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RESEARCH AND INNOVATION FOR SUSTAINABILITY TRANSFORMATION – MODERN OUTLOOKS AND ACTUAL CHALLENGES

Bogdan Fleacă¹, Elena Fleacă², Sanda Maiduc³, Ionut Marius Croitoru⁴

^{1,2,3,4} *University Politehnica of Bucharest, Splaiul Independetei 313, 060042, Bucharest, Romania*

*E-mails:*¹ bogdan.fleaca@upb.ro; ² elena.fleaca@upb.ro; ³ sanda.maiduc@upb.ro; ⁴ ionut.croitoru0208@upb.ro

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Abstract. Technology innovations, the expanding digitisation of all sectors and global megatrends are changing how European citizens live, offering huge potential and unique challenges. The concept of innovation has become more general, exceeding the boundaries of research and development, patents, scientific articles and publications. It increasingly includes new business models, social aspects and technical matters for environmental protection. The paper investigates the modern outlooks of research and innovation that represent the ubiquity concerns of Europe facing global competition and striving to maintain its distinctive social model in line with sustainable development. The authors focused on an updated literature review on research and innovation for a sustainability transition. They analysed the political frameworks and strategic initiatives to support certain interventions for promoting the overarching role of innovation toward sustainable development. Through analysing secondary data provided by well-known innovation performance indicators (i.e. Global Innovation Index and European Innovation Scoreboard), different vulnerabilities of the local context (i.e. Romania country) were identified, and relevant improvement measures were emphasised to meet the agenda focused on a transition to sustainability. The findings made a structured contribution to the emerging field of research and innovation for sustainability transformation. They can be valuable for academics, researchers and decisional factors interested in increasing awareness about the EU strategic initiatives in research and innovation as well as some of the challenges of the country's innovation performance.

Keywords: innovation; sustainability; competitiveness; research and development; science and technology

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1. Introduction

The current challenges of global warming, pollution, biodiversity loss, health pandemic, economic migration and ageing, and technological changes in the industry and artificial intelligence require both technological and social innovation. Science, technology, and innovation play a central role in the transformation toward a sustainable future. To this end, a paradigm shift is required, and research and innovation for sustainability (e.g. trans-disciplinary research) must be actively promoted and supported as a common complement to traditional research and development approaches (OECD, 2020).

As acknowledged by OECD (2021), addressing complex societal challenges is a shared responsibility that requires well-designed measures for research and development systems targeting innovations that either generate public goods or have a high potential for knowledge spillovers. In addition, at the local, regional, and global levels, future levels of government support for science, research and innovation will be shaped by societal preferences and the recognition of innovative research as an essential actor in socio-technical transitions to meet the goals of sustainability, inclusiveness, and resilience.

The paper aims to emphasise significant interventions at the European Union level and subsequent state of play in the local context (i.e. Romania country) to decipher structural vulnerabilities and innovation challenges required to meet an agenda focused on a transition to sustainability. The methodological approach consisted of qualitative research using secondary data sources from relevant scientific literature and public sources of information. In this vein, the study commences with an updated literature review on research and innovation for sustainability transition, followed by the analysis of secondary data provided by two trustworthy innovation performance indicators as monitoring tools having international coverage and large applicability in a wide range of industries and business sectors (i.e. Global Innovation Index and European Innovation Scoreboard). Finally, the main improvement needs related to local context were outlined to address country vulnerabilities and to ensure the progress toward sustainability transition.

2. Theoretical background

The concept of innovation has been broadened, exceeding the boundaries of research and development, patents, scientific articles and publications. The understanding has become more general, including new business models, social aspects and technical matters for environmental protection (WIPO, 2022b). In response to global challenges, there is a growing interest in analysing the research and innovation trends focused on sustainable development. Figure 1 depicts the main building blocks enabling research and innovation systems to contribute to transformation for sustainability at the national, regional and European levels.

