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SUSTAINABLE DEVELOPMENT IN THE SPACE ECONOMY: CONCEPTUAL FOUNDATIONS AND FUTURE CHALLENGES

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Abstract. The purpose of this study is to provide a comprehensive analysis of the conceptual foundations of the formation and development of the space economy in a global dimension, to determine its contribution to sustainable development, and to identify the key challenges that may constrain this process in the future. *Methodology.* The research methodology includes: the application of a systemic approach to defining the conceptual foundations and categorical framework of the examined phenomenon; identification of development trends in the space economy at the level of global actors and, specifically, the European Union and its competitiveness in this sector, which involves the use of statistical analysis of official data, comparative methods for cross-country benchmarking, and content analysis of analytical and academic sources to assess and determine developmental trajectories; an assessment of the orientation of the space economy towards sustainable development through frame analysis, which enables the identification of boundaries for the integration of sustainable development goals into the sector's evolution; and predictive analysis to evaluate future directions of growth and potential barriers. *Results.* The study systematizes approaches to defining the concept of the space economy, distinguishing resource-based, structural, responsibility-oriented, goal-oriented, and balanced approaches. It identifies the stages of global development of the space economy, namely: the emergence of the space sector under government leadership (1950s–1960s); the commercialization of space activities through public–industrial partnerships (1970s–2000s); the "New Space" stage characterized by the interaction of entrepreneurship, state, and industry (2000s–2022); and the stage of renewed international competition in space technologies and exploration at the state level (from 2022 to the present). The findings reveal that technological and scientific advances in the space economy facilitate the implementation of sustainable development goals within the EU, supported by the modernization of the sector's regulatory framework. Moreover, during the period 2010–2024, investment volumes and industry sales exhibited steady growth despite crises in global and national economies, with the EU space economy demonstrating particular resilience. This suggests that the sector is currently in the growth stage of its life cycle. The research also outlines a set of threats and risks to the development of the EU space economy, the mitigation of which will strengthen its competitive position in the global market. *Practical implications.* The recommendations developed in this study may serve as a foundation for programmatic frameworks of global partnerships as well as partnerships at the level of Ukraine and EU space economy stakeholders. *Value/originality. T*he scientific novelty of this study lies in the advancement of the conceptual foundations of the space economy and in identifying the specific features of its evolutionary, economic, technological, and organizational development, with particular attention to its role in fostering the achievement of sustainable development goals.

Keywords: sustainable development goals, space economy, space-for-Earth, space-for-space, competition, public and private financing.

JEL Classification: L16, L78, L88, L89, O13, O14, O19

1. Introduction

The development of the space economy facilitates the emergence of services and products that are critical to numerous sectors of socio-economic life. Technologies developed by actors in this sector are employed for data transmission and communication in regions lacking terrestrial infrastructure. Navigation systems provide precise object positioning, while space technologies deliver accurate data on

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changes in the Earth's surface, atmosphere, and aquatic biodiversity – information essential for the implementation of "smart" management systems across various industries, including agriculture (Goel and Vishnoi, 2025).

In recent years, space technologies have also played a pivotal role in strengthening national security and defense. The demand for military satellites – used for early warning systems, intelligence operations, and navigation – has significantly increased. The further advancement of such technologies depends on progress in space science and the commercialization of innovative developments. Satellite design and deployment have become integral components of national security strategies in many countries, a trend accompanied by intensified global competition (Racionero-Garcia and Shaikh, 2024).

As with any sector of the economy in the twenty-first century, the space economy is closely interlinked with the strategic objectives of individual states and the global economic system in the implementation of the Sustainable Development Goals (SDGs), as established by United Nations frameworks and endorsed at both national and corporate levels. Due to its innovative character, this sector provides a wide range of technological solutions that support sustainable development across industries and infrastructures. At the same time, the activities of space economy stakeholders in outer space require recognition and adherence to a broad spectrum of commitments that ensure the realization of the SDGs in environmental, social, and economic dimensions. The evolution of the Industry 5.0 paradigm further underscores the necessity of clearly recognizing, across all sectors, the responsibilities of stakeholders, nations, and the global community in terms of sustainable development.

