

Innovative Contributions of Space Research to Other Sectors: Recommendations for Technology Policy Makers

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Abstract

Space research is not only limited to the development of space technologies, but also has the potential to provide innovative solutions to other sectors. This study examines how the technological advances achieved by space research can be transferred to various industries and the role of policy makers in this process. In particular, the innovative contributions of space technologies to strategic sectors such as energy, health, agriculture, communications and defence are discussed and concrete examples of the applicability of these technologies to other fields are presented. In this context, the study provides strategic recommendations for technology policy makers and underlines the necessary steps for sectoral transformation and sustainable growth. Technologies derived from space exploration offer effective solutions in a wide range of fields, from innovative materials to artificial intelligence, from robotic systems to data processing capacity. The study emphasises that policy makers should embrace these innovative solutions provided by space exploration and support sectoral adaptation processes. By creating regulations that encourage the transfer of innovative technologies, policy makers can strengthen cross-sectoral cooperation and accelerate the diffusion of new technologies. Moreover, the establishment of cooperation platforms between the public and private sectors can increase the sharing of technological know-how and contribute to the development of the innovation ecosystem.

1. Introduction

Space exploration, beyond increasing humanity's knowledge, is an important driving force in advanced technology development processes. Technologies developed to solve basic problems such as life in space, exploration and secure communication can find wide application in other sectors.

In innovation and technology transfer processes, the impact of space research on different sectors is increasing day by day (Silva et al., 2019). The challenging conditions encountered in space lead to the emergence of many innovative solutions, from durable materials to advanced data analysis techniques. These solutions not only contribute to the success of space missions, but also to industries on Earth (Neukart, 2024). For example, satellite technologies increase productivity in sectors such as agriculture and energy, while advanced imaging technologies used in medical research bring innovations to the health sector (Pesapane et al., 2018). Technologies developed in space exploration have the capacity to create major transformations in various industries on Earth. For example, solar panels used in the energy sector are a direct result of technologies developed in space (Bermudez-Garcia et al., 2021). Advanced imaging devices used in the healthcare sector were inspired by technologies developed during space exploration (Zang et al., 2015; Dastagiri and PV, 2020). In the field of agriculture, space-

based satellite technologies are being used to increase productivity and promote sustainable agricultural practices (Martos et al., 2021). These innovative solutions show that space exploration is not only an exploration tool but also a source of innovation for the global economy.

The importance of space exploration is not only limited to discoveries, but also has the potential to provide innovative solutions that directly affect the welfare of societies. Technology-generating policy makers play an important role in the formulation of science and technology policies. These policies cover not only the acceleration of innovation and the development of new technologies, but also the transfer and application of these technologies to different sectors (Voulvoulis and Burgman, 2019). The successful transfer of innovations developed by space research to other sectors depends on the strategic moves of policy makers. Their task is to promote scientific research, support the innovation ecosystem and strengthen cross-sectoral cooperation (Shmeleva et al., 2021). In this context, it is important for policymakers to develop incentives and regulations to accelerate the integration process of space technologies into different sectors for sustainable growth and technological transformation.

In line with the above information, the main research question of this study is: 'While the technologies developed in space research offer innovative solutions in strategic sectors, what role should policy makers play in this process and how

can they ensure the effective transfer of these technologies? 'This question emphasizes the applicability of space technologies on a sectoral basis and the importance of policy makers' strategic decisions in this process. By focusing on the innovative solutions provided by space exploration to other sectors, this study develops a unique perspective that provides strategic recommendations for policy makers who produce technology. While providing a new perspective on the economic and industrial impacts of space exploration on Earth, the study aims to be a guiding resource for sustainable development and sectoral transformation by examining the role of policy makers in this process in depth.