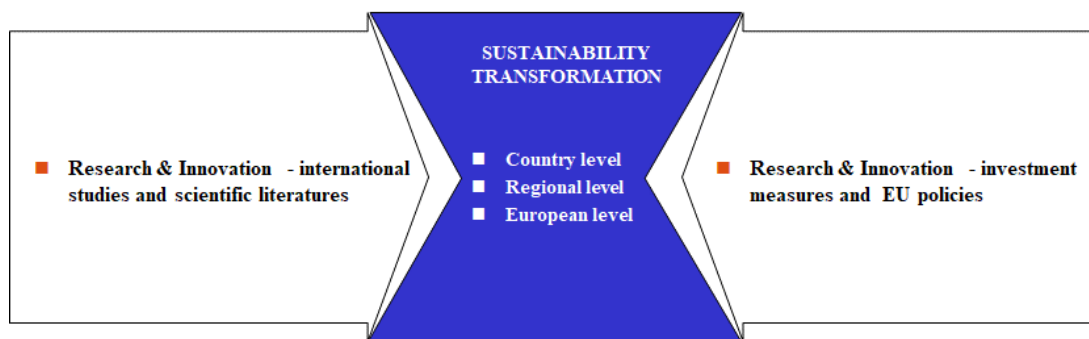


Figure 1. Sustainability transformation and research and innovation systems

Source: The authors' elaboration

2.1. Research and innovation – a catalyst for change

Using a knowledge-based view on innovation, Yu et al. (2017) argued the key role of knowledge creation and technological innovation capabilities (i.e. product and process innovation capabilities) in the process of creating the organisations' sustainable competitive advantage. The findings emphasised the knowledge creation process's insignificant effect on an organisation's sustainable competitive advantage in the absence of fully operationalised technological innovation capabilities. Consequently, the knowledge creation process favours the development of

technological innovation capabilities for processes and products because processes and products can lead to sustainable competitive advantage.

An inspiring attempt was made to connect the innovation process to the idea of responsibility, which entails a continuous dedication to assess the potential benefits and drawbacks of research and innovation in communication with a wide range of stakeholders to produce responsible outcomes. Based on a meta-synthesis of empirical studies, the findings designated the multiple involvements of stakeholders in the late stage of the innovation process, more precisely during the market launch, and provided recommendations for improvement, including the early involvement of users in the innovation process and the extension of the design phase to enable the involvement of stakeholders in the innovation process for responsible outcomes (Silvia et al., 2019).

Other studies investigated the influence of eco-innovation capability in terms of internal setting, strategies, operations and structure on sustainability-driven innovation that mainstream process, organisational and product practices. The results designated the direct and positive effect of eco-innovation capability in triggering a specific type of innovation practice, i.e., sustainably driven innovation which properly integrates the business's economic, social and environmental aspects (Ceptureanu et al., 2020).

2.2. Research and Innovation for Sustainability

In the attempt to capture the influence of innovation factors embedded in an organisation's sustainable development model, Carro-Suárez et al. (2020) measured the statistical correlation between the sustainable development dimensions, as output factors, and the innovation process, as predictors or inputs factors. The results stressed the critical role of technology, knowledge and business market as dynamic factors outside the organisation and culture and organisation as transfer factors which seem essential to a new sustainable organisational culture. Notably, the human element was the ideal way to connect the innovation process and implement the sustainable model.

The concern for the critical role of innovation in the pursuit of sustainability transformation has gained particular emphasis, and researchers directed their efforts to analyse the factors across economic, environmental, and societal systems.

Economic challenges

The economic concern has been studied by plenty of researchers that emphasise the central role of the research and development process in supporting a green economy and quality of life, primarily through policies promoted at the European Union level (Ionescu et al., 2022). In addition, Lüdeke-Freund (2020) introduced the business models for sustainability innovation and studied how business models mediate between sustainability innovations (e.g. new processes, products or services) and business cases for sustainability (e.g. the creation of ecological, social, and economic value). Notably, three relevant business models were distinguished: new business models employing given technologies, given business models taking up new technologies, and new business models triggered by new technologies.

By looking at the whole spectrum of consequences, the scholars noticed that innovation brings new growth opportunities to navigate sustainability transition and disrupts existing practices leading to new or more profound inequalities (Engwall et al., 2021). Other studies introduced the concept of frugal innovation focused on core functionalities, user-oriented design, lower resource intensity, and overall cost minimisation, which is expected to create new market opportunities. Through stakeholders collaboration (e.g. enterprises, universities, knowledge-intensive business services, and research centres) along all stages of the innovation cycle, from its development to adoption or diffusion, the tendency to drive sustainable development outcomes could be increased to a larger

spectrum of results in terms of social sustainability, depending on the type of actors involved and the business models used for the adoption and implementation of the innovation (De Marchi et al., 2022).

