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History and Technological Innovations: The Impact of Technological Progress on the Course of Historical Events: A Systematic Review

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ABSTRACT

Technological breakthroughs shaped economic, political, and social changes in Albania, Kosovo, and Ukraine, according to this study. The research sought to link important technology advances to major historical shifts in these countries. The methodology examines how technology advances from industrialization to the digital era affected governance, warfare, and economic institutions. Industrialization in Albania in the 20th century increased manufacturing output, while Kosovo's post-war reconstruction focused on energy and telecommunications advances. Technological improvements in agriculture and aerospace helped Ukraine expand economically, increasing agricultural production by 25%. Digital revolution has increased economic integration in all three nations, with Ukraine becoming a key IT outsourcing hub and Kosovo witnessing growing digital entrepreneurship. These trends can be quantified using GDP growth, employment movements, and technological adaption data. The study shows how technology has affected political stability, economic development, and social transformation in various locations. The paper discusses the long-term effects of technology progress on human civilization and how Albania, Kosovo, and Ukraine may use innovation for sustainable development.

Keywords: Western balkans digital entrepreneurship, Ukrainian IT outsourcing, Albanian renewable energy modernization, Kosovo post-war infrastructure reconstruction, Ukrainian agricultural biotechnology

Introduction

Technology has shaped economic structures, political systems, and social changes throughout history. From the Industrial Revolution to digital technology, science and engineering have changed history. Albania, Kosovo, and Ukraine are under political and economic transition, therefore technical growth and historical change are especially important. Transforming from centrally planned to market economies, recovering from war, and joining global economic and technological networks have been distinct challenges for these countries. Technology has had a global impact, but little scholarship has examined its importance in these three nations' histories.

Existing literature has examined the influence of technological progress on economic and social development. Shkurti and Mustafa¹ highlighted the interaction between technological evolution and institutional change, while Schneider and Vipond² analyzed labor market shifts driven by automation. Kaefer et al.³ discussed data-driven technologies and societal well-being, and Josifidis and Supic⁴ debated whether

institutions outweigh technology in shaping development. Dub et al.⁵ analyzed the socio-economic impact of global technological change. However, these works rarely address the historical contexts of Albania, Kosovo, and Ukraine. This gap underscores the need for a focused study, drawing on Gao,⁶ who links cultural heritage and innovation, and Maljichi et al.,⁷ who examine trust in healthcare institutions in the Western Balkans.

This study connects Abramovitz's⁸ "catching-up" theory, Nelson's⁹ national innovation systems, and Pavitt's¹⁰ sectoral innovation patterns to analyze technological progress in Albania, Kosovo, and Ukraine. Abramovitz's⁸ theory is reflected in Albania and Kosovo's adoption of foreign technologies through investment and cooperation, aligning with the idea of "catching-up" by integrating existing technologies. Nelson's⁹ framework, focusing on institutional roles, explains how Albania's EU integration, Kosovo's international aid dependence, and Ukraine's EU/NATO partnerships influence technological advancement through institutional support. Pavitt's¹⁰ sectoral patterns highlight how each country follows distinct innovation paths: Albania in energy and agriculture, Kosovo in digital services, and Ukraine in IT and aerospace, driven by sector-specific needs and external influences. These frameworks guide the analysis of how technology adoption, institutional reforms, and sectoral strategies drive modernization in these countries.

This study examines the impact of technological progress on the political and economic transformations in Albania, Kosovo, and Ukraine, emphasizing the intersection of industry, digital infrastructure, and scientific innovations with geopolitical factors. Unlike studies that treat technological change as a universal phenomenon, this research offers a comparative analysis of transition economies in Southeastern and Eastern Europe, highlighting the roles of war, reforms, and global integration. It addresses a gap in existing literature by focusing on how these countries' unique trajectories have shaped their technological progress and modernization. The study explores how external factors, such as globalization and international cooperation, have influenced technological advancements in these regions.

Materials and Methods

This research examines the impact of technological innovations on historical transformations in Albania, Kosovo, and Ukraine. Drawing on scholarly publications, statistical data, and official documents, it

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compares the industrial, digital, and scientific progress of these countries. These countries have varied yet similar development trajectories, making them perfect for comparison. Albania and Kosovo, with transitional economies and post-socialist histories, share European integration goals but differ in reconstruction and development. Ukraine, more industrialized, faces challenges from its Soviet legacy, tech growth, and geopolitical issues, offering insights into technology's impact on political and economic changes in transitional economies.

Quantitative analysis utilized data on GDP, employment rates, and digital transformation from reputable international databases such as the World Bank Group,¹¹ and Employment – annual statistics.¹² GDP indicators before and after key technological innovations were compared to assess changes in productivity and economic growth, with cross-verification for data accuracy. Conflicts were resolved by prioritizing official reports.

To ensure reproducibility, a systematic search strategy was applied across four major databases: Scopus, Web of Science Core Collection, JSTOR, and Google Scholar. The final searches were completed on 19 May 2025. Search strings were tailored to the syntax and field specifications of each database to capture relevant literature on technological innovation, digital transformation, industrial development, and renewable energy in Albania, Kosovo, and Ukraine.

In Scopus, searches were conducted within the fields of titles, abstracts, and keywords using the following expression: TITLE-ABS-KEY (“technological innovation” OR “digital transformation” OR “industrial development” OR “renewable energy”) AND (“Albania” OR “Kosovo” OR “Ukraine”). The coverage window was set from 1980 to 2025, and results were restricted to English-language publications. Similarly, in the Web of Science Core Collection, the search string was applied to the topic field (TS), which includes titles, abstracts, and keywords: TS=(“technological innovation” OR “digital transformation” OR “industrial

development” OR “renewable energy”) AND TS=(“Albania” OR “Kosovo” OR “Ukraine”), with the same coverage window and language restriction.