2. Technologies and Innovative Applications Used in Space Exploration

Space exploration has been at the forefront of technological advances, and many innovations have arisen from the need to overcome the harsh conditions of space. In particular, great progress has been made in areas such as durable materials sciences, advanced data processing techniques and energy generation. For example, the lightweight and strong materials used in spacecraft have started to be used in the aviation and automotive sectors (Gohardani et al., 2014). Experiments conducted in space have led to the development of new alloys and composite materials. For example, NASA's research on Titanium Aluminide has encouraged the use of lighter and more durable materials in the automotive and aerospace industry (Zhang et al., 2019). In addition, advanced sensor technologies and artificial intelligence play important roles in data analysis and operational processes in space exploration (Bi et al., 2022). Another important technology is the efficient use of solar energy. Making solar panels lighter, more durable and more efficient during space exploration has made great contributions to the energy sector on Earth (Verduci et al., 2022). For example, the solar panels used on NASA's Voyager 1 and 2 spacecraft were designed to withstand the harsh conditions in space. This technology is also used for solar power plants on the earth's surface and is constantly being improved to increase efficiency (Levchenko et al., 2018). The methods of obtaining electrical energy in space have offered new ways for sustainable energy sources on Earth, leading to significant developments, especially in the renewable energy sector. These technologies are widely used worldwide for clean energy production and carbon footprint reduction (Al-Shetwi, 2022).

Robotics and artificial intelligence technologies are another innovative area of space research. The remote control and autonomous operation of spacecraft and robots have inspired the integration of robotic systems, especially in industrial production, health and service sectors (Holland et al., 2021). These experiences gained from space technologies have paved the way for the rapid spread of automation and robotics. These systems, especially supported by artificial intelligence, enable more efficient and effective management of business processes (Pramod, 2022). The health sector has also gained significant innovations from space research. Medical devices and methods developed to solve the health problems faced by astronauts in space have been directly transferred to medical applications on earth. For example, advanced imaging techniques used in space research have initiated a new era in cancer treatment and diagnosis of neurological diseases (Scarpa et al., 2023). Moreover, tele-medicine applications and remote health services have emerged as a by-product of space research (Jeminson and

Olabisi, 2021). Satellite technologies and global communication systems are one of the most common and effective technologies developed in space exploration. Many applications that affect our daily lives, such as GPS, weather forecasting and earth observation systems, are the result of space research (Yazıcı and Darıcı, 2019). The communication and information technologies sector also makes significant gains from space research. Satellite systems used in space have contributed to the expansion and improvement of communication networks worldwide. These technologies are used to increase internet access and accelerate global information flow, especially in developing countries (Rausser et al., 2023). The agricultural sector is another area that benefits from the integration of space technologies. Satellite technologies developed in space are used to increase agricultural productivity and manage natural resources more effectively. Satellite data used in agriculture are used to monitor weather conditions, analyze soil fertility and optimize crop management. This integration contributes to the dissemination of sustainable agricultural practices, especially among large agricultural producers and farmers (Kumar et al., 2024). Furthermore, data processing and artificial intelligence systems used in space exploration are an important source of sectoral solutions based on big data analysis. Finally, the defence sector has the potential to directly benefit from the technological advances offered by space exploration. Satellite-based security systems, robotic technologies developed during space exploration and artificial intelligence-based monitoring systems help to strengthen defence strategies (Rashid et al., 2023). These technologies can contribute to the reshaping of defence policies worldwide by offering new solutions in the field of national security.

2.1. The role of space technologies in sectoral transformation

Sustainable growth requires an approach that does not ignore environmental and social problems while ensuring economic development. In this context, space research helps to achieve sustainable growth targets by providing innovative solutions. Innovative solutions obtained from space technologies, especially in important areas such as renewable energy, water management and agriculture, contribute to the sustainable realization of economic development. In particular, experiments conducted in space have the potential to provide new materials and technologies to industries around the world. For example, materials science experiments conducted on the International Space Station (ISS) have enabled the development of more durable and efficient materials for solar panels. Thin film coating technologies tested in low gravity on the ISS have contributed to the production of longer-lasting and more efficient solar panels for the energy sector on Earth (NASA, 2018). Similarly, experiments in biotechnology in space have revolutionized the agricultural sector. The Veggie Project has not only improved the nutrition of astronauts through research on growing vegetables in space, but has also contributed to the development of agricultural techniques that are resilient to climate change around the world. Such experiments offer innovative solutions that make it possible to achieve higher yields with the use of limited water resources. In addition, high-fidelity water purification systems experiment in space have provided technologies that can be applied on Earth to increase access to clean water in developing countries. Water purification systems developed by NASA are now being used to provide clean drinking water in remote areas (NASA, 2013).