Having a systemic approach which transforms the same types of inputs (e.g. knowledge and financial resources) into the same kinds of positive outcomes (e.g. innovative products and services), Ratner et al. (2023) measured the efficiency of national innovation systems in progress toward innovation-based economic growth, especially in the post-Soviet countries. The findings argued that no evidence might support the assumptions that EU institutions or the type of economic model of the country are directly related to the effectiveness of the national innovation system. Instead, the ease of doing business and the protection of investors are most related to the degree of effectiveness, explaining the differences in the performance of different national innovation systems.

Environmental challenges

Regarding innovation for environmental concerns, the scholars highlighted the negative consequences induced by industrialisation and increased consumption, which have contributed to growing the economy at the cost of environmental degradation (Chi, 2022; Zhang & Xie, 2022). In addition, the studies introduced the concept of green innovation as a more inclusive concept of sustainable innovation composed of the development of products and processes resulting in a reduction of environmental impact compared with alternative practices. The findings promoted novel insights into the complexity of the value chain, and several configuration models were proposed to implement this innovation (e.g. systemic innovation technology-independent enterprises). Also, by cooperation to increase efficiency, the organisations may facilitate the implementation of green innovation along the value chain (Abadzhiev et al., 2022).

The role of managers' strategic intelligence and green environmental awareness in elaborating and implementing green product strategies was also studied. As scholars argued, managers with high-cognition strategic intelligence believe that innovation in green product design can better grasp market development trends and consumer needs. Therefore, green products designed and innovated according to consumer demands and market trends can better meet demand and increase market share (Yang & Liu, 2021).

Other findings investigated the interconnections among recent technological progress (i.e. Industry 4.0), innovation, and sustainability implications, concerning understanding the underlying mechanisms and enabling capacities of sustainable innovation. The findings stressed that innovation related to industry 4.0 supported various innovation types (e.g. product, process, organisational) that advanced the concept of the triple bottom line of sustainability, circular economy, sustainable business models, as well as the achievement of sustainable development goals (Khan et al., 2023). Moreover, the current research considered industrial waste and overall energy consumption, revealing the significant gaps in innovation efficiency among EU regions. The findings argued the central role of government environmental protection policies in innovation efficiency, which explained why the northern and southern areas of the EU remain the fundamental forces driving technological innovation in the EU (Xu et al., 2023).

The studies on the role of environmental uncertainty, complexity and regulations emphasised the significant promotion effect on firms' green technological innovation. The increasing uncertainty (e.g. high degree of competition in the industry) motivates firms to carry out green technological innovation, improve the handling efficiency and control ability of luck, comply with the environmental policies to promote enterprises' green technological innovation, maximise the firms market value (Chen et al., 2022). In addition, Li et al. (2022) argued that the firm's green innovation performance depends on its absorptive capacity, which may lead to proactively responding to external policy pressures and internal innovation learning capabilities to accelerate the pace of green innovation.

Social challenges

The innovation for social concerns, seen as a distinct type of innovation, is characterised by a lesser emphasis on political and technological success factors and an increased focus on the positive impact on the quality and quantity of life (Repo & Matschoss, 2019; Haskell, et al., 2021). Notably, human-related factors were considered relevant in predicting innovation outputs providing solutions for many pressing social, economic and environmental issues communities face. The quality of intellectual capital in terms of knowledge, skills, competencies, and involvement in research & development and international scientific collaboration networks were also mentioned as driving factors reinforcing innovation for social challenges (Martinidis et al., 2021).

The concern for innovation as a trigger in the structural changes argued its complicated role within modern development tendencies. Druzhynina et al. (2020) paid attention to the negative impact of innovation on employment by the changing nature of work, automation of tasks and reduction of the current workforce, which may hinder the supporting living standards and progressive socioeconomic state development. In addition, financial rewards and personnel training were outlined as key drivers for expanding innovation capacity, which in turn shape the enterprises' ability to develop better products and positively affect operating performance and profitability (Chin-miel, 2018).

Other studies revealed a close relationship between learning, creativity, and responsible research and innovation (Timmermans et al., 2020). In addition, Schröer (2021) argued that innovation is based on the results of internal learning processes. Individuals, teams, and even organisations learn and engage in creative problem-solving to create new and innovative products and services. In addition, making favourable conditions enabling innovation was linked to the innovation policy in higher education and science, which contributed to creating an innovative environment for transformational change. The findings outlined the critical contribution of higher education in innovation policy due to the mission to research and disseminate knowledge and educate and train qualified specialists (Romanovskyi et al., 2021).

