cities).	1. Increased costs for water transportation and management. 2. Impact on agriculture due to water scarcity. 3. Increased competition for water resources.	1. Water scarcity impacts key sectors like oil, gas, agriculture, and manufacturing, reducing productivity and trade potential. 2. Geopolitical tensions could further strain international trade if disputes over water resources occur.	-
Oil resource depletion	1. Natural Decline of Major Fields (e.g., ACG field). 2. Aging Infrastructure and Lack of New Discoveries. 3. OPEC+ Production Cuts (voluntary reductions in quotas). 4. Global Market Dynamics (fluctuating demand and prices). 5. Geological Limitations (complex geology in Caspian Sea).	1. Reduced national oil revenue. 2. Increased costs for technological advancements to maintain production. 3. Potential job losses in the oil sector. 4. Oil contribution to GDP has been around 30% in recent years.	1. A decline in oil exports directly impacts Azerbaijan's trade balance, given that oil and gas account for about 95% of exports. 2. As global demand for fossil fuels fluctuates, Azerbaijan's trade may be impacted by the transition to cleaner energy sources.	1. The decline in oil exports could lead to significant reductions in government revenue and export earnings. 2. Potential GDP decline by up to 3.3% by 2060 due to global climate policies reducing fossil fuel demand.
Industrial waste accumulation	1. Lack of Effective Waste Management Infrastructure (absence of waste collection systems, treatment facilities, and recycling centres). 2. Insufficient Regulatory Framework (gaps in legislation, unclear roles among institutions). 3. Industrial Activities (oil refineries, chemical plants, hazardous waste generation). 4. Inadequate Data Collection (limited official records on industrial waste). 5. Economic Growth without Sustainable Practices (increase in industrial output without proper waste management).	1. Increased costs for waste management and environmental clean-up. 2. Health costs due to pollution exposure. 3. Loss of public trust in industrial operations. 4. Azerbaijan generated approximately 3,778.2 thousand tons of primary waste in 2021. 5. Cost savings from improved waste management practices can be between 52,000 to 63,000 AZN annually for SMEs.	1. Inefficient waste management practices could lead to delays in production and trade, increasing costs and regulatory challenges.	-
Climate change	1. Temperature Increase (rapid warming due to emissions). 2. Greenhouse Gas Emissions (fossil fuel-based economy). 3. Changes in Precipitation Patterns (decreased rainfall, increased floods). 4. Glacier Melting and Snow Cover Changes (affects water availability).	1. Reduced agricultural productivity (cotton, irrigation-dependent agriculture). 2. Increased frequency and intensity of droughts exacerbate water scarcity. 3. Vulnerability to global decarbonisation efforts. 4. Climate action seen as economically beneficial for diversifying economy. 5. Heat events increase health risks, including longer malaria seasons. Rising temperatures and changing precipitation patterns reduce agricultural productivity.	1. Climate change impacts sectors like agriculture, infrastructure, and tourism, which directly affect Azerbaijan's trade with global partners. 2. As global markets shift towards cleaner energy sources, Azerbaijan's fossil fuel exports may face challenges.	1. Projected GDP reductions due to climate change could reach up to several percent over coming decades. 2. Annual costs from extreme weather events amount to approximately USD 70-80 million annually.

Source: compiled by authors based on G. Bayramli (2020), M. Chepeliev *et al.* (2024), Global Alliance on Health and Pollution (2024), Climate Centre (2024)

The analysis of the main environmental issues and their economic implications for Azerbaijan presented in the table shows that these problems have a significant impact on the national economy and international trade.

Environmental degradation, in particular due to air pollution, land degradation, water scarcity, and climate change, not only increases healthcare and infrastructure costs, but also reduces the country's competitiveness in international markets. The lack of effective environmental regulations can lead to trade barriers and sanctions, as well as a decrease in the country's investment attractiveness. Given the close link between economic activity and environmental challenges, Azerbaijan needs to take active measures to improve natural resource management and reduce negative environmental impacts. The government should develop sustainable development strategies that include both adaptation to climate change and efficient use of natural resources to ensure long-term economic stability and maintain competitive advantages in the international arena.