By supporting the integration of these innovations with other sectors, policy makers can accelerate the transformation of industry and pave the way for industrial innovation by providing productivity-enhancing solutions to many sectors with findings from space exploration. For example, organizations such as the European Space Agency (ESA) and the Japanese Space Agency (JAXA) continue to transform sectors such as energy, health and agriculture by sharing the results of experiments conducted in space (ESA, 2022).

The application of technologies obtained from space research in the field of renewable energy is one of the most important components of sustainable growth. In particular, solar energy panels and energy storage technologies have made great progress in space research and these technologies have become widespread on earth (Chel and Kaushik, 2018). For example, energy storage technologies, especially lithium-ion batteries, are important not only for individual users but also for energy infrastructure projects (Omer, 2008). Tesla's energy storage systems were developed to provide uninterrupted power in renewable energy production and increased energy supply security (Aşchilean et al., 2021). Similarly, energy storage systems used in smart grids in Japan have been effective in reducing carbon footprint by reducing fossil fuel consumption (Zhang et al., 2012). These technologies, inspired by battery management systems used in space exploration, make a great contribution to the energy sector. By developing policies that encourage such innovative energy solutions, policymakers can reduce dependence on fossil fuels and increase environmental sustainability. For example, the European Union's "Green Deal" program aims to expand energy storage technologies (European Commission, 2020).

Water management and agricultural technologies constitute another important dimension of sustainable growth. Advanced sensor technologies and satellite data used in space research are being used to increase productivity in agriculture and manage water resources more effectively (Abiri et al., 2023). Farmers in the USA optimize water use by analyzing soil moisture levels and crop growth with data provided by NASA's Landsat satellites (Zaussinger et al., 2019). In some countries in Africa, satellite imaging technology plays an important role in rural development projects (Oshri et al., 2018). These systems increase the productivity of agricultural lands and enable more effective management of water resources. By integrating such innovative solutions into rural development and agricultural policies, policy makers can contribute to solving global challenges such as food security and protection of water resources. For example, the European Space Agency's (ESA) Copernicus program uses satellite data to provide sustainable solutions in the agricultural sector (Schiavon et al., 2021).

Sustainable growth also includes social responsibility and community development goals. Medical devices and telemedicine applications developed in space research improve healthcare services in rural and disadvantaged areas (Asi and Williams, 2018). By integrating such innovative health solutions into national health policies, policymakers can create a development model that extends to society at large. In this context, the application of space technologies for social benefit can strengthen the social dimension of sustainable development.

Space technologies attract attention with their ability to collect and analyze big data. Thanks to satellite systems, large amounts of data are obtained in areas such as transport, climate change and natural disaster management. These data support sectoral decision-making processes, enabling the development of more effective strategies (Sebestyén et al., 2021). By

making regulations to increase the accessibility of space data, policy makers can encourage the use of these data by local businesses and research institutions. In this way, cross-sectoral collaborations are strengthened and innovative solutions can be realized more quickly.

The impact of space technologies on sectoral transformation also manifests itself in the field of labor and employment. Space research leads to the emergence of new professions and specializations (Cooke, 2004). Policy makers should develop training programmes and employment policies to support this change. The creation of new occupational fields related to space technologies encourages young generations to turn towards this field and increases the qualifications of the labor force. In this way, it is possible to provide qualified labor force and increase job opportunities in sectoral transformation processes. Space technologies can serve as a catalyst for transformation not only in its own field but also in many other sectors.