In sum, plenty of scientific literature investigated the threats and challenges of research and innovation for sustainable development. There is a considerable need to ascertain further how current political frameworks and strategic initiatives from international, regional and local levels guide and support certain investments and measures for promoting research and innovation for sustainability transformation.

3. Research and innovation - outlooks of EU policies

Research and innovation in many sectors of the economy reflect the pressing issues facing Europe as it tries to compete while preserving its distinctive social model tied to sustainable development. At the level of strategic decisional factors and bodies, there is an overarching interest in innovation towards sustainable development within Europe and beyond. Addressing the innovation divide across Member States and regions is the leading force that shapes a wide range of strategic initiatives and interconnected development objectives toward accelerating the diffusion of innovation and improved competitiveness. To this end, table 1 presents the blueprint with the main strategic initiatives to support research and innovation performance towards sustainable development at the European Union level.

Table 1. Policy initiatives for innovation and sustainable development - the EU level

Framework & year	Aims & Description
"A Renewed Agenda for Research & Innovation", 2018	Set of actions to create a research and innovation friendly-environment based on: • public and private investment instruments; • a better regulatory framework for innovation; • widening the boundaries of research and innovation; • re-skilling and up-skilling of the workforce; • modernisation of the education system.
"The European Green Deal", 2019	Set of transformative policies with SDGs at the core of policymaking and actions in the areas of: • climate neutrality; • clean, affordable and secure energy; • industry for a clean and circular economy; • energy and resource-efficient buildings; • sustainable and smart mobility; • fair, healthy and environmentally-friendly food system; • preservation of ecosystems and biodiversity; • pollution prevention and a toxic-free environment.
"Competitive Sustainability Agenda", 2021	Promotes a prosperity-focused policy agenda based on four pillars: • environmental sustainability; • productivity; • fairness; • macroeconomic stability.
"A New Europe Innovation Agenda", 2022	Five flagship areas to strengthen the EU's twin transition considering: • growth of deep-tech start-ups; • deep tech innovation for the uptake of innovative new products and processes; • innovation ecosystems across the EU; • fostering, attracting and retaining deep tech talents; • improving the innovation policymaking framework.

Source: European Commission (2018; 2019; 2022a; 2022b)

The Renewed Agenda for Research & Innovation

The ageing population, climate change and security are among the significant societal and industrial issues that Europe's unique innovation model is intended to address (European Commission, 2018). This agenda for research and innovation promoted a set of actions aimed to modernise industry and sustain the social and economic model through innovation which permeates social, economic and industrial decisions. Concrete measures were proposed as reactions to the changing nature of innovation and encouraging collaborations and international investment in research and innovation through:

- Increasing the scale of private and public investment in research and innovation at local, national and European levels for productivity enhancement and competitiveness. Albeit the headline investment target of 3% of GDP (Gross Domestic Product) in Research & Development (R&D) has yet to be fulfilled, it provided a stimulus for EU growth and competitiveness (European Commission, 2022d). In 2020, EU research and development expenditure relative to GDP stood at 2.31 %, higher than in the previous year when it recorded 2.23 %, but lagging China with 2.4%, Japan with 3.26% and the United States with 3.45% (European Commission, 2018; Eurostat, 2022).
- Creating a better regulatory environment for innovation that includes common standards and interoperability guidelines to make it easier for innovative solutions to be adopted and deployed on the market. Additionally,

a careful balance between consistency and adaptability and the assurances of fair competition has been taken into account.

- Widening the boundaries of research and innovation by considering the investments across multiple sectors such as energy and climate, transportation, advanced manufacturing, health and food, digital, scientific fields (including social sciences and humanities), and various players and stakeholders.
- Significant investments in education, training, and research system help with faster knowledge dissemination, reuse, and access and decrease the skills gap.
- Supporting the modernisation of education and public research organisations through cross-border cooperation, increased student, professional, and researcher mobility, and meaningful transnational European knowledge-creating teams.

There is a growing emphasis on addressing the twin challenges of green and digital transformation driven by technological progress and industry 4.0 revolutions which changed the nature of work and raised new business models with embedded digital components (European Commission, 2022d). Thus, the EU's growth model that bundles environmental concerns, reduced inequality, improved well-being, and resilience fully encompassed the research and innovation initiatives and policies as important components of the revolutionary change needed to achieve sustainable futures.