Given that the contemporary development of the space economy constitutes a major driving force of sustainable progress in other sectors and significantly impacts society, the study of its conceptual foundations, indicators, challenges, and prospects emerges as a crucial field of modern scientific inquiry, underscoring the relevance of this research.

The aim of the present study is to provide a comprehensive analysis of the conceptual foundations of the formation and development of the space economy in the global dimension, to assess its contribution to sustainable development, and to identify the key challenges that may constrain this process in the future. To achieve this aim, the following research objectives have been established:

1) to trace the evolution of approaches to defining the concept of the "space economy" and the frameworks of space-for-Earth and space-for-space;

2) to examine current trends in the development of the space economy in the global context and at the level of the European Union (through its space programs in ensuring competitiveness), and to evaluate the link between the space economy and the Sustainable Development Goals;

3) to identify the main risks and threats arising from the expanding scale of commercial space activities.

2. Literature Review

Conceptual Foundations of the Terminology of the Space Economy

The conceptualization of the space economy is necessary for defining its content and key components, which are used as evaluative elements in the comprehensive analysis of the sector's condition. To this end, we turn to the identification of approaches to the characteristics and interpretation of the term space economy and related concepts.

Some scientific studies define the space economy in the context of a resource-oriented approach. For instance, Yolusever (2025) conceptualizes the space economy as a complex that encompasses a range of activities aimed at scientific exploration and the commercial utilization of resources located in outer space, contributing to the transformation of the global economy through the innovative potential associated with this sector. This interpretation emphasizes that the space economy represents a domain enabling the use of space resources. The author also rightly underlines that the effective development of the space economy in the twenty-first century requires clearly defined economic, technological, and institutional frameworks conducive to sustainable development. Accordingly, the researcher's focus on establishing such frameworks reflects the orientation of contemporary scholarship toward the integration of sustainable development into all economic sectors, thereby indicating the adoption of a responsibility-oriented approach.

A structural approach to defining the space economy can also be identified in the literature. In this context, Lionnet (2021) characterizes the sector as functioning within three segments based on traditional economic categories: the supply segment (market operators of the space economy), the demand segment (needs of actors from various industries and infrastructures), and the induced markets segment (goods and services generated by the space economy). Scholars such as Kulu (2023) and Pietrzak (2025) support this perspective but stress that the induced markets segment is still in its formative stage. Furthermore, the supply segment may undergo transformation towards the consolidation of corporations and enterprises engaged in the creation and production of space economy goods and services, together with actors in the consumer market (state customers and the business sector).

Another approach considers the space economy in terms of its developmental goals (the goal-oriented approach). Denis et al. (2020), Punnala et al. (2024), and Weinzierl (2018) interpret the space economy as a distinct industry that has emerged as a result of the commercialization of space research, the introduction of regulatory and programmatic frameworks, institutionalization, and the establishment of state-business partnerships to promote space development. Although these authors recognize the contribution of the space economy to the growth of key national industries (space-for-Earth), they emphasize that the sector primarily targets the space-for-space paradigm. Their arguments also align with an evolutionary perspective, as they highlight that the space economy became an independent field due to legal, institutional, and organizational transformations. Nevertheless, a purely space-for-space orientation in conceptualizing the space economy appears somewhat restrictive, as it does not fully capture the multifaceted nature of its development. The goal-oriented and resource-based approaches are interdependent, since the realization of the objectives of space economy actors would be impossible without space resources.

In the context of the resource–goal-oriented approaches, the OECD (2022) defines the space economy as full-cycle activities involving the utilization of space resources, aimed at generating benefits and creating value for humanity in the processes of research and management of outer space. This definition incorporates both the resource-based and goal-oriented approaches and is formulated from the perspective of the space-for-Earth paradigm.