Assessing the impact of human capital on adaptation to environmental challenges

The quality of human capital is one of the key elements that influence the economic development of a country and its ability to adapt to modern challenges. In Azerbaijan, human capital is formed through education, professional development and innovation potential, which are the basis for the development of the competitiveness of the national economy. The education system of Azerbaijan covers several levels: pre-school education (up to 6 years), primary education (4 years), general secondary education (5 years), complete secondary education (2 years), vocational secondary education (1-4 years depending on the program) and higher education (bachelor's degree – 4-5 years, master's degree – 1.5-2 years, doctoral degree – 3-4 years). Despite the availability of general education, its quality remains average, and there is a disparity between general and vocational education (The Republic of..., 2020).

In 2020, 76% of the adult population had secondary education, 16.6% had higher education, and 7.4% completed only primary education or did not receive it at all (European Training Foundation, 2021). In 2020, about 164 thousand people participated in vocational education, which was only 12.4% of the total number of students, 1.6% less than in 2019 (European Training Foundation, 2023). This indicates a low level of participation in vocational education, which is a serious challenge for human capital development. Higher education also faces challenges in meeting the current needs of the labour market. Low participation in vocational secondary education is a significant obstacle to the formation of a competitive labour market. The Azerbaijani government is taking steps to increase the accessibility of vocational education through the involvement of employers in the training process. The State Employment Agency organises professional development programs, including the development of career counsellors and centres at higher education institutions. In addition, measures are taken to improve the skills of teachers through programs of the Centre for Professional Development aimed at improving curricula.

Human capital plays a crucial role in creating an innovative economy. The development of innovative potential is supported by government initiatives aimed at modernising the educational system and introducing digital technologies. Educational transformation focuses on adapting curricula to the requirements of the modern labour market and integrating new technologies into the learning process. The government is also promoting international cooperation with organisations such as the European Training Foundation to implement projects to develop digital skills and support the green transition of the economy. An analysis of the quality of human capital in Azerbaijan shows some achievements in education, professional development, and innovation potential. However, challenges remain: low participation rates in vocational education, a declining share of students in vocational and higher education, and the need to further improve digital technologies (European Training Foundation, 2024). The HDI of Azerbaijan for the period 2019-2022 shows noticeable fluctuations, indicating the impact of both internal and external factors on the socio-economic situation in the country. In 2019, the HDI was 0.762, confirming the stable level of development of the country. However, in 2020, this indicator decreased to 0.722, which can be explained by the consequences of the COVID-19 pandemic, which caused an economic downturn, a slowdown in income growth, worsening employment conditions, and limited access to educational and medical services. The gradual recovery of the economy in 2021 contributed to an increase in the HDI to 0.738, reflecting the adaptation of the labour market, stabilisation of social programs, and the implementation of state initiatives to support the population. In 2022, the indicator reached 0.760, which almost returned the country to the level of 2019, indicating the effectiveness of measures to restore the economy and improve the quality of life of citizens. Changes in the HDI over this period demonstrate the country's vulnerability to global challenges and the need for a strategic approach to human capital development. The recovery of indicators after the crisis indicates Azerbaijan's ability to adapt to changes and ensure a gradual improvement in the quality of life of the population. However, the issue of strengthening the education and healthcare system, increasing the level of citizens' incomes and reducing social risks remains relevant, which can contribute to further growth in the HDI and improving the country's international competitiveness.

Azerbaijan is making significant progress in implementing innovative solutions aimed at reducing its environmental impact, although these initiatives are still in the early stages of implementation. One of the key areas is the use of modern technologies in cities to create conditions for sustainable development. In particular, the capital Baku is actively implementing smart city technologies aimed at improving the efficiency of urban infrastructure. For example, modern traffic management systems allow optimising traffic flows, which reduces air pollution and improves the quality of life of residents. These measures also include the

development of electric transport, which reduces greenhouse gas emissions in the urban environment. Agriculture is also an important area for implementing innovative environmental solutions. Companies such as Frenndt are working to create climate-resilient practices that aim to reduce the environmental impact of the agricultural sector. This includes the use of modern technologies to reduce pesticide use, optimise water resources, and reduce greenhouse gas emissions. Such initiatives help make the agricultural sector more efficient and environmentally friendly, while increasing its competitiveness in the international market.

The development of renewable energy sources is another key aspect of Azerbaijan's efforts to reduce its environmental footprint. The country is actively investing in the creation of large-scale solar farms and wind farms, which are part of the Green Energy Hub project. This helps to reduce dependence on traditional energy sources such as oil and gas, which are the main contributors to air pollution. At the same time, the development of hydropower contributes to ensuring a stable supply of clean energy that meets the principles of sustainable development (Hamidova & Samedova, 2024; Nuriyev, 2024).