2.2. Challenges encountered in the innovation process and solutions

Many challenges are encountered in the process of applying space technologies in other sectors. One of these challenges is the complex nature of space technologies. An appropriate framework needs to be established to integrate space-derived data into specific industries. To overcome this complexity, policy makers should develop legislation that encourages standardization and harmonization processes. Thus, the integration of space technologies can be realized more smoothly.

Another challenge in the innovation process is the lack of financing. Space technologies are often mega projects that require high costs, making it difficult for private sector players to invest (Denis et al., 2020). Policy makers can facilitate the financing of such projects by encouraging public-private partnerships. They can also support innovative projects by establishing funding programmes for space technologies.

Lack of training and expertise is also an important obstacle in innovation processes. Professionals with the necessary know-how are needed for the application of space technologies in other sectors (Arciénaga Morales et al., 2018). Therefore, policy makers should increase the qualified workforce by improving education programmes related to space technologies. They can also accelerate the flow of knowledge in the sector by establishing collaborations with universities and research institutions.

Technological harmonisation and integration problems are also one of the obstacles to the innovation process. Existing systems in different sectors need to be harmonised with space technologies (Shirowzhan et al., 2020). For example, the integration of energy storage technologies developed in space research into existing electricity grids around the world poses serious technical challenges. Sectoral cooperation and standardisation efforts are of great importance for solving such problems. Policy makers can facilitate integration processes by encouraging sectoral cooperation. For example, the European Union's Horizon Europe programme is developing multi-stakeholder projects to support the integration of space technologies with the energy and agriculture sectors (European Commission, 2021).

Financial challenges are another major barrier to the implementation of space technologies. Space research and development processes often require large investments, which can take time to translate into commercial applications. For example, SpaceX's development of reusable rocket technology was carried out at great cost, but the economic benefits of this

technology only emerged in the long term. Therefore, public-private partnerships should be encouraged, consultancy services and technical support mechanisms should be established to accelerate technology transfer processes and reduce the financial burden (Vance, 2017).

Legal and regulatory barriers are also among the other major challenges faced in the implementation of space technologies. In particular, data sharing and intellectual property rights cause significant problems in this process. For example, national and international laws regulating civilian use of satellite data sometimes restrict the use of these technologies in critical areas such as agriculture and water management. In India, satellite data-based agricultural applications developed by ISRO (Indian Space Research Organisation) were initially used on a limited scale due to regulatory issues (OECD, 2020).

To address such regulatory issues, policy makers can work with sectoral actors to develop more flexible and inclusive regulations. For example, the NASA Technology Transfer Programme in the US has allowed the private sector to adopt technologies developed in space exploration more rapidly by relaxing legal regulations (NASA, 2020).

In conclusion, technological adaptation, lack of financial resources and legal regulations are the main challenges faced in the implementation of space technologies. In order to overcome these obstacles, sectoral cooperation needs to be strengthened, advisory and technical support mechanisms need to be established, and more flexible regulatory frameworks need to be adopted. An active role of policy makers in these processes will ensure that the benefits derived from space technologies reach a wider audience.

2.3. Transferring lessons learnt from the space ecosystem to other sectors

Lessons learnt from the space ecosystem constitute an important resource for innovative applications in other sectors. The experiences offered in areas such as space research, system integration, data management and co-operation inspire sectoral applications. Especially in data analytics and big data management, the space sector offers solutions that can be applied in many areas. The adoption of these experiences by other sectors can accelerate innovation processes. The cooperation and partnership model offered by the space ecosystem can also be a valid strategy for other sectors. Since public and private sector co-operation is of great importance in space research, this model can also be applied in sectors such as energy, health and agriculture to encourage knowledge and resource sharing. Policy makers can contribute to the strengthening of sectoral co-operation by making regulations that support such co-operation.

Lessons from the space ecosystem are also valuable in the field of process management and project management. Space projects are managed under tight timelines and budget constraints. Other sectors can improve the effectiveness of their projects by adopting management strategies from these projects (Garon, 2006). Policy makers can provide guidance documents and guidelines for sectors to adopt such strategies.