Taking into account the generalizations and the inherent debates within these approaches, we propose the following authorial definition: the space economy is a domain that has evolved from a sector associated with national and international space research – historically shaped by global competition – into a distinct industry. Its emergence has been driven by regulatory, institutional, organizational, and technological transformations, as well as by the involvement of a wide range of stakeholders (states, space agencies, industry, business actors, and private investors). It is directed towards research activities, the utilization of space resources, and the creation and implementation of sustainable development goals (environmental, social, and economic), thereby ensuring the continuity of life both on Earth and in outer space. This definition integrates elements from the resource-based, structural, goal-oriented, and responsibility-oriented approaches and emphasizes the necessity of embedding sustainable development frameworks into space exploration. Moreover, it balances the space-for-Earth and space-for-space paradigms.

Table 1 presents a systematization of the main approaches to defining the essence of the space economy.

Table 1

Approaches to the Interpretation of the Concept of the Space Economy

Approach	Characteristic
Resource-based	The space economy is defined as a sphere that provides opportunities for the utilization of space resources
Responsible	The development of the space economy is considered through the lens of the Sustainable Development Goals (environmental, social, and economic dimensions)
Structural	The phenomenon is characterized in terms of its structural components: the supply segment, the demand segment, and induced markets
Goal-oriented	The concept is examined in the context of the strategic objectives of the space economy
Balanced	Emphasis is placed on the need to reconcile the space-for-Earth and space-for-space concepts

Source: compiled from (Denis et al., 2020; Kulu, 2023; Lionnet, 2021; OECD, 2022; Pietrzak, 2025; Punnala et al., 2024; Weinzierl, 2018; Yolusever, 2025)

An emphasis on the defined approaches serves as a prerequisite for assessing the state of the space economy in terms of its key features. The emergence of new characteristics of this concept may, in our view, occur in the case of further social, technological, and economic transformations.

3. Methods

The research methodology includes:
– the application of a systems approach to defining the conceptual foundations of the categorical framework of the phenomenon under study;
– the identification of development trends in the space economy at the level of global players and within the EU, with particular attention to its competitiveness in the sector. This direction involves the use of statistical analysis for the evaluation of official data on industry development, the comparative method for juxtaposing indicators, as well as content analysis of analytical and scientific materials to determine development tendencies of the space economy;
– the assessment of the orientation of space science toward sustainable development, carried out through frame analysis, which makes it possible – on the basis of analytical and scientific data – to establish the scope of integration of the Sustainable Development Goals into the formation of the sector;
– the use of predictive analysis, which made it possible to evaluate development trajectories and barriers in the sector.

4. Result and Discussion

4.1. Development of the Space Economy: Global and European Dimensions

The formation of the space economy has gone through several system-forming stages, the study of which is necessary to assess the prerequisites for the emergence of current development trends in the sector. The systematization of scientific and analytical approaches has made it possible to establish a list of stages in the creation of the space economy at the global level (Table 2).

We will analyze the dynamics of the global space economy for the period 2010–2024 (Figure 1) and examine the trends in its development at the current stage.

As the results show (Figure 1), during the study period there was steady growth in the global turnover of the space economy. This indicates that, at the current stage, the sector – driven by continuous technological progress – is in its growth phase.

The structure of funding sources formed as a result of 2020 and 2024 (Figure 2) confirms our statement that the current stage of the global space economy is characterized by the return of state involvement in financing the sector and by intensified competition among participating countries.

Since this study focuses on the state of the EU space economy, we will assess the dynamics of its key indicators and the factors behind their changes.