In JSTOR, the database's search constraints were addressed by applying the expression (“technological innovation” OR “digital transformation” OR “industrial development” OR “renewable energy”) AND (“Albania” OR “Kosovo” OR “Ukraine”) across titles, abstracts, and full texts where available. The coverage period was set from 1980 to 2025, and only English-language results were retained. In Google Scholar, the advanced search function was employed using the same Boolean structure. The search was limited to works published between 1980 and 2025, with explicit restriction to English-language materials.

The inclusion criteria comprised: (1) publications focused on technological innovations and transformations in the target countries; (2) peer-reviewed or otherwise reputable sources; (3) studies presenting empirical data on technological, economic, or political progress; and (4) scientifically credible materials. Exclusion criteria were: (1) irrelevant or anecdotal studies; (2) works lacking empirical data; and (3) inaccessible sources.

The search process initially yielded 200 records. After removing 40 duplicates, 160 unique records remained. Title and abstract screening excluded 40 items, including those that were out of scope ($n = 15$), inaccessible ($n = 10$), not in English ($n = 5$), or of limited rigor ($n = 10$). A total of 120 full-text articles were then assessed, of which 40 were excluded for missing or incomplete data. Consequently, 81 studies were included in the final review, as illustrated in the PRISMA flow diagram (Figure 1).

Quality appraisal was conducted using the Mixed Methods Appraisal Tool,¹³ which is suited for studies employing qualitative, quantitative, and mixed-methods designs (Appendix A). Each study was assessed based on five criteria, with high-quality studies ($n=53$) prioritized and lower-quality studies ($n=28$) used as supplementary evidence, noting potential bias. This

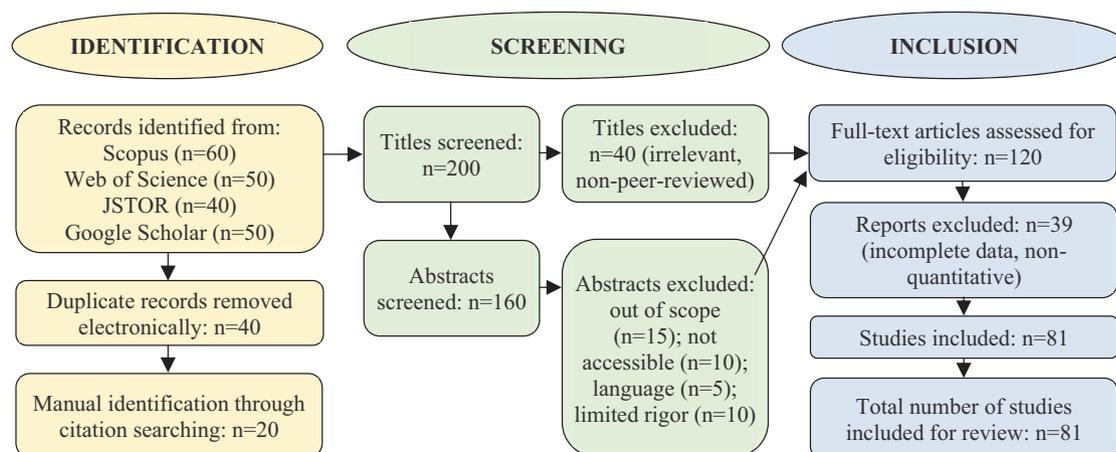


Fig 1 | PRISMA flow diagram of the process of selecting research sources

Source: Compiled by the authors.

ensured that conclusions were grounded in systematically weighted evidence.

A comparative approach allowed for an assessment of technological development stages in Albania, Kosovo, and Ukraine. This analysis, integrating official documents, statistical reports, and scholarly publications, examined how technological innovations influenced economic and political shifts, considering both domestic progress and external factors like globalization and international cooperation.

Results and Discussion

Albania: Path to technological modernization through industrial growth and digital transformation

In the Industrial Era, Albania's shift from a centralized economy to a market-based system marked a turning point.¹³ The collapse of communism in the early 1990s enabled privatization, infrastructure modernization, and the introduction of foreign technologies. The government revitalized mining and textile industries and invested in transportation and energy infrastructure, boosting manufacturing capacity and job creation.¹⁴ Yet, outdated equipment and limited access to global markets slowed industrial progress. In the Digital Era, Albania prioritized digital infrastructure and ICT expansion.¹⁵ High-speed internet and e-governance platforms improved access to public services and business communication.¹⁶ Support for tech startups and innovation hubs fostered IT sector growth, attracted foreign investment, and created jobs, with Albania's Balkan location positioning it as a regional hub for digital entrepreneurship.

In Scientific Innovations, Albania focused on renewable energy, particularly hydropower and solar projects, collaborating with international institutions and participating in EU-funded programs to promote sustainable energy and environmental protection. Agricultural technology advancements also improved crop yields and rural development.¹⁷ External influences were crucial for Albania's technological progress. Financial support from the EU, World Bank, and IMF facilitated infrastructure upgrades and innovation, while participation in initiatives like the Western Balkans Digital Agenda aligned national policies with European standards.¹⁸ Quantitative analysis shows GDP growth, higher employment, and improved productivity, driven by industrial modernization, digital transformation, and scientific advancements.¹⁹ According to the World Bank,¹¹ the share of ICT in GDP reached 4.6% in 2023 (ITU). The e-Government Development Index (EGDI) stood at 0.64 in 2022 (UNE-Government Survey), which is above the regional average. In renewable energy, more than 95% of electricity is generated from hydropower, while solar capacity increased to 35 MW in 2023. According to UNCTAD,²⁰ FDI inflows amounted to 1.4 billion USD in 2022, with a significant portion directed toward energy and ICT.