The challenges faced in space exploration and their solutions can be applied to other sectors. In particular, difficulties in technology transfer and innovation processes can be overcome by learning from the experiences in the space sector (Shmeleva et al., 2021). Policy makers can organize platforms and workshops to share these experiences. Such events can encourage innovation by increasing knowledge exchange between different sectors. The sustainability-oriented approach of the space ecosystem can set an example for other sectors. Space exploration offers important lessons

on environmental sustainability and resource management. Adopting these lessons can contribute to the development of sustainable practices in sectors such as energy and agriculture. Policy makers can help sectors to reduce their environmental impacts by making regulations that encourage these sustainable practices.

2.4. International co-operation and coordination among policy makers

Space research is an important field that encourages international co-operation. Countries share their experiences in space technologies, develop joint projects and ensure the flow of information. In this context, international co-operation plays a key role for the integration of space technologies into other sectors. Policy makers can benefit from the experiences of different countries by making arrangements to increase co-operation in international platforms.

International co-operation encourages the sharing of knowledge and experience. Co-ordination between countries enables different approaches to come together to identify best practices. Policy makers help this process to become more efficient by creating appropriate platforms for international cooperation (Bull and McNeill, 2019). In particular, collaborative efforts that support the integration of space technologies into other sectors can stimulate sectoral innovations.

Coordination among policymakers is an important factor in transferring knowledge gained in space research to other sectors. Policy makers from different countries coming together to develop common strategies can accelerate sectoral transformation processes (Stone et al., 2020). Such coordination can facilitate the adoption and implementation of space technologies and provide more effective solutions at the global level. International co-operation and co-ordination support the implementation of sustainable solutions obtained in space research in other sectors. Space technologies can promote sustainable development by providing solutions to environmental challenges. Policy makers can ensure the dissemination of these solutions through international co-operation. Thus, the social and environmental benefits of space exploration can be increased.

3. The Importance of Co-Operation in International Space Research and Technology Transfer

Cooperation in international space research and technology transfer plays an important role in accelerating the scientific and technological progress of countries around the world. Since space exploration is a complex and costly project, different countries need to pool their knowledge, resources and experience. These collaborations allow each country to achieve more effective and efficient results by combining its own capabilities and areas of expertise. This encourages innovation not only in space research but also in other scientific disciplines around the world.

Another important aspect of international co-operation is that it increases knowledge sharing. Researchers and experts from different countries, working on space projects, have the opportunity to benefit from each other's knowledge and experience. Such interactions accelerate innovation processes and pave the way for new ideas (Wulf and Butel, 2017). For example, international organizations such as the European Space Agency (ESA) and NASA collaborate on large data sets, experimental findings and technological innovations through joint projects (Adams, 2019). Such collaborations enable the advancement of space research at a global level, while at the same time increasing synergy in the scientific community. Furthermore, co-operation in international space exploration helps to use resources more efficiently. Since space missions are often costly, many countries can share this financial burden by pooling their resources. This

contributes to making space exploration more sustainable (Gao and Chien, 2017). For example, the International Space Station (ISS) project demonstrates the endeavor of different countries to come together to achieve common goals. Such projects strengthen not only space research but also international relations (Stewart and Dittmer, 2023). International co-operation also contributes to the development of skills in science and technology. The exchange of knowledge and experience between countries offers new opportunities to young researchers and scientists (Standke, 2006). Such collaborations can be supported by training programmes, internship opportunities and joint research projects. By encouraging international collaborations, policy makers can contribute to the career development of scientists and thus increase the human resource potential in space research.

Cooperation in international space research and technology transfer promotes a culture of peace and co-operation. The co-operation of different countries in the field of space not only achieves scientific and technological goals, but also increases solidarity and understanding in the international community. Such cooperation emphasizes the importance of cooperation in solving international problems and builds trust between countries. Therefore, cooperation in international space research and technology transfer is an important element that promotes not only scientific progress but also global peace and co-operation.