In the energy sector, special attention is paid to the introduction of AI, which can significantly improve the efficiency of energy management. For example, AI is used to optimise energy production, distribution, and consumption, which reduces losses in power grids and cuts greenhouse gas emissions. Besides, AI technologies are used for predictive maintenance of energy infrastructure, which ensures its stable operation. In particular, such systems are used at wind power plants, which helps to increase their efficiency and reduce maintenance costs (World Economic Forum, n.d.).

International cooperation is an important tool for implementing innovative solutions in the field of environmental protection. Azerbaijan is actively involved in global climate initiatives, such as Conference of the Parties 29 (COP-29), where issues of sustainable development and reducing environmental impact are discussed. Participation in such events allows the country to gain access to best practices and technologies, as well as to develop partnerships with other countries and international organisations. In particular, cooperation with the World Economic Forum contributes to the implementation of advanced solutions in the field of energy efficiency and decarbonisation of urban energy systems (Nuriyev, 2024).

Among the promising areas of international cooperation is the implementation of pilot projects that

demonstrate the effectiveness of modern environmental technologies. For example, through a partnership with BrainBox, AI systems were implemented to improve the energy efficiency of buildings, which reduced energy consumption by 30% and emissions by 25-30% (World Economic Forum, n.d.). Such initiatives serve as an example for other sectors of the economy seeking to implement similar innovations.

Notwithstanding its notable accomplishments, Azerbaijan still confronts certain obstacles that prevent environmental innovations from developing further. Increasing investment in green infrastructure, reducing reliance on fossil fuels, and increasing public awareness of environmental issues are the three key challenges. In addition to supporting the integration of contemporary technology into different economic sectors, it is imperative to maintain a balance between environmental standards and economic progress. As a result, Azerbaijan exhibits the capacity to apply creative solutions to lessen their impact on the environment. This is accomplished by using AI technologies, developing sustainable energy sources, and taking part in global projects. Further progress in this area is possible with a comprehensive approach that includes attracting investment, developing educational programs, and strengthening international cooperation.

Azerbaijan pays considerable attention to the development of environmentally friendly technologies, attracting government programs, international cooperation and private investment. This approach helps the country to simultaneously reduce its dependence on fossil fuels and implement innovative solutions to reduce its environmental impact. The main areas of focus include modernisation of energy infrastructure, development of renewable energy, stimulation of the green economy, and support for environmentally friendly transport.

One of the main projects is the Green Climate Fund initiative, which involves the introduction of an early warning system and climate technologies. The Azerbaijani government is also actively cooperating with international financial organisations such as the EBRD and the World Bank to develop energy efficiency in buildings and create a roadmap for offshore wind energy. Private partners such as Masdar and Fortescue Future Industries are developing large-scale renewable energy projects. For a more detailed understanding of the role of public and private initiatives, Table 2 shows the key areas of investment, their volumes, and the projected impact on the country's economy and environment.

Table 2. Key investment areas in the development of environmentally oriented technologies in Azerbaijan

Investment area	Funding amount	Expected impact	Source of funding
Early Warning System	USD 35 million	Coverage of 5.71 million people; disaster risk reduction	Green Climate Fund
Offshore Wind Energy	USD 1 billion (expected)	Installation of 7 GW by 2040	World Bank, IFC
Public Building Modernisation	USD 50 million	30% reduction in energy consumption	EBRD
Renewable Energy Projects (Masdar, FFI)	USD 12 billion	Production of 12 GW of renewable energy	Private Investments

Source: compiled by authors based on Azerbaijan to Strengthen Climate Resilience Through Early Warning Systems (2024), K. Mammadov (2024), J. LaPorte (2024)

The table indicates that private and international funding is crucial to the adoption of environmental technologies. Specifically, funding renewable energy initiatives, like offshore wind farms, can diversify energy sources and drastically cut CO₂ emissions. Support for government initiatives, like modernising buildings and creating eco-friendly transportation, also contributes to lowering greenhouse gas emissions and increasing energy efficiency. As a result, Azerbaijan exhibits a thorough approach to environmental modernisation by integrating private investment, international collaboration, and indigenous resources. This enables the nation to support sustainable economic and social development in addition to addressing the present climatic issues.