The European Green Deal

Given the complexity and interdependency of economic, social, and environmental concerns, the European Green Deal put forward a set of transformative policies centred on the Sustainable Development Goals (SDGs), which integrate and indivisible balance the economic, social, and environmental facets of sustainable development (United Nations, 2015). As European Commission (2019) acknowledged the, transformational change is foreseen through the set of investment measures aimed to support and accelerate innovation endeavours framed by sustainability concerns in the areas of:

- transforming the economy with the aim of climate neutrality by additional greenhouse gas emissions reductions; as well as a significant increase in sustainable public and private investment to encourage changes in consumer and business behaviour;
- investment in research and innovation projects for renewable energy, circular economy, and efficient buildings;
- attaining sustainable transport by offering more readily available, less expensive, healthier, and cleaner mobility options;
- developing a sustainable food value chain by using novel, creative methods to increase the food system's sustainability (e.g. organic farming, agro-ecology, agro-forestry, etc.);
- improving the legislative framework for better monitoring, reporting, prevention and remedying pollution from the air, water, soil, and consumer products.

The Competitive Sustainability Agenda

An interesting outlook in the attempt to decouple economic prosperity as far as possible from environmental degradation was advocated by the European Economic and Social Committee, which pinpointed the need for a holistic approach to the EU growth model. As the Competitive Sustainability Agenda acknowledges, environmental sustainability, productivity, fairness, and macroeconomic stability are crucial pillars for a fair, green and digital transition, fostering innovation. These pillars are closely interlinked, equally important, and

mutually reinforcing (European Commission, 2022b). In addition, innovation is promoted as a cross-cutting constituent in the attempt to overcome climate change and environmental degradation, enhancing productivity in a fair and prosperity-orientated way by reinforcing people's skills, stepping up training and education, strengthening the transfer and valorisation of knowledge and promoting resource efficiency; strengthening the public finance and the stability of the financial markets for preventing social hardship.

Innovation is also the engine for technological advancement, a green and digital transition transforming how people work, live and communicate. The uptake of cloud technologies, the Internet of things, cyber-security, data analytics, 3D printing, artificial intelligence, robotics and automated machinery become underlying reasons for innovation concerns and investments. Also, given the complex nexus with interrelated socio-technical systems, goals and interests, innovation gained particular importance as the primary source of prosperity and catalyst for change.

The New Europe Innovation Agenda

In the race to enable conditions for research and innovation, the new Europe Innovation Agenda promoted ambitious framework conditions conducive to innovative solutions to critical societal challenges (European Commission, 2022a). It put forward concrete new measures that strengthen the Europe twin transition and improve innovation performance through five flagship areas:

- growth of deep-tech start-ups focused on private capital investments;
- deep tech innovation using public procurement to create local initiatives for a green and digital transition;
- new models of collaboration between public and private sectors for the adoption of new technologies and the spread of innovations;
- training of specialists in fields having high innovation potential to further deployment of these digital technologies across all economic sectors;
- creating a shared understanding of the current status of innovation and the many elements and trends in the European Union.

4. Research and innovation – measurement frameworks

Measuring innovation performance has gained particular relevance in the attempt to thwart research and innovation shortcomings. Various monitoring tools and assessment frameworks support knowledge sharing, sustainability uptake, and leveraging innovation across regions and Member States. These help decisional factors consider practical triggers and boundaries for further innovation endeavours. However, looking at the innovation concern, the current landscape is varied with multiple definitions concerning key terminology and embedded components, which often lead to certain difficulties when comparing innovation performance across countries.

Having an integrative look at innovation, the Global Innovation Tracker assesses the full spectrum of innovation performance from idea inception to impact. It considers four stages of the innovation cycle, which are grounded on relevant triggers for innovation potentials such as science and innovation investments (e.g. scientific publications, R&D expenditures), technological progress and adoption, and socioeconomic impact of innovation in terms of labour productivity, life expectancy, and carbon dioxide emissions (WIPO, 2022a).