4. The Importance of Co-Operation in International Space Research and Technology Transfer

In a global competitive environment, space research and technology transfer play an important role in the scientific and technological development of countries. This competition creates an accelerating effect in the development of space technologies. Countries try to gain competitive advantage in the global market by accelerating technological innovations through international co-operation. In this context, it is of great importance for policy makers to make arrangements to support innovative projects.

Competition in space research encourages the sharing of scientific knowledge and technology. Countries can utilize their resources more effectively by cooperating in certain areas. For example, joint projects in space bring together the knowledge and experience of scientists and engineers to produce innovative solutions (Rausser, 2023). Policy makers should develop funding mechanisms and incentives to support such joint projects.

In order to accelerate technological innovations in a global competitive environment, education and human resource development is also a critical factor. Countries should offer training programmes and scholarships to increase the qualified workforce in the field of space technologies. In this way, young generations are encouraged to be interested in space research, while increasing the expertise in the sector (Zickafoose et al., 2024). In this process, policy makers can strengthen education programmes in cooperation with the private sector and academic institutions.

In addition, collaborations between countries facilitate technology transfer in a global competitive environment. International collaborations in the development of space technologies bring together the expertise and experience of different countries. This enables the development of innovative solutions more rapidly (Pandey et al., 2022). By encouraging such collaborations, policymakers can increase competitiveness at the international level. Supporting innovation in a global competitive environment is the responsibility of policymakers. In order to accelerate technological innovations, policymakers should develop policies that encourage R&D investments. In addition, they can accelerate technological developments by creating support programs for innovative initiatives. In this way,

competitiveness in the field of space research and technology transfer can be increased and sustainable growth can be achieved.

5. Conclusion

This study examines the innovative contributions of space research to other sectors and how technology policymakers can benefit from these contributions. The benefits provided by space technologies in various fields such as energy, health, agriculture, defense and communication show that these technologies are not limited to space exploration alone, but also have a significant impact on many sectors around the world. This situation reveals that space research has a strategic importance and emphasizes the need for policymakers to increase investments in this field.

Space research is considered an important resource in the search for solutions to global problems with its long-term contributions to environmental sustainability, data management and innovative solutions. In particular, the integration of remote sensing and communication technologies ensures that applications in different sectors become more efficient. In addition, supporting space research through international collaborations increases knowledge sharing and accelerates innovation processes between countries. In this context, encouraging collaborations in the space field by policymakers will support both scientific developments and economic growth. The strategies suggested for policymakers provide a roadmap to develop the applications of space research in other sectors. Regulations to be made in the fields of education, research and investment will ensure that space technologies reach a wider audience, while also increasing the role of these technologies in producing innovative solutions. In particular, the creation of educational programs and career opportunities for young generations will strengthen the human resources in this field and contribute to future space projects. As a result, the opportunities offered by space research are not limited to space exploration alone, but also make significant contributions to innovation processes in many sectors.

6. Discussion

This study examines the innovative contributions that space exploration brings to different sectors and how these contributions can be evaluated by technology development policy makers. In particular, the role of these technological achievements in increasing efficiency, sustainability and competitiveness in various sectors is noteworthy. The study aims to provide strategic recommendations on how policy makers can use these contributions more effectively. For example, Victor et al. (2024) emphasized the potential of remote sensing technologies to increase efficiency in agriculture and showed that the data support provided by these technologies to farmers makes significant contributions to sustainable agricultural practices. Similarly, Zohrehvandi et al. (2020) stated that data obtained from space is important for resource management in the energy sector. Such findings reveal that the applications of space exploration in different sectors require not only a technical but also a strategic approach.

The effects of space exploration on the health sector are also remarkable. A study by Shirah et al. (2023) examined how experiments conducted in space contribute to the development of remote health services. Such studies show how critical the innovative solutions offered by space technologies in the field of health are in terms of access to health services, especially in rural and hard-to-access areas. In this context, it is obvious that technology policy makers need to develop strategic plans to maximize the potential of space research in the field of health.