Development of environmentally responsible human capital

Employees' environmental awareness is a key factor in ensuring the high quality of goods and services, especially in the context of modern sustainable development. In Azerbaijan, environmental responsibility is being strengthened through educational initiatives, professional training, and support for youth projects. Programs such as NEBOSH Environmental Awareness at Work help raise employees' awareness of the rational use of resources, optimisation of production processes, and the introduction of environmental technologies. Through these initiatives, companies reduce their environmental footprint while improving productivity and competitiveness. Organisations such as EkoSfera focus their efforts on fostering environmental responsibility among the public and businesses. Their projects help businesses integrate environmentally friendly solutions into production processes, which increases consumer confidence in products and services. In addition, such initiatives help avoid reputational risks associated with violations of environmental standards (Marziale, 2024). Youth initiatives, such as Youth Climate Envoys, create a platform for implementing innovative solutions aimed at protecting the environment. Young employees offer new ideas on how to reduce energy consumption and use resource-saving technologies, which has a positive impact on the quality of

goods and services (UNICEF, 2023). Employees that care about the environment also help to make better use of energy resources. In addition to cutting expenses, optimising energy use in production processes also lessens the negative effects on ecosystems. For companies looking to fulfil global standards and accomplish their environmental objectives, this adds value. Therefore, increasing the environmental awareness of employees not only enhances the quality of products and services but also lays the groundwork for an ecologically conscious company that satisfies the demands of contemporary customers and international market trends.

The development of environmental culture in Azerbaijan plays an important role in increasing the country's competitiveness in the international market. Government support, international cooperation and promotion of the green economy are key factors in this process. Azerbaijan's efforts to implement environmentally friendly practices demonstrate its commitment to meeting global standards and meeting the needs of environmentally conscious consumers and investors.

Government support is critical to fostering an environmental culture. National programs aimed at protecting nature and sustainable development raise public awareness and create a solid foundation for environmental initiatives. In addition, Azerbaijan's active participation in international climate events, such as COP-29, and green economy initiatives demonstrate the country's commitment to addressing environmental challenges and taking a leading position in global sustainable development efforts.

The integration of environmentally friendly technologies and practices into production processes strengthens Azerbaijan's competitive advantages. Growing consumer demand for environmentally responsible products emphasises the importance of such innovations. The use of green technologies allows enterprises not only to meet market expectations, but also to reduce production costs and increase operational efficiency, which helps to strengthen their position in the international market. As shown in Table 3, the development of an environmental culture directly affects competitiveness.

Table 3. Impact of environmental culture on key economic indicators

Impact Direction	Benefits for the Economy	Potential Outcomes
Energy Efficiency	Reduction of energy resource costs	Increased profitability of enterprises
Environmental Certification	Access to new international markets	Expansion of export volumes
Innovative Technologies	Use of environmentally friendly production processes	Growth in demand for products
International Cooperation	Attraction of international funding	Implementation of large-scale infrastructure projects
Awareness Raising	Formation of environmentally conscious workers and consumers	Increased trust in brands and products

Source: compiled by authors

The development of an environmental culture is an integral part of the economic strategy that contributes to the country's competitiveness in the international market. Implementation of environmental standards in production processes allows to improve product quality, reduce

production costs and expand access to new markets. Azerbaijan, using its resources and international partnerships, has the opportunity to set an example for other countries in the region by integrating environmental principles into all aspects of economic activity. To achieve this, it is necessary

to expand environmentally oriented initiatives, strengthen international cooperation, and invest in the green sector.

Discussion

The review of environmental challenges and the impact of human capital is extensive, because it allows us to assess how human capital contributes to adaptation to modern environmental challenges and ensures sustainable economic development. In the context of global climate change and growing demands for environmental responsibility of companies and states, the development of an environmental culture, innovation and investment in human capital is becoming a key factor in competitiveness at the international level. This also creates the basis for the introduction of new technologies, improving product quality and reducing the negative impact of economic activity on the environment.