Envisioned to capture the innovation status across the world, the Global Innovation Index (GII) was built as a composite indicator including measurements on the political environment, education, infrastructure and knowledge creation of each economy around the globe. The set of seven measurement variables (e.g. institutions, human capital and research, infrastructure, market development, business growth, knowledge and technology outputs, and creative outputs) enables researchers to measure the innovation performance through a wide range of metrics which highlight strengths, weaknesses, and gaps in innovation data. For example, the data revealed that

the United States continues to lead in the number of GII innovation indicators for which it ranks first globally, ranked the highest for 15 of the 81 indicators analysed. Additionally, Europe continues to host the most innovative leaders among the top 25 regions, with a total of 15, while there is a persisting regional innovation gap (WIPO, 2022b).

Having a more regional perspective, another trustworthy monitoring tool pertains to the European Innovation Scoreboard built on 12 innovation dimensions grouped into four categories as follows (European Commission, 2022f):

- framework conditions related to the primary triggers of innovation external to the organisation (e.g. quantity and quality of the workforce, the attractiveness level of research systems, and the level of digital technologies);
- degree of investments for research and innovation, the level of private investments, and the use of information technologies;
- innovation in the business sectors that stand for the share of products and business process innovators, the degree of collaboration for innovation capabilities, and the intellectual assets generated by the innovation process;
- impacts of innovation on employment, economic activities, and environmental sustainability.

Worthy, both monitoring tools used for assessing innovation performance (i.e. Global Innovation Index and European Innovation Scoreboard) integrate critical economic, social and environmental indicators in such a way as to measure the progress towards sustainable development. This may provide a better understanding of differences between countries struggling to foster research and innovation for better sustainability performance.

In sum, to respond to the new geopolitical challenges posing uncertainties of economic and social development at the global and European levels, the innovation concern is put at the centre of political initiatives and measurements towards sustainability transformation.

5. Research and innovation – local challenges

Albeit measuring the innovation performance is challenging, the EU growth model depends on the capability of each Member State to overcome the shortcomings of productivity and competitiveness through adequate measures for sustaining innovation. These points out the necessity of investigating the state of play in the local context to better understand substantial threats and opportunities of innovation for sustainable development.

The analysis of Romania's progress on sustainable development revealed a series of structural vulnerabilities from high regional disparities in terms of productivity, investments and employment gaps. Figures demonstrate that productivity (69%) was below the EU average, with significant regional heterogeneity and a lack of essential resources, including transportation infrastructure, highly skilled people, and high employment levels in high-technology sectors and R&D spending (European Commission, 2022c). Also, Romania is well below the EU average regarding resource productivity, which measures how effectively the economy uses natural resources to create wealth and had the lowest level in the EU in 2020. The public expenditure on R&D as a percentage of GDP has decreased from 0.28% in 2010 to 0.19% in 2020 whilst the business expenditure shows a slight increase from 0.18% to 0.28%. Several improvements were noticed in environmental sustainability (e.g. Zero hunger- SDG2; Industry, Innovation, infrastructure-SDG9; Clean water and sanitation-SDG6; Sustainable cities and communities-SDG11; Climate action-SDG13; Life on land-SDG15.) whilst the poorest performance level was for responsible consumption and production-SDG12.

Romania has done well in employment and growth; between 2015 and 2020, its long-term unemployment rate was reduced by half, bringing it to 1.5% from 2.4%, below the EU average. However, it also demonstrates low public spending on R&D (0.47% in 2020 vs an EU average of 2.32%), which impacts the development of patents and industrial capabilities. In contrast to the EU's overall growth over the previous five years, tertiary educational accomplishment (at 24.9% in 2020) is also dropping (European Commission, 2022c).

Looking at the overarching role of innovation, the Global Innovation Index ranked Romania in the upper middle-income group with an overall innovation score of 34.1 out of 100 points (49th place out of 132 countries), having a performance innovation level below expectations. There are considerable countries differences, with top performers as Switzerland (64.6 pct.) and the United States (61.8 pct.), while Romania is lagging behind other EU countries such as Slovenia (40.6 pct.), Hungary (39.8 pct.) and Bulgaria (39.5 pct.), facing weaknesses in terms of policies for doing business, entrepreneurship policies and culture, percentage of firms offering formal training as well as the lack of global corporate R&D investments and venture capital investors. However, when considering the country's performance by income group, Romania is the top-ten performers in its group, ranked in 8th out of 36 countries, followed by Brazil and Serbia (WIPO, 2022b).