The share of the EU in global financing of space economic activities was as follows (The European

Table 2
Stages of the development of the space economy at the global level

Stage	Characteristic
Emergence of the space sector under government leadership (1950s–1960s)	This stage corresponds to the Cold War period and is associated with technological and space races. Key players: USA, USSR. A period of initial exploration and early research of outer space. Source of funding for space programs – state budgets
Commercialization of space activities through government–industry partnerships (1970s–2000s)	The creation of new space programs involving major industrial companies, and the commercialization of space projects aimed at developing technologies required for the needs of various sectors
"New Space" stage (entrepreneurship–government–industry) (2000–2022)	Emergence of start-ups engaged in the creation of new technological solutions in the field of the space economy. Continued reliance on government funding alongside R&D investments from major corporations.
Stage of renewed international competition in the creation of space technologies and exploration (from 2022 onwards) (author's contribution)	Despite the growing role of private capital and actors, international competition between states in mastering outer space in the economic sphere is being revived (including the use of technologies and solutions for military and defense purposes).

Source: compiled from (Punnala et al., 2024; Walter, 2022)

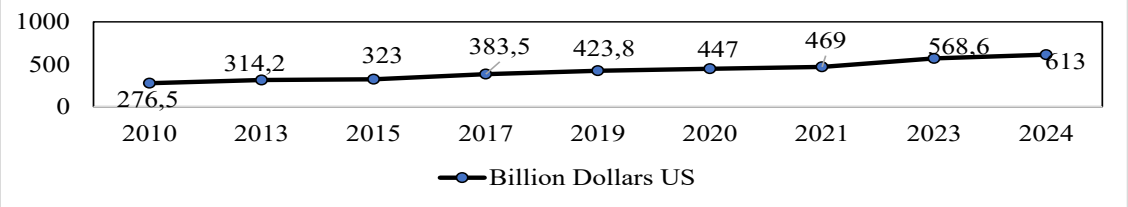

Figure 1. Dynamics of the global space economy volumes

Source: based on (Space Foundation, 2025; Statista, 2025)

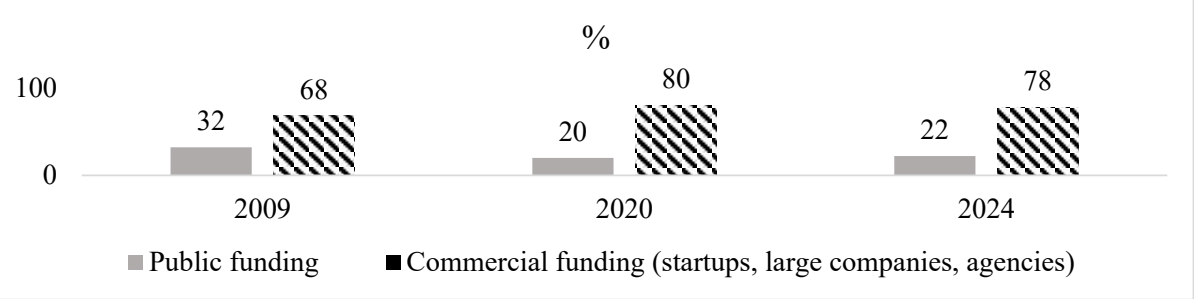

Figure 2. Structure of funding sources of the global space economy

Source: based on (Space Foundation, 2009; Space Foundation, 2025; Statista, 2025).

Space Agency, 2025): in terms of public funding: 10% in 2024 (equal to €12.6 billion, 2% higher compared to 2023); in terms of private financial contributions: 22% in 2024 (€1.5 billion, 56% higher compared to the previous year).

Although private funding of the sector is growing at a rapid pace, in absolute terms public funding remains dominant, also showing stable growth rates. This supports our assumption that both the global community and the EU have entered a new phase of the space economy (the stage of renewed international competition in the creation of space technologies and exploration, starting from 2022).

We will now examine the structure of the main segments and actors of the EU space economy as it has developed at the current stage.

It can be stated that, during the studied period, the largest volume of capital expenditures from public funds was allocated to the Military Observation segment, while private funds were primarily directed toward Civil communications.