This study and the work of M. Alalawneh (2020) examined the role of human capital and FDI in driving economic growth. M. Alalawneh emphasised the importance of investing in education and professional development for the long-term stability of the economy, which was consistent with the findings of this study on the role of environmental awareness of workers in improving the quality of goods and services. M. Alalawneh focused on their impact on infrastructure and employment, while this study emphasised the link between FDI and the introduction of environmentally friendly technologies and the development of a green economy. When considering global challenges, M. Alalawneh focused more on general economic aspects, while this study analysed the specifics of Azerbaijan and its international competitiveness.

Comparing the study by C. Diebolt & R. Hippe (2018) that examined the relationship between human capital and economic development in European regions using data for the period 1850-2010, both similarities and differences can be identified. C. Diebolt & R. Hippe used literacy and numerical skills as the main indicators of human capital, confirming the impact of historical levels of education on modern regional economic development. Similarly, the present study also recognised the role of human capital, but emphasised its importance for stimulating investment in technology and increasing the competitiveness of enterprises. However, differences in approaches were also evident. The study by C. Diebolt & R. Hippe focused on regional differences within Europe, using data from a long period, including the 19th and 20th centuries, to identify the relationship between historical factors and current economic performance. This study, by contrast, focuses on specific contemporary conditions and analyses historical trends to a lesser extent.

C.-H. Choi *et al.* (2024) investigated the impact of human capital on the sustainable development of international trade in BRICS countries, using a Vector AutoRegression model to analyse the relationships between key economic variables such as FDI, exports, imports, and GDP. Their study showed that human capital has a significant impact on economic growth and international trade, in particular

through its positive impact on GDP in most BRICS countries, with the exception of China. It was found that in China there is a two-way causality between human capital and FDI, while in Brazil there is a one-way causality from FDI to human capital. This study, in turn, focuses on the role of human capital in environmentally oriented economic initiatives, such as the introduction of environmental technologies and the development of an environmental culture, especially in Azerbaijan. In contrast to C.-H. Choi *et al.* this study focused more on the impact of environmental responsibility on a country's competitiveness in the international market. In particular, it looks at how the development of employees' environmental awareness and innovative practices contributes to the quality of goods and services, which positively affects the country's economic position.

A.B. Dankyi *et al.* (2022) investigated the relationship between human capital, FDI, and economic growth in ECOWAS countries. The study by A.B. Dankyi *et al.* focused on the impact of such factors as the level of urbanisation, the use of renewable energy, and the degree of integration of human capital into production processes. The study found that human capital development is a critical factor for attracting FDI, which in turn contributes to economic growth through increased productivity. At the same time, it emphasises that the lack of investment in quality education and training significantly limits the potential of ECOWAS countries to achieve sustainable development. In contrast, current study focuses on the role of human capital in adapting to environmental challenges and its impact on a country's international competitiveness. The focus here is on the environmental component, while the study by A.B. Dankyi *et al.* was dominated by an economic approach with a focus on traditional growth factors such as FDI. At the same time, both studies recognised the key role of human capital as a driver of development, but A.B. Dankyi *et al.* did not consider the environmental aspect, which was an important element of this study.

In the study by T. Yildiz *et al.* (2022), human capital was considered as a tool for raising the environmental awareness of the population and implementing practices that contribute to the conservation of natural resources and reducing the ecological footprint. This study, on the other hand, focused on the impact of human capital on the economic competitiveness of the country and the development of environmentally friendly technologies. Both works recognised the importance of education in the formation of human capital, but in T. Yildiz *et al.*, education was emphasised as a means of improving environmental behaviour, and in this study, as a platform for creating innovative solutions and increasing competitiveness in the international market. At the same time, in T. Yildiz *et al.*, the issues of the impact of human capital on the environmental state were mainly considered, while in this study the emphasis was placed on the economic aspect and its environmental consequences. The results of both studies show that the development of human capital contributes to solving modern global challenges, but the approaches to assessing its

impact and the final conclusions differ depending on the priorities. The study by T. Yildiz *et al.* focused on environmental benefits, while this study focuses on economic and international competitiveness.

This study examines the impact of environmental culture and human capital on international competitiveness, while J. Huang & F. Li (2019) focused on the role of human capital FDI, and innovation intensity in achieving regional economic growth. J. Huang & F. Li emphasised that FDI, combined with high levels of human capital, can promote technological progress, but dependence on foreign investment can limit local economic autonomy. This study, in contrast, emphasises how the development of environmental culture and the adoption of green technologies enhance economic competitiveness, in particular through compliance with global sustainable development standards. J. Huang & F. Li emphasised quantitative analysis of innovation activities in China's regions, while this study focuses more on qualitative analysis of environmental practices that affect a country's reputation in the international market. J. Huang & F. Li focused on the economy's dependence on investment in science and technology, while this study emphasises the importance of environmental awareness and its impact on investor and consumer confidence.