Alongside this, the European Innovation Scoreboard placed Romania in the emerging innovators' group together with Bulgaria, Croatia, Hungary, Latvia, Poland, and Slovakia, having an overall performance level of 32.6% in 2022, below 70% of the EU average (European Commission, 2022f). The high-level analysis revealed that innovation is below the average of this group of innovators (50.0%). Despite some progress in increasing the performance innovation rate, Romania performance gap with the EU is becoming larger.

A detailed analysis is needed to ascertain further the relative strengths and weaknesses of the country's performance to fully comprehend particular difficulties involved in driving the twin green and digital transition and enhancing social and economic resilience. In this regard, table 2 shows performance scores by country level, measured relative to that of the EU in 2022.

Table 2. Romania's performance innovation scores

Innovation category	Performance score relative to EU in 2022	Performance change relative to EU between 2015-2022
Human resources	19.2	- 24.2
Attractive research systems	35.5	19.0
Digitalisation	86.7	12.7
Finance and support	29.5	3.7
Firm investments	12.2	- 6.5
Use of information technologies	13.0	3.3
Innovators	4.6	6.5
Public-private linkages	7.4	- 1.4
Intellectual assets	32.7	5.6
Employment impacts	8.0	0.0
Economic impacts	69.3	7.7
Environmental sustainability	45.6	- 14.4

Source: European Commission, (2022f)

The relative strengths of the country seem to be digitalisation, with the highest composite score of 86.7 followed by the economic impact of innovation scored at 69.3. The relative weaknesses of the country are the innovators' pillar with the lowest combined score of 4.6 composed by enterprise product innovation scored at 6.7 vs. the EU

average of 27.00 and business process innovators scored at 5.3 vs. the EU average of 41.6. Worryingly, the country is lagging behind the EU average for both innovation triggers. Another chronic difficulty comes from the linkage performance having a low composite score of 7.4 formed by the innovative collaboration of enterprises with the value of 1.5 vs the EU average of 11.7 and public-private co-publications scored at 53.9 vs the EU average of 133.8 (European Commission, 2022f).

In conclusion, Romania has the lowest rate of innovation in the EU. Despite a slight gain in GDP of 0.5% in 2017, the total R&D intensity declined to 0.47% of GDP in 2020, maintaining significantly below the initial aim of 2%. Moreover, the 2021 Eco-Innovation Scoreboard, which assessed resource efficiency outcomes, socioeconomic conditions, eco-innovation inputs, activities, and outputs, also identified other structural weaknesses. Romania scored 71, placing it in 24th place on the "2021 Eco-Innovation Scoreboard", indicating the need to increase its eco-innovation efforts (European Commission, 2022e).

Discussions

The results of this research stress the need to overcome the shortcomings of productivity and competitiveness through adequate measures for sustaining innovation at the local and regional levels, primarily through effective policy instruments for sustainability transition (Miedzinski et al., 2022). Additionally, the investments in product innovation and business process innovators may take advantage of open innovation practices (e.g. sharing innovation free of charge), which may contribute to the diffusion of innovation, and inclusive, social, and responsible innovation, enabling sustainable path creation for sustainability transitions (Costa & Matias, 2020; Eppinger, 2021; Priyono & Hidayat, 2022).

The findings are consistent with other research in the field and highlight structural vulnerabilities in terms of underdeveloped investments and lack of adequate measures which hamper Romania's innovation performance. Addressing the interdependency of economic, social, and environmental concerns for sustainable growth requires specific changes to support the progress toward sustainability innovation, and appropriate attention shall be paid to counteracting measures at the country level, such as:

- a) Increasing public support for private research and development to reinforce the collaboration between academia – public research, and businesses;
- b) Steeping up science-business cooperation by increasing the public-private scientific co-publications as a share of total publications;
- c) Strengthening the performance of the public research system through better working conditions and career prospects for researchers and increasing the investment in public science, including sustainability innovation outcomes;
- d) Increasing the investments in education and training to foster research and innovation projects, public and private networks, dissemination of innovation knowledge, and decreasing the creativity and critical thinking skill gaps.

Finally, it is essential to understand that research and innovation capabilities contribute to the competitiveness of a country. Designing appropriate measures to enable incremental improvements in the path of sustainability transformation may involve public investment support, development of research projects through university – industries cooperation, innovation cluster development for achieving innovation outputs as well as more social innovation projects (Novillo-Villegas et al., 2022; Nagy & Somosi, 2022).