Next, let us analyze the structure of sales of products (services) by the main space programs operating in the EU space economy as of the end of 2024 (The Space group in ASD, 2025): 1) Commercial programmes (Europe): volumes ranged from €1,500 million (current e.c.) in

Table 3

Structure of capital expenditure financing in the EU space economy, 2020-2024

Funding sources	Volume by segments, € billion										Total, € billion
	Civil communications	Other civil programmes	Human spaceflight	Space science and exploration	Civil observation	Civil GNSS	Military (other)	Military GNSS	Military Observation	Military communications	
Government funded	12	5	43	30	30	2,5	12	7,5	91	19	252
Privately funded	33	3	1	0,6	8,5	0,1	0,1	0,1	0,1	1,5	48
Total	45	8	44	30,6	38,5	2,6	12,1	7,6	91,1	20,5	300

Source: compiled from (The Space group in ASD, 2025)

2010 to €800 million in 2023; in 2024 they increased to €900 million (programs focused on Civil observation and Civil communications services); 2) Eumetsat Programmes: volumes ranged from €125 million in 2010 to €140 million in 2024 (satellite observation services for climate change and disaster forecasting, applied in sectors such as agriculture); 3) National Military Programmes: volumes increased from €480 million in 2010 to €1,000 million in 2024 (military warning, satellite communications, and observation services); 4) EU programmes: volumes increased from €400 million in 2010 to €900 million in 2024 (secure communication, navigation, and Earth observation services, essential for climate change mitigation, security, etc.); 5) National Civil Programmes: volumes grew from €600 million in 2010 to €1,150 million in 2024 (satellite communications, observation, navigation, and scientific research services); 6) European Space Agency (ESA) programmes: volumes increased from €1,800 million in 2010 to €3,200 million in 2024. These are the largest in terms of overall EU space programs. This category covers space probes and telescopes for space exploration, as well as satellite observation and communications services. Such services are used for geology, astrophysics, and various economic sectors (including agriculture). ESA programs enhance the EU's competitiveness in the global space economy. Their functioning, supported by research and development, is also directed toward space advancement, including within the framework of sustainable development.

4.2. Sustainable Development of the Space Economy

The formation of the EU space economy at the present stage is taking place under the course of the Member States and the Community as a whole towards achieving the Sustainable Development Goals (SDGs) in the environmental, social, and economic spheres. The EU has two programmatic documents that confirm its initiatives in establishing and implementing sustainable development goals in economic activities in outer space (European Commission, 2025):

1) Vision for the European Space Economy (adopted and published on 25 June 2025). This programmatic document aims to establish the strategic aspects of achieving EU leadership in the global space economy. It covers measures for the development of both existing and new activities (including resource extraction and utilization in outer space). The document is primarily focused on technological, innovative, and economic dimensions of sustainable development. It also defines the characteristics of the ecosystem underpinning the EU's future leadership in the global space economy;

2) EU Space Act (25 June 2025). This legislative act aims to harmonize the EU regulatory framework in the space economy sector (prior to 2025, there were 13 regulatory documents, which created challenges due to inconsistencies among them). The Act sets out the conditions and requirements for space activities, simplifying access for small and medium-sized enterprises and startups, which, through innovation, can contribute to the sector's development. Within this legislative framework, three strategic orientations have been established: Resilience, Safety, and Sustainability. The Sustainability orientation focuses on fostering sustainable development in the EU by leveraging the opportunities and resources of the space economy. It provides for the following:

– in the context of SDG 7 (Affordable and Clean Energy): monitoring through satellite technologies and implementing measures to reduce the negative impacts of renewable energy market participants on biodiversity and the environment (including addressing the issue of bird mortality caused by wind power plants, threats to the welfare of other wildlife and flora); development of renewable energy projects in outer space; and protection of outer space from debris and byproducts of space operators' activities;

– implementation of SDG 9 (Industry, Innovation, and Infrastructure): creation and operation of innovative infrastructures (networks of EU enterprises, including startups) capable of realizing circular projects, thereby enhancing the innovative competitiveness of the EU space economy;

– Orientation towards SDG 13 (Climate Action): strengthening infrastructure for orbital climate monitoring to serve the needs of various sectors (including agriculture), and SDG 15 (Life on Land): monitoring biodiversity on Earth, including forest protection.