Challenges such as limited skilled labor and bureaucratic inefficiencies, however, persist. Integration into global technological networks and digital

infrastructure development have been central to Albania's modernization. According to Gjoni and Elezi,²¹ the government's strategies enhanced the ICT sector and attracted foreign investment, notably through the e-Albania platform, which digitized services, reduced bureaucracy, and increased transparency. Broadband expansion bridged the digital divide, supporting SMEs. According to Llazo and Neza,²² digitalization reduced obstacles for SMEs, enabling growth in a connected environment. Technology parks and innovation hubs, such as the Protik Innovation Center in Tirana, fostered startups and international collaboration. Cybersecurity and data protection measures aligned with European standards, ensuring a secure digital environment and building investor trust.

Digital payment systems and e-commerce platforms have enabled local businesses in Albania to expand internationally, enhancing its global competitiveness. International cooperation, especially with the EU, World Bank, and tech giants, provided vital financial and technological support. These advancements also benefited the education sector, with ICT-based learning and digital literacy programs empowering the younger generation for the digital economy. Despite progress, challenges like the urban-rural digital divide and cybersecurity investment remain, but Albania is poised to strengthen its digital economy with continued international support and strategic policies.²³⁻²⁶

Albania has made significant strides in renewable energy and agriculture through technological innovation. Hydropower, which provides over 95% of the country's electricity, is being modernized to improve efficiency and reduce environmental impact.²⁷⁻²⁹ Solar investments have expanded with EU and international support, while smart grids enhance supply stability. In agriculture, precision farming, satellite imagery, and data analytics have optimized resource use and productivity.^{30,31} These technologies have reduced water consumption, improved soil fertility, and boosted exports, particularly through greenhouse and organic farming.³²⁻³⁴ International collaborations and EU projects have fostered knowledge transfer and provided farmers with essential data for sustainable practices.³⁵ These advancements in energy and agriculture contribute to Albania's growth, sustainability, and rural development.³⁶

EU support and foreign investment have been pivotal to Albania's modernization, enhancing digital infrastructure, energy efficiency, and agricultural innovation. The EU's IPA program improved public services, while FDI boosted industrial production and renewable energy. EU-backed projects also advanced vocational training and university collaboration, preparing the workforce for a tech-driven economy.³⁷

Technological progress has also shaped GDP, employment, and productivity. Between 2005 and 2025, the country experienced steady economic expansion, largely driven by innovations in renewable energy, digital infrastructure, and agriculture. Industrial modernization and digitalization boosted GDP, while IT sector development created revenue streams, attracted

investment, and strengthened Albania's regional role. Employment shifted from traditional labor to technology-driven industries.³⁸ The IT sector and startups provided urban jobs, while precision agriculture improved rural employment by enhancing productivity and reducing manual labor. Renewable energy technologies lowered costs and expanded output, while smart grid systems optimized distribution.^{39,40} EU-funded innovation programs and international research partnerships further improved productivity in transportation, logistics, and healthcare.⁴¹ This focus on innovation has driven sustainable GDP growth, a dynamic labor market, and greater efficiency across industries, positioning Albania for deeper integration into the global digital economy.

Albania's broader economic transformation highlights its adaptability. The Industrial Era marked a shift from state control to market economy, with infrastructure investments laying foundations for growth. In the Digital Era, ICT and digital infrastructure diversified the economy, strengthened IT services, and boosted productivity. Scientific advances in renewable energy and agriculture fostered sustainable development and resilience. External support from the EU and international institutions accelerated modernization, aligned policies with European standards, and enhanced global competitiveness. Quantitative analysis confirms substantial improvements in GDP, employment, and productivity, while also pointing to the need for ongoing structural reforms.

Kosovo: Post-war technological advancement and sustainable development

Following the Kosovo War in 1998–1999, the country faced major challenges in rebuilding its infrastructure and economy. Post-war reconstruction prioritized restoring and modernizing the energy sector and telecommunications networks, both heavily damaged during the conflict. In energy, the government, supported by the EU and World Bank, rehabilitated power plants, upgraded the electricity grid, and invested in renewable projects such as small hydropower and solar energy to reduce dependence on imports. Badallaj⁴² notes that the EBRD significantly financed these initiatives between 2013 and 2020, advancing Kosovo's shift toward sustainable energy. Telecommunications development improved domestic connectivity and regional ties. Market liberalization attracted foreign investment, expanding mobile networks and internet access, which facilitated digital services and e-commerce growth. Transportation infrastructure reconstruction further supported industrial zones, regional trade, employment, and overall living standards. These efforts laid the foundation for sustainable industrial growth and future technological and economic progress.

Since 2015, Kosovo has emerged as a leader in digital entrepreneurship and e-governance in the Western Balkans. Strategic government initiatives, international partnerships, and a dynamic startup ecosystem drove this progress. The establishment of the

Innovation Centre Kosovo (ICK) in 2016 was pivotal, supporting over 300 tech startups by 2020 through mentorship, funding, and advanced digital skills training.⁴³

Digital entrepreneurship has also transformed small businesses in retail, hospitality, and agriculture, which increasingly use online payments, social media marketing, and e-commerce to reach wider markets. Digital bookkeeping and cloud management have lowered costs for family businesses, while gig-economy platforms have created new income opportunities. Rural producers, in particular, use digital marketplaces to connect directly with consumers, enhancing competitiveness. These developments illustrate how grassroots innovation is reshaping Kosovo's economic culture, reducing barriers for small firms, and expanding self-employment opportunities.