In this view, especially in Romania's context, a set of measures and investment interventions are critical to keeping pace with the EU innovation performance trends in all sustainability dimensions (economic, social, and environmental concerns) which require the integration of specific sustainability objectives in the policy areas related to national research and innovation system (Baldassarre et al., 2020). It is also critical to stimulate

interregional linkages, improve dialogue between innovation policymakers and other policy domains, enhance cooperation between business and research, and improve the research system to generate relevant research and knowledge ecosystems (Kivimaa, 2022).

Conclusions

Given the unprecedented challenges for sustainable transformation, there is increasing interest at all levels to enhance the innovativeness and competitiveness solutions to support the twin transition through investments in innovation, technological advancement and increased socioeconomic effect of innovation. The future economic growth at the European Union level depends on the capacity to leverage innovation across regions through a set of regulatory packages to improve the national research and innovation system's management for mobilising public research funding and infrastructure as well as investment packages to support international cooperation and links between academia and other private sectors.

The study aimed to fill the knowledge gap in the innovation trends in the light of sustainable development concerns. It can be valuable for academics, researchers and decisional factors interested in increasing awareness about the EU strategic initiatives in research and innovation as well as some of the long-run challenges related to the country's innovation performance.

The novelty of the research relies on the structured analysis of the implications of current research and innovation endeavours on the sustainability transition. It contributes to enhanced dialogues between scholars from different specialisations and disciplines and between decision-making factors responsible for innovation performance in three areas, i.e. economic, environmental and social outcomes. Our findings add to a growing body of scientific literature on the role of political frameworks and strategic initiatives in pursuing innovation toward sustainable development. The paper's original aspects are provided by identifying local vulnerabilities linked to innovation performance indicators, which may contribute to the early identification of suitable improvement measures to meet the agenda focused on the transition to sustainability.

Also, the paper has managerial implications supported by several recommendations for actions at the individual level for those academics, researchers and decisional factors which are willing to foster research and innovation on multiple levels and dimensions (i.e. economic, environmental and social aspects), becoming active agents of change in the transformation towards sustainable development.

However, the paper still needs to improve regarding a limited number of political frameworks and strategic initiatives selected for analysis. Further research is required in order to expand the scope of strategic initiatives and to include additional values for the country's performance scores which can deepen the knowledge of local improvement measures in the pursuit of research and innovation for sustainability transformation.

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Author Contributions: Conceptualisation: B.F, E.F., S.M.; methodology: B.F, E.F., S.M., I.M.C; data analysis: B.F, E.F., S.M., I.M.C; writing—original draft preparation: B.F, E.F., S.M., I.M.C; writing; review and editing: B.F, E.F., S.M., I.M.C; visualisation: B.F, E.F., S.M. All authors have read and agreed to the published version of the manuscript.

Bogdan FLEACĂ is associate Professor at the Faculty of Entrepreneurship, Business Engineering and Management (FEBEM), University Politehnica of Bucharest (UPB), Romania; Ph.D. in Industrial Engineering. Research interests: Quality 4.0 and management standards; business productivity; innovation & process optimisation; education and sustainable management system; sustainability in Higher Education.

ORCID ID: <https://orcid.org/0000-0001-5469-0885>

Elena FLEACĂ is professor at the Faculty of Entrepreneurship, Business Engineering and Management (FEBEM), University Politehnica of Bucharest (UPB), Romania; Ph.D. In Industrial Engineering; Doctor habilitate in Industrial Engineering. Research interests: business analysis; innovation and process improvement; project management processes; sustainable development in higher educations; standards for sustainability reporting.

ORCID ID: <https://orcid.org/0000-0002-7828-2330>

Sanda MAIDUC is researcher at Department of Management for Scientific Research Activities, University Politehnica of Bucharest, Romania; Ph.D., economist; specialised in Entrepreneurship and Intellectual Property. Research interests: creativity, innovation and entrepreneurship, sustainable entrepreneurship, employment relations and organisational climate, organisational creativity and innovation including learning in the workplace, motivation and work environment.

ORCID ID: <https://orcid.org/0000-0002-8801-1091>

Ionut Marius CROITORU is teaching assistant at University Politehnica of Bucharest, Romania; Ph.D., economist; specialised in European studies and European Project Management. Research interests: project management, innovation and research, efficiency of investments, financial management and public procurement, entrepreneurship and innovation.

ORCID ID: <https://orcid.org/0009-0007-1290-6394>

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