Thus, it can be concluded that at the EU level, an effective regulatory framework is being formed to ensure the integration of sustainable development goals into the governance of the space economy

and the activities of its actors (both public and private entities).

4.3. Discussion

The study of the features and directions of the development of the EU space economy allows us to conclude that this sector evolves under the influence of a number of risks and threats. The main ones can be identified across key categories:

1. Economic. Risk of losses may lead to the bankruptcy of EU space economy entities. Inconsistencies among EU member states affect the irregularity of funding, and the absence of a unified approach to mandatory expenditures on space R&D (compared to NATO funding practices) results in an insufficient level of competitiveness on the global market.

2. Environmental. The increased presence of new players, both European and foreign, in outer space entails risks of negative impacts on the space environment. For example, initiatives by certain large private and state agencies in the USA and China aim to implement large-scale space projects and conduct tests (including proposals for nuclear bombardments of Mars, etc.). Given the lack of a globally coordinated sustainable development plan for outer space, the EU cannot significantly influence the decisions of other countries.

3. Social. There is a risk of inequality in access to certain space technologies and products (e.g., satellite communications) due to social gaps within EU countries. This risk may pose a threat in situations where ordinary communication is disrupted by emergencies. There is also a risk of workforce reduction at enterprises operating in the space economy due to bankruptcies or declining profitability.

4. Legal. The absence of globally harmonized legal frameworks regulating relations among space activity entities, including states, creates a risk of conflicts and disputes over space resources. Although the EU harmonizes its own legislation in this field, the implementation of such procedures at the global level is necessary.

5. Technological. Cyber threats to satellites from certain countries can destroy satellite communications and monitoring capabilities. Technology monopolization is also a concern, linked to the imperfections or inefficiency of international law in this area.

Considering these risks and threats is essential for the further functioning of the EU space economy at both the domestic and global levels. It can be assumed that mitigating and countering them will contribute to improving the EU's competitive positions and efficiency in this sector.

5. Conclusions

Based on the results of the study, the following conclusions can be drawn:

1) Global, national, and regional objectives for achieving sustainable development are becoming more attainable thanks to the technologies and resources of the space economy, which represents a distinct sector of the economy. The space economy acts as a catalyst for sustainable development due to its capabilities and activities that support the achievement of goals in this area. The sector's course toward achieving sustainable development goals (economic, social, and environmental) should be balanced and positioned between space-for-Earth (benefit for the Earth) and space-for-space (development of space for future generations and protection of the space environment). This is driven by the need to create a global approach to ensure equitable relations among countries engaged in space research and economic activities in outer space. This direction requires extensive consultations, communications, agreements, and the establishment of international legal frameworks that guarantee the protection of the rights and interests of all participants in this field while promoting the realization of sustainable development goals in the sector.

2) To define and implement security measures that would guarantee the economic rights of investors both within the EU and in other countries, it is recommended to introduce into international law provisions for mandatory audits of projects that pose risks to outer space and its participants. This process requires additional legal regulation and organizational support, but it is essential to enhance the investment attractiveness of space economy projects at present and in the future.

3) Ukraine, which is at the stage of EU accession, and the Community can implement joint projects that support the development of directions and segments of the space economy. These can include public-private partnerships conducting innovative R&D in the creation of new space

technologies and their adaptation in outer space. Ukraine, possessing certain scientific, technical, and technological potential, can carry out innovative developments, while EU space economy entities can adapt them in outer space. Thus, equitable partnerships can promote Ukraine's integration into the global space economy market and strengthen the EU's positions.

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