Additionally, Kosovo's high internet penetration rate, which reached nearly 100% by 2022, has further accelerated the growth of the digital economy.⁴⁴ The government's commitment to digital transformation was reinforced with the National Strategy for Digitalization, launched in 2018. This strategy aimed to modernize public services and reduce bureaucratic inefficiencies through digital solutions. A key achievement was the launch of the eKosova portal in 2020, which digitized over 500 public services, allowing citizens to handle administrative tasks such as tax filings and business registrations online. This initiative not only improved efficiency and transparency but also strengthened Kosovo's global standing in digital governance.⁴⁵ In 2023, Kosovo signed a USD 20 million agreement with the World Bank to enhance digital governance and service delivery. This partnership aims to improve the country's network infrastructure and expand shared digital platforms, further strengthening the foundation for sustainable digital growth.⁴⁶

The impact of these efforts on Kosovo's economy has been profound. According to the World Bank,¹¹ internet penetration reached 99.7% in 2022 (ITU), and the EGDI was 0.65 in 2022 (UN). Over 240 MW of small hydroelectric plants and solar stations have been installed in the energy sector, reducing dependence on electricity imports by 20%.⁴² The ICT sector accounted for 7% of GDP in 2023 and created more than 10,000 jobs. According to Bund and Esteve-González,⁴⁷ the ICT sector's contribution to GDP rose from 2% in 2015 to 7% in 2023, while the digital sector created about 10,000 new jobs, providing opportunities for Kosovo's youthful population. Growth in digital outsourcing and e-commerce has boosted foreign investment and positioned Kosovo as an emerging regional tech hub. Rapid advances in digital entrepreneurship and e-governance stem from strategic policymaking, international cooperation, and local innovation. These achievements modernized public services, improved productivity, reshaped small business practices, and paved the way for deeper integration into the global digital economy.

Since 2015, Kosovo has advanced environmental technologies and infrastructure to support sustainable

development and improve citizens' quality of life. Projects in water management, renewable energy, and modernization were backed by international investments and partnerships.⁴⁸ A modern wastewater treatment plant in Mitrovica, financed by the European Investment Bank (EIB) with EUR 19.8 million in 2021, improved sanitation for 213,000 residents. Likewise, the EUR 11 million EIB-funded facility in Gjilan/Gnjilane (2020) enhanced access to clean water for 90,000 people.⁴⁹ The FLOWS project, backed by the World Bank, introduced advanced water monitoring technologies. Together, these initiatives reduced pollution and improved public health. Kosovo also aims to raise renewable energy to 32% of total consumption by 2030 and cut greenhouse gas emissions by 16.3% compared to 2016. Supported by the EBRD, efficiency measures in public buildings reduced energy use and CO₂ emissions.⁵⁰ The USAID Energy Sustainability Activity (ESA) has further strengthened Kosovo's energy market and attracted sustainable energy investment. Infrastructure upgrades remain central: Routes 6 and 7, built by Bechtel and ENKA, linked Kosovo with neighbors and supported trade.⁵¹ Through the Western Balkans 6 initiative, Kosovo has secured funding for modernizing railways and road networks.⁵² Overall, advances in environmental technologies and infrastructure have spurred growth, improved health, and boosted energy efficiency.

Since independence in 2008, Kosovo's development has relied heavily on international aid. The EU, through IPA programs, supported democratic institutions, infrastructure, digital transformation, and green energy.^{53,54} USAID contributed over USD 1.1 billion since 2001, though a 2025 freeze disrupted USD 162 million in reforms.⁵⁵ Germany invested over EUR 1 billion via GIZ, focusing on youth employment, and maintained NATO KFOR stability, reinforced by Secretary-General Mark Rutte's 2025 visit. The World Bank funded renewable energy and rural development.^{56,57}

Economic recovery accelerated in 2024–2025 through ICT growth. IPKO modernized telecommunications, Trajnimi trained over 30,000 citizens in digital skills, and outsourcing firms like 3CIS attracted investment and high-paying jobs.⁵⁸ The World Bank's Digital Economy Project expanded internet and e-commerce, boosting GDP, reducing unemployment, and narrowing the digital divide.⁵⁹ Kosovo's reconstruction has shifted from infrastructure to digital entrepreneurship and sustainability. The Innovation Centre Kosovo, e-governance tools like eKosova, and environmental projects in energy and wastewater improved living standards. Supported by international partners and widespread digital literacy, Kosovo has reduced youth unemployment and created tech-driven opportunities, demonstrating its capacity for innovation and sustainable growth.

Ukraine: Innovation-driven progress in agriculture, IT, and renewable energy

During Ukraine's industrial era, technological advancements in agriculture and aerospace significantly

boosted productivity and economic growth. Heyets⁶⁰ notes that these innovations were pivotal for strategic industrial activities. In agriculture, automated harvesters, efficient irrigation, soil analysis, precision fertilization, and improved seed technologies, including genetic modifications, increased productivity by 25%. Ukraine's aerospace sector progressed through enterprises like Antonov Design Bureau and Yuzhnoye Design Office. Antonov's aircraft, such as the AN-225 Mriya, demonstrated global engineering expertise, while Yuzhnoye's rocket and satellite technologies reinforced Ukraine's space capabilities. Integration across sectors, including drones and satellite-based monitoring in agriculture, optimized resources, reduced costs, and minimized environmental impact, laying a foundation for sustainable growth and future innovations.