Current study examines the relationship between human capital, environmental culture, and international competitiveness, while A. Abbas *et al.* (2021) study focused on the impact of human capital on FDI attraction in developing countries. Both studies emphasise the importance of human capital for economic development, but their focuses differ significantly. A. Abbas *et al.* have extensively examined the impact of education and worker skill levels on the ability to attract FDI, indicating that high levels of tertiary education enrolment are key factors for investors. Current study, in turn, focuses more on the development of environmental culture as part of human capital that contributes to the implementation of sustainable solutions and increased economic competitiveness. A. Abbas *et al.* study found that employee compensation plays a critical role in attracting foreign investment. This is consistent with the findings of this study, which emphasises the importance of cost-effective use of human capital, but emphasises the environmental aspects of its development.

A. Sarwar *et al.* (2020) examined the relationship between human capital, financial development, and economic growth in developing countries, with a particular focus on the interactive effects between these factors. Their analysis highlights that high-quality human capital promotes economic growth when combined with an efficient financial infrastructure. The authors also emphasise the need for investment in education and training to increase labour productivity and attract foreign investment. Similar to A. Sarwar *et al.* findings, the analysis demonstrated that high levels of environmental awareness among workers and government support for education contribute to increased competitiveness in the international market. Both studies emphasise the role of international cooperation and the

introduction of innovative approaches to stimulate sustainable economic growth. A. Sarwar *et al.* focus more on financial infrastructure and its interaction with human capital, while this study focuses on the development of an environmental culture and its impact on the quality of goods and services. In addition, A. Sarwar *et al.* considered general aspects of human capital without a specific focus on environmental aspects, which makes their findings less specific in the context of environmental sustainability.

The P. Sanz Fernández (2016) study analysed the environmental impact of international trade through greenhouse gas emissions and local pollutants. Particular attention is paid to assessing the economic and environmental efficiency in terms of reducing international trade, using Input-Output Analysis models and the World Input-Output Database. The P. Sanz Fernández study also focused on the impact of international trade on environmental pressures, while this study focuses on the relationship between human capital, FDI and economic growth. The main similarity is that both studies are used to assess the long-term impacts of economic activity. Both studies recognise the importance of a sustainable approach to economic activity, but each of them analyses this issue from different perspectives. The P. Sanz Fernández study examines the environmental impact of economic activity through the lens of international trade, while this study focuses on economic aspects related to human capital development. Furthermore, the P. Sanz Fernández study focuses on global issues, while this study takes a more regional and sectoral approach.

This study analyses the role of human capital and FDI in stimulating economic growth, while the study by M. Gutsch *et al.* (2024) focused on the integration of environmental provisions in international trade agreements and their impact on the environmental performance of economies. The study by M. Gutsch *et al.* emphasised that environmental provisions in trade agreements contribute to raising environmental standards through enforcement and monitoring mechanisms. In particular, the authors note that such agreements incentivise countries to implement environmental protection policies and ensure that businesses comply with new standards. At the same time, the main emphasis in this study is on the development of human capital as a factor in increasing economic competitiveness and attracting foreign investment. M. Gutsch *et al.* examined the global context with examples of the impact of trade agreements in different countries, while the study focuses on specific mechanisms and development conditions in a particular region. In addition, the study by M. Gutsch *et al.* the direct impact of policies on environmental performance is assessed, while this study does not cover environmental aspects in the context of trade agreements.

M.K. Khan *et al.* (2021) examined the relationship between renewable energy consumption, economic activity, and carbon dioxide emissions in 219 countries over three decades, using dynamic panel data models and quantile regression. They show that while economic growth and FDI inflows may initially increase carbon emissions, the