In the digital era, Ukraine has emerged as a key IT outsourcing hub and cybersecurity developer. According to Poliakova et al.,⁶¹ a strong scientific and educational base fostered a robust IT sector, contributing about 4% of GDP by 2021. ICT services in exports grew from 3.9% in 2010 to 38.1% in 2021 (USD 7.11 billion). Major cities including Kyiv, Kharkiv, Lviv, Dnipro, Donetsk, and Simferopol host software companies employing roughly 250,000 engineers, with notable firms such as EPAM Systems (12,389 specialists), SoftServe (9,462), GlobalLogic, and Ciklum.⁶¹

Challenges in the 2010s, such as low domestic demand and outsourcing dependence, limited value creation. Government measures like the 2013 ten-year VAT exemption, reduced corporate taxes, the IT Creative Fund, and the Diia platform enhanced training, digitization, and digital literacy. Ukraine's cybersecurity expertise, driven by exposure to cyber threats, facilitated international collaboration. For example, the U.S. Department of Defense expanded Ukraine's access to SpaceX's Starshield system in August 2023, increasing terminals to 3,000 and strengthening secure communications.⁶² These developments underscore Ukraine's role in global IT outsourcing and cybersecurity, reflecting adaptability and resilience.

Between 2020 and 2024, Ukraine advanced in biotechnology and renewable energy despite geopolitical and economic challenges. As of 2022–2023, more than 660 MW of new renewable energy capacities were introduced.⁶³ The share of "green" generation in the energy balance amounted to approximately 20.3% in 2023, with around 10% coming from solar and wind. In biotechnology, clinical trials of stem cells were initiated. Ukraine's EGDI reached 0.711 in 2022 (UN), surpassing the global average. The IT sector's share in GDP grew from 1.5% in 2010 to 7% in 2025, and IT services exports exceeded USD 8.5 billion in 2024.¹¹

Ukrainian research advanced GMOs, pest-resistant seeds, vaccines, and biopharmaceuticals, while renewable energy grew through biomass, wind, and solar, including the 500 MW Tyligulska Wind Power Plant, powering 900,000 homes.^{63,64} Stem cell therapies entered clinical trials in 2024, solar panels reached schools and hospitals, and bioenergy startups

attracted foreign investment, boosting sustainability and competitiveness.

EU cooperation and foreign investments supported technological growth. Joining Horizon Europe in 2022 provided research funding for green energy, digital transformation, and biotechnology, with IT and renewable energy startups receiving over EUR 70 million by 2024.⁶⁵ BSEC, EIB, and EBRD investments improved infrastructure and cybersecurity, and EU Defense Innovation Hub participation facilitated access to advanced technologies.⁶⁶ Startups like Grammarly, Petcube, and Reface expanded internationally, positioning Ukraine as a leading IT outsourcing hub contributing 7% to GDP by 2025.⁶⁷

From 2022 to 2025, Ukraine’s economy faced major shifts. Barash⁶⁸ notes the Russian invasion caused a 35% GDP drop in 2022, followed by moderate growth in 2023–2025 (IMF). Employment shifted from agriculture (27% to 14%) to services (46% to 61%). Steel exports fell sharply in 2022 but recovered by 2024,⁶⁸ while agricultural exports kept Ukraine a leading wheat supplier.⁶⁹ Despite structural and geopolitical challenges, the economy shows resilience.

The continued strength of agricultural exports offers a foundation for future growth, but sustained recovery will require strategic investments in infrastructure and workforce development (Table 1).

Table 1 illustrates technological developments in Albania, Kosovo, and Ukraine across five dimensions: Industrial Era, Digital Era, Scientific Innovations, External Influences, and Quantitative Analysis. Albania’s progress reflects post-communist industrial modernization, EU-supported integration into global networks, and advances in renewable energy and agriculture, boosting GDP, employment, and productivity. Kosovo’s evolution, shaped by post-war reconstruction, emphasizes energy, telecommunications, digital entrepreneurship, and e-governance, supported by international aid, contributing to economic recovery and improved digital literacy.⁷⁰ Ukraine’s growth in agriculture and aerospace, along with its rise as an IT outsourcing and cybersecurity hub, has increased productivity by 25%, enhanced exports, and strengthened its role in the global technology market (Table 2).

Table 2 summarizes the economic impact of technological progress in Albania, Kosovo, and Ukraine. Albania’s digital economy grew by 30% over five years, fueled by EU-backed infrastructure projects, creating jobs in IT and renewable energy and boosting exports in agriculture and energy technologies. E-governance and digital literacy initiatives further strengthened its social and economic development. In Kosovo, renewable energy projects reduced energy dependence by 20%, supporting economic recovery, digital entrepreneurship, and social inclusion. Improved telecommunications and energy technology exports were driven by international aid. In Ukraine, the IT sector now contributes 7% to GDP, reflecting its role in IT outsourcing and cybersecurity.^{5, 11} EU partnerships and foreign investment enhanced IT, software, and agricultural exports, while digital inclusion programs strengthened social infrastructure. Ukraine’s economy shifted toward innovation-driven sectors, with agricultural productivity up 25%, aerospace exports contributing to GDP, and renewable energy capacity growing 40% between 2020 and 2025. Scientific innovations in biotechnology and renewable energy, supported by EU investments, further boosted sustainability and resilience despite geopolitical challenges.

Comparative analysis: Technological innovation in transition economies of Eastern Europe

Below is a comparative Figure 2 of GDP per capita (in current USD) for Albania, Kosovo and Ukraine for selected years. These data provide a quantitative basis for comparing economic growth rates and changes in the level of well-being of the population in the countries studied.

As can be seen from the Figure 2, all three countries show long-term growth in GDP per capita, with Albania having the highest figure in 2024 (10011 USD), while Ukraine lags behind (5389 USD). These differences should be taken into account in further analysis of the impact of technological innovation on economic stability and living standards in each country.