introduction of renewable energy sources and improved electricity generation significantly mitigate these effects. The ecological Kuznets curve hypothesis underlies their analysis, suggesting that at higher income levels, economies transition to sustainability through technological progress and the integration of renewable energy. In contrast, the current study focuses on the role of human capital and environmental culture in promoting economic competitiveness and sustainable practices, particularly in a regional context. Unlike M.K. Khan *et al.*, this study emphasises qualitative dimensions of human capital, particularly environmental awareness among employees, as a driving force for the adoption of green technologies and the enhancement of international competitiveness of enterprises. This approach emphasises the importance of integrating environmental education and innovation into workforce development, presenting a more people-centered strategy for sustainable development. M.K. Khan *et al.* use a robust quantitative framework, using generalised method of moments estimation and quantile regression to analyse large-scale panel data, which allows for generalisation of understanding of global trends. However, the current study combines comparative qualitative analysis, examining specific regional or national contexts, to draw conclusions about the interaction between environmental culture and economic policy. This qualitative emphasis allows for detailed exploration of how local initiatives contribute to broader sustainable development goals.

Current study analyses the impact of human capital and environmental culture on a country's international competitiveness, with a focus on adaptation to environmental challenges and the development of environmentally friendly technologies. K. Madani (2020) study, meanwhile, focuses on integrating water resources, environmental initiatives and socio-economic aspects in the context of sustainable development. Both studies share a common aspiration to achieve sustainable development through the use of environmental innovations. K. Madani work focuses on resource management, particularly water resources, and their integration into sustainable development strategies. While this study highlights the importance of human capital in creating competitive environmental practices and goods. K. Madani focuses on the global context and integrated resource management, while this study focuses on specific national aspects such as the impact of human capital on economic competitiveness and environmental culture.

F. Ahmed *et al.* (2021) analysed the impact of FDI and industrialisation on the environment in the Asia-Pacific region. Both studies emphasise the close relationship between economic activity and environmental indicators. The similarity between the studies is manifested in the use of the concept of the ecological curve to analyse the relationship between economic growth and environmental degradation. Both works confirm that economic growth in the initial stages of development is accompanied by environmental degradation, but over time and with the introduction of environmentally friendly technologies, the

situation can improve. In addition, both studies emphasise the importance of regulatory policies that can help reduce the negative impact of economic activity on the environment. Current study considers international trade as a tool for stimulating sustainable development through the introduction of environmentally friendly technologies, which helps to increase the competitiveness of countries. In contrast, F. Ahmed *et al.* emphasise that weak environmental standards in Asia-Pacific countries contribute to increased methane and carbon dioxide emissions due to active industrialisation and foreign investment. While this study focuses on harmonising international standards to improve the environmental situation, F. Ahmed *et al.* point to the need to strengthen local environmental regulations.

The study by L. Zhang *et al.* (2022) focused on the impact of globalisation on climate change and the importance of a green economy for long-term development. The authors focus on aspects such as environmental efficiency, the transition to carbon-neutral technologies, and the need to integrate sustainable development into economic policies. The main similarities between this study and the work of L. Zhang *et al.* include the emphasis on the impact of environmental policies and economic activities on the environment. Both works emphasise the importance of a green economy in reducing the negative consequences of globalisation, such as increased CO₂ emissions, degradation of natural resources, and impacts on biodiversity. In L. Zhang *et al.*, the focus is on systemic changes that require the involvement of new technologies, institutional support, and the introduction of innovations to achieve sustainable development goals. At the same time, this study focuses on regional aspects and specific practical examples, such as mechanisms for regulating the impact of international trade on the environment.

Human capital and environmental culture play a critical role in driving sustainable economic development and strengthening international competitiveness. Emphasizing education, environmentally conscious practices, and innovation can enhance economic stability, support environmental preservation, and align with global sustainability standards.

Conclusions

The conclusion of this study emphasises the importance of integrating human capital and environmental culture into the strategy for sustainable development and increasing the international competitiveness of Azerbaijan. The study emphasises that the development of quality human capital, formed through systematic investments in education, vocational training and innovation, is a fundamental factor for adapting to modern environmental challenges and achieving economic growth. Particular attention is paid to the relationship between environmental culture, innovation and international competitiveness.