The comparative analysis of technological innovation in Albania, Kosovo, and Ukraine reveals both shared trends and distinct differences shaped by

Table 1 | Key technological milestones in each country

Category	Albania	Kosovo	Ukraine
Industrial Era	Post-communist industrial modernization and manufacturing output improvements	Post-war reconstruction with a focus on energy and telecommunications	Technological progress in the agricultural and aerospace sectors, with a 25% increase in productivity ⁶³
Digital Era	Integration into global technological networks and digital infrastructure development	Rapid expansion in digital entrepreneurship and e-governance	Emergence as a leading IT outsourcing hub and development of cybersecurity technologies
Scientific Innovations	Advances in renewable energy and agriculture	Development in environmental technologies and infrastructure	Advances in biotechnology and renewable energy
External Influences	Impact of European Union support and foreign investments	International aid and support from international organizations	European Union cooperation, technological partnerships, and foreign investments
Quantitative Analysis	GDP growth, employment shifts, and technology-driven productivity improvements	Impact on economic recovery, job creation, and digital literacy	Economic performance, employment patterns, and export growth

Source: Compiled by the authors.

Table 2 | Economic impact of technological progress

Category	Albania	Kosovo	Ukraine
GDP Growth	30% increase in digital economy activities over five years ¹¹	20% reduction in energy dependence due to renewable projects ¹¹	7% contribution of IT sector to national GDP ^{5,11}
Employment Patterns	Creation of jobs in IT and renewable energy sectors	Expansion of digital entrepreneurship and e-governance jobs	Growth in IT outsourcing and cybersecurity jobs
Export Growth	Increased exports in agricultural and renewable energy technologies	Improved telecommunications services and energy technology exports	Expansion in IT services, software development, and agricultural products
Foreign Investments	EU-backed infrastructure and technological investments	International aid and support from global organizations	European Union partnerships and investments in digital and energy sectors
Social Impact	Enhanced public services through e-governance and digital literacy programs	Improved access to digital tools and job opportunities	Increased innovation-driven social projects and digital inclusion initiatives

Source: Compiled by the authors.

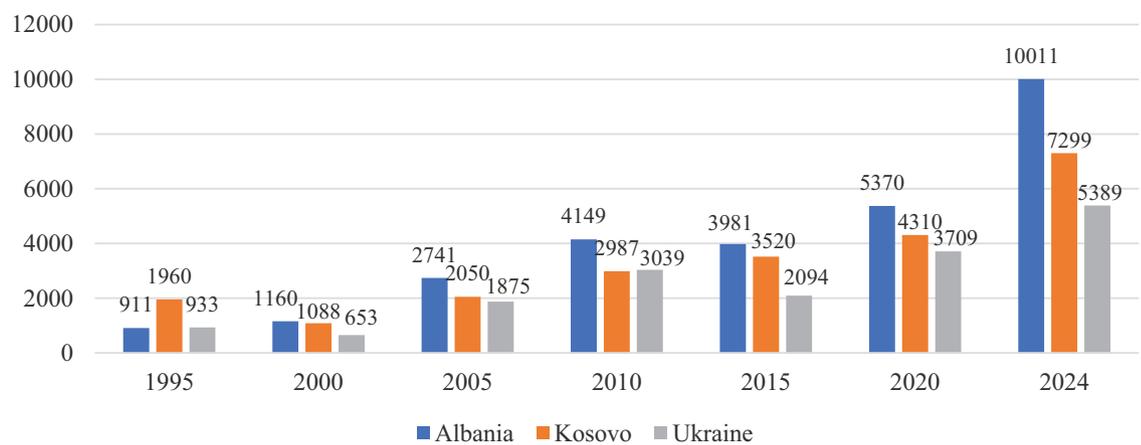


Fig 2 | GDP per capita in Albania, Kosovo, and Ukraine from 1995 to 2024, USD (\$)
 Source: Compiled by the authors based on World Bank Group,⁷⁷ data extracted on 15 September 2025.

historical context, geopolitical shifts, and economic priorities. In all three countries, technological progress has been closely linked to external influences and foreign investments. Albania's integration into global networks through EU support and foreign capital accelerated digital infrastructure development and renewable energy projects. Kosovo's post-war reconstruction relied on international aid, emphasizing energy and telecommunications. Ukraine leveraged European cooperation and foreign investment to expand IT outsourcing and develop renewable energy technologies.⁷¹ Across all three, digital transformation and innovation-driven growth have become central: Albania's e-governance reforms and IT sector expansion, Kosovo's digital entrepreneurship boom, and Ukraine's rise as an IT outsourcing hub illustrate technology's role in modernizing economies and generating employment.⁷² Ukraine's focus on cybersecurity and aerospace innovation, however, reflects its strategic response to geopolitical threats.

Technological innovation extends beyond economic growth.⁷³ In Ukraine, wartime conditions have highlighted its importance for digital security, energy independence, and sustaining public services. In Kosovo,

technological development has supported post-conflict reconstruction, with digital infrastructure, renewable energy projects, and e-governance enhancing social trust, service delivery, and institutional capacity. Across all three nations, innovation has promoted social inclusion, improved governance, and environmental sustainability, positioning technology as a multidimensional driver of resilience rather than merely economic modernization.

Geopolitical factors have shaped technological advancement in Albania, Kosovo, and Ukraine.^{74,75} Albania's EU accession funded infrastructure modernization, Kosovo benefited from organizations like the European Investment Bank and USAID, and Ukraine leveraged NATO and EU partnerships to strengthen its digital economy and cybersecurity amid conflict with Russia. Impacts vary: Albania improved public service efficiency, Kosovo fostered youth entrepreneurship, and Ukraine enhanced economic resilience. Success depends on government support, international collaboration, and skilled workforces, though instability and security challenges, especially in Ukraine, remain barriers.

Sectoral trends reflect context-driven innovation.⁷⁶ Albania relies on hydropower, Kosovo on small-scale renewables, and Ukraine on biomass, wind, and solar. Ukraine's precision farming offers lessons for Albania and Kosovo. Digital services are most dynamic: Albania's e-governance, Kosovo's startups, and Ukraine's IT outsourcing and cybersecurity show how policy, investment, and human capital drive transformation.

Technological innovation reshapes social structures. Digital education expands knowledge and skills,^{78,79} while labor shifts widen rural-urban divides. Digital entrepreneurship offers mobility, but marginalized groups risk exclusion. Rapid adoption increases vulnerabilities: Ukraine's IT outsourcing faces geopolitical risks,⁸⁰ and expanding digital ecosystems heighten cybersecurity threats. Renewable energy and infrastructure growth raise environmental and regulatory challenges.

Foreign investments and international cooperation are key drivers, aligning with Josifidis and Supic.⁴ Albania and Kosovo's digital transformation mirrors global trends,^{3,62} while Ukraine's IT sector reflects geopolitical tensions.^{2,63} Renewable energy priorities differ: Albania's hydropower,¹⁷ Kosovo's solar,⁴⁷ and Ukraine's biomass and wind.⁶² Geopolitical influences and global integration, including EU accession and international support, critically shape technological development.⁵ This comparative approach highlights how historical and political contexts uniquely shape innovation and how instability affects innovation-driven growth, particularly in Ukraine.

The framework highlights mechanisms such as technology transfer through foreign investment, institutional reforms enabling innovation, and sector-specific trajectories (e.g., energy and agriculture in Albania, telecommunications and digital services in Kosovo, IT outsourcing and biotechnology in Ukraine). While data show strong associations between technological innovation and growth indicators, the relationship is not strictly causal. Progress often results from the interaction of external funding, governance reforms, and geopolitical shifts. For example, Kosovo's ICT expansion coincided with aid flows and market liberalization, while Ukraine's IT rise was shaped by both integration with Europe and security pressures. Economic modernization also attracts new investment, which reinforces further innovation. Albania's digital economy expanded partly due to EU funds, but improved governance and growth also drew in more capital. These reciprocal effects caution against treating technological change as a one-way driver of transformation. Instead, innovation and modernization reinforce each other through context-dependent feedback loops.

Policy implications

This study emphasises how certain policy measures can help Albania, Kosovo, and Ukraine use technological breakthroughs for sustainable development. The importance of digital governance is highlighted by Albania's achievement in digital transformation;

governments should use AI and digital tools to increase transparency, cut down on red tape, and improve public services. To protect data and draw in international investment, cybersecurity requirements should be in line with EU laws. The expansion of Kosovo, which has been driven by digital entrepreneurship and infrastructure improvements, demonstrates the necessity of spending money on digital services, renewable energy, and technology. Encouraging innovation hubs and startup ecosystems will stimulate entrepreneurship, generate employment, and link regional companies with international markets. As Ukraine develops becoming a centre for IT outsourcing, it is critical to prioritise STEM education and digital literacy. Innovation will be encouraged by funding educational changes and working with global organisations to create a workforce with the necessary skills. Ukraine's IT industry can be further strengthened by encouraging international IT firms to invest in local talent. Finally, in order to guarantee energy security and sustainability, the three nations must place a high priority on renewable energy, promoting private investments in solar, wind, and biomass technologies as well as regional collaboration.

Conclusions

According to the report, although Albania, Kosovo, and Ukraine exhibit comparable trends in terms of digital transformation, renewable energy, and the expansion of the IT sector, their distinct historical and geopolitical backgrounds have influenced their technological advancements. Reforms spearheaded by the EU and foreign investments, especially in renewable energy, have bolstered Albania's digital economy. Foreign aid-funded post-war reconstruction in Kosovo has cultivated environmental and digital technologies. Ukraine's strategic alliances with the EU and NATO have fuelled its advancements in cybersecurity, IT outsourcing, and the generation of renewable energy.

The study emphasises how important international collaborations, government assistance, and foreign investments are to the advancement of technology. Political stability is still a problem, particularly in Kosovo and Ukraine. Among the suggestions include strengthening Ukraine's cybersecurity through international collaboration, extending digital entrepreneurship in Kosovo, and incorporating AI into Albania's public administration. To maintain innovation, STEM education and career training are equally crucial.

However, the absence of long-term socioeconomic data, especially in Kosovo and Albania, limits the study. Future studies ought to concentrate on how the digital revolution will affect employment and social inclusion in the long run. The results highlight how technical innovation can propel political stability and economic modernisation, promoting sustained growth and international competitiveness in economies undergoing transition. Each nation is advised to invest in renewable energy infrastructure, promote

digital entrepreneurship, improve cybersecurity, and integrate AI into the public sector.