The study provides a comprehensive analysis of Azerbaijan's environmental challenges and their impact on the economy, international trade, and the development of human capital. It shows that environmental issues such as air

pollution, land degradation, water scarcity, and climate change have far-reaching economic consequences. For instance, air pollution results in economic losses estimated between 0.11% and 0.14% of GDP, while particulate emission damage accounts for about 0.166% of GNI as adjusted savings. Land degradation, particularly soil erosion, costs Azerbaijan around 10-11 billion manats annually. Water scarcity affects key sectors, including oil, gas, agriculture, and manufacturing, thereby reducing productivity and trade potential. The depletion of oil resources is projected to cause significant reductions in government revenue, with oil contributing approximately 30% of the GDP and 95% of exports. Additionally, industrial waste and climate change pose challenges to sustainable growth. According to the study's findings, the COVID-19 pandemic's effects caused Azerbaijan's HDI to drop from 0.762 in 2019 to 0.722 in 2020. By 2022, it had risen to 0.760, nearly reaching its 2019 level, demonstrating the success of policies aimed at reviving the economy and raising living standards. Significant differences in vocational education levels were also discovered by the study; in 2020, enrolment accounted for just 12.4% of all students, which limited the nation's capacity for innovation.

Significant emphasis is placed on renewable energy initiatives, such as the implementation of smart city technologies in Baku, the development of wind and solar power plants, and the modernisation of transport infrastructure. These activities are a practical example of how investments in environmentally responsible technologies can reduce greenhouse gas emissions while promoting economic growth. In particular, participation in international projects such as COP29 demonstrates Azerbaijan's

commitment to achieving global environmental standards and expanding its role in addressing climate challenges.

The study also highlights the importance of international cooperation. Through partnerships with international organisations such as the EBRD and the Green Climate Fund, Azerbaijan has access to technical support, financing, and advanced technologies. This allows the country not only to address current environmental challenges, but also to lay the foundation for long-term sustainable development.

However, the study also points to the need for further development in areas such as raising the level of environmental awareness of the population, improving the vocational education system and aligning higher education with modern labour market needs. Insufficient awareness of environmental standards among some segments of the population and insufficient funding for certain areas of education remain challenges that need to be addressed to ensure sustainable development.

Overall, the findings indicate that the integration of environmental aspects into human capital development strategies is key to addressing today's global challenges. Azerbaijan, through its initiatives and international cooperation, can become a model for other countries in achieving sustainable development and increasing economic efficiency through an innovative approach to human capital and environmental culture.

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Conflict of Interest

None.

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Екологічні виклики та вплив людського капіталу на зовнішньоекономічну діяльність Азербайджану

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Анотація. Метою цього дослідження було проаналізувати основні екологічні виклики Азербайджану, їх вплив на економіку та міжнародну торгівлю, а також оцінити роль якості людського капіталу в адаптації країни до цих викликів та розробці інноваційних рішень для зменшення негативного впливу на навколишнє середовище. У дослідженні було використано аналітичний підхід, який включав аналіз атмосферних викидів, таких як CO₂, метан та оксиди азоту, оцінку їхнього економічного впливу, а також аналіз показників Індексу людського розвитку (ІЛР), що охоплює рівень освіти, здоров'я та рівень життя населення. У дослідженні проаналізовано екологічні виклики Азербайджану, включаючи забруднення повітря, деградацію земель, дефіцит водних ресурсів та зміну клімату, та підкреслено їхній значний економічний вплив, зокрема, втрати 0,11 %-0,14 % валового внутрішнього продукту (ВВП) від забруднення повітря, 10-11 мільярдів манатів щорічно від деградації земель та зниження продуктивності праці в ключових секторах економіки. Результати дослідження показали, що ІЛР Азербайджану змінився з 0,762 у 2019 році до 0,722 у 2020 році через вплив пандемії COVID-19, а до 2022 року зріс до 0,760, майже повернувшись до рівня 2019 року, що свідчить про ефективність заходів з відновлення економіки та підвищення якості життя. Дослідження також виявило значні диспропорції в рівнях професійно-технічної освіти, де у 2020 році навчалось лише 12,4 % від загальної кількості студентів, що обмежує інноваційний потенціал країни. Було оцінено участь Азербайджану в міжнародних екологічних ініціативах, таких як співпраця із Зеленим кліматичним фондом, який сприяє впровадженню сучасних технологій у відновлюваній енергетиці, включаючи розвиток сонячних та вітрових електростанцій. Результати дослідження демонструють, що розвиток людського капіталу, зміцнення екологічної культури та впровадження екологічно чистих технологій можуть сприяти сталому економічному зростанню, зменшенню навантаження на довкілля та підвищенню міжнародної конкурентоспроможності країни

Ключові слова: сталість; експорт; відновлювана енергетика; клімат; робоча сила