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Appendix A**Key characteristics of the studies and MMAT item-level scores**

Study	Method	Outcomes	Sector	MMAT Score
Shkurti, L. & Mustafa, L. ¹	Mixed Methods	GDP growth, employment shifts, digital transformation	Industrial, Digital, Scientific	4
Schneider, B. & Vipond, H. ²	Qualitative, Quantitative	Labor market shifts, automation	Industrial, Digital, Scientific	3
Kaefer, F. et al. ³	Quantitative	Data for societal good, societal changes	Industrial, Digital, Scientific	4
Josifidis, K. & Supic, N. ⁴	Qualitative, Quantitative	Institutions vs. innovation in development	Industrial, Digital, Scientific	3
Dub, A. et al. ⁵	Mixed Methods	Impact of technological change on society	Industrial, Digital, Scientific	5
Gao, Y. ⁶	Qualitative, Quantitative	Cultural heritage in relation to technological innovation	Industrial, Digital, Scientific	4
Maljichi, D. et al. ⁷	Mixed Methods	Trust in healthcare institutions in the Western Balkans	Industrial, Digital, Scientific	4
Hoxha, V. et al. ¹⁵	Mixed Methods	Innovations in digital governance	Industrial, Digital, Scientific	5
Abramovitz, M. ⁸	Qualitative, Quantitative	Technology adoption in less developed economies	Industrial	5
Nelson, R. ⁹	Qualitative, Quantitative	National innovation systems	Industrial, Scientific	5
Pavitt, K. ¹⁰	Qualitative, Quantitative	Sectoral innovation patterns	Industrial	5
Gjoni, M. & Elezi, E. ²⁰	Qualitative	Digital economy development in Albania	Digital	4
Llazo, E. & Neza V. ²¹	Quantitative	SME growth through digital transformation	Digital	3
Tase, M. & Lulaj, E. ³⁶	Quantitative	Impact of perceptions on tourism	Industrial, Digital, Scientific	4
Xhindi, T. ¹⁷	Qualitative, Quantitative	Renewable energy revolution in Albania	Scientific, Environmental	5
Zeneli, M. ²⁴	Qualitative	Cybersecurity standards in Albania	Digital, Scientific	4
Bund, J. & Esteve-González, P. ⁴⁶	Quantitative	Cybersecurity capacity in Kosovo	Digital	5
Murtezaj, I. et al. ⁵⁰	Mixed Methods	Energy sector development in Kosovo	Energy, Environmental	4
Heyets, V. ⁵⁹	Qualitative, Quantitative	Strategic industrial activities in Ukraine	Industrial, Economic	5
Poliakova, Y. et al. ⁶⁰	Quantitative	International IT outsourcing in Ukraine	IT, Economic	4
Chumak, O. ⁶¹	Qualitative, Quantitative	Development of the IT market in Ukraine	IT, Economic	5
Wąs, A. et al. ⁶²	Quantitative	Potential of Ukrainian agriculture's biomass for energy	Agriculture, Energy	4
Sala, D. et al. ⁶³	Quantitative	Renewable energy investment in Ukraine's electric power industry	Energy, Environmental	4
Stavytskyy, A. et al. ⁶⁵	Quantitative, Qualitative	Political and technological factors on foreign investment	Economic, Political	4
Barash, A. ⁶⁶	Quantitative	Employment structure and war impact in Ukraine	Employment, Economic	3
Shveda, N. et al. ⁷⁵	Mixed Methods	Digital transformation under martial law in Ukraine	Digital, Political	4
Shcherban, T. et al. ⁷⁴	Quantitative	Digital transformation impact on Ukraine's economy	Digital, Economic	4
Hoxha, V. et al. ⁴⁵	Mixed Methods	Smart governance components in Kosovo	Governance, Digital	5
Xanthopoulou, P. et al. ⁴⁴	Qualitative, Quantitative	Drivers of digital governance adoption in public administration	Governance, Digital	5
Meha, D. et al. ⁵⁶	Quantitative	Integration of variable renewable energy in Kosovo's coal-based energy system	Energy, Environmental	4
Badallaj, A. ⁴¹	Quantitative	EBRD financing impact in Kosovo	Economic, Energy	3
Voloshina, A. et al. ²⁶	Quantitative	Artificial intelligence in crime counteraction	Technology, Legal	3
Tkach, V. et al. ²³	Quantitative	Development of new environmental monitoring technologies for agriculture	Environmental, Agriculture	4
Mykhailiuk, O. et al. ⁶⁴	Quantitative	EU-Ukraine innovation and investment cooperation	EU Relations, Economic	4

PRISMA 2020 checklist

Section and Topic	Item #	Checklist item	Location where item is reported
TITLE			
Title	1	Identify the report as a systematic review.	Page 1
ABSTRACT			
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	Page 1
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	Page 1
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	Page 2
METHODS			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	Page 2
Information sources	6	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	Page 2
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	Page 2
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	Page 2
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	Page 3
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	Page 3
	10b	List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	Page 3
Study risk of bias assessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	Page 2
Effect measures	12	Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results.	Page 2
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)).	Page 4
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	Page 3
	13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	Page 3
	13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	Page 3
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression).	Page 3
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	Page 3
Reporting bias assessment	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	Page 3
Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	Page 3
RESULTS			
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	Page 3
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	Page 3
Study characteristics	17	Cite each included study and present its characteristics.	Pages 1–18
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	Pages 1–2
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g. confidence/credible interval), ideally using structured tables or plots.	Pages 25–26

(Continued)

Continued

Section and Topic	Item #	Checklist item	Location where item is reported
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	Pages 5–17
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	Pages 5–17
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	Pages 5–17
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	Pages 5–17
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	Pages 5–17
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	Pages 5–17
DISCUSSION			
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	Pages 5–18
	23b	Discuss any limitations of the evidence included in the review.	Pages 5–18
	23c	Discuss any limitations of the review processes used.	Pages 5–18
	23d	Discuss implications of the results for practice, policy, and future research.	Page 17
OTHER INFORMATION			
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	Page 1
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	Page 1
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	Page 1
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	Page 1
Competing interests	26	Declare any competing interests of review authors.	Page 1
Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	Page 1

Source: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ* 2021;372:n71. doi: 10.1136/bmj.n71. This work is licensed under CC BY 4.0. To view a copy of this license, visit <https://creativecommons.org/licenses/by/4.0/>