At the same time, studies on the economic and social impacts of space research also provide important results. Pyka (2017) emphasized the positive effects of space technologies on economic development and explained the role of these technologies in sectoral transformation in terms of employment, new business opportunities and innovative solutions. At this point, it is concluded that policy makers should increase their investments in space research and support cooperation in this field. In addition, encouraging international cooperation will contribute not only to information sharing but also to the acceleration of technological innovations at the global level.

Discussions in the existing literature on the application areas and potential benefits of space research also reveal some difficulties. For example, the obstacles encountered in technological integration processes and the effective management of resources constitute a significant obstacle to the application of space research in other sectors (Hew and Brush, 2007). Therefore, it is of great importance for technology policy makers to develop strategies to overcome these difficulties and encourage sectoral cooperation. In order to increase the applicability of space technologies and to make the most of these technologies, policy makers need to develop innovative solutions in collaboration with relevant stakeholders. As a result, the innovative contributions of space research to other sectors are discussed in a wide range in the existing literature. However, in order to make the best use of these contributions, technology-producing policy makers need to encourage sectoral collaborations and develop strategic plans. Space research should be considered not only as a scientific discipline but also as an important tool for social and economic development, and this potential should be maximized.

7. Recommendations

7.1. Recommendations for increasing coordination among policy makers

International space research and technology transfer is a complex and multi-stakeholder process. In this process, effective coordination between policy makers from different countries increases the efficiency of cooperation. Policy makers can encourage the sharing of experience and knowledge by organizing regular meetings and conferences. Such events strengthen relations between countries and help develop a common understanding of different aspects of space research. In addition, it is important to establish an effective communication network among policy makers. This network makes it easier to follow current developments in space technologies and research. Social media and digital platforms, in particular, can increase cooperation opportunities by providing a rapid flow of information. Effective use of these platforms by policy makers can strengthen coordination and cooperation. Common goals need to be determined in order to encourage international cooperation. Policy makers can develop common strategies on these issues by determining the areas and goals to be cooperated in space research. Common goals ensure that cooperation is carried out in a more structured manner. In this context, issues such as sustainable development in space, solving environmental problems and scientific research can be determined as common goals.

Policymakers' arrangements that support the sharing of technological developments will also increase coordination. Such arrangements facilitate the transfer of knowledge and technology between countries, further strengthening cooperation. For example, simplifying the licensing and patent processes related to the use of certain space technologies can pave the way for international cooperation. In this way, interaction between countries will increase, and innovative solutions in space research can be implemented more quickly. It is important to increase

transparency in international space cooperation. Policymakers should conduct cooperation processes in a transparent manner and inform the public about these processes. Transparency contributes to the creation of an environment of trust and increases the trust that countries have in each other. This trust is a critical factor for the success of international cooperation. By adhering to the principle of transparency, policymakers can make international space research cooperation more effective.

7.2. Recommendations for cross-sectoral collaborations

Policy makers should prioritize the establishment of frameworks that foster cross-sectoral collaborations between space research and industries such as healthcare, energy, agriculture, and telecommunications. These collaborations should be driven by shared goals, such as enhancing sustainability, improving resource management, and accelerating technological advancements. By aligning space technologies with the needs of other sectors, policy makers can create mutually beneficial partnerships that not only promote innovation but also ensure the practical application of space-derived solutions in solving global challenges. This can be achieved through targeted incentives, funding mechanisms, and the development of multi-disciplinary platforms that encourage dialogue and idea exchange across sectors. Such collaborations will unlock new opportunities, driving innovation and contributing to the broader goal of sustainable economic growth.

Additionally, policy makers should encourage the development of public-private partnerships (PPPs) to facilitate the integration of space research outputs into diverse sectors. These partnerships can provide the financial and technical resources necessary to bring space-derived technologies to market quickly. Policymakers can create policies that offer incentives for private sector investment in space-related innovations while ensuring that the benefits of these technologies are distributed across sectors. By establishing clear, supportive regulations and frameworks for collaboration, policy makers can facilitate seamless interactions between public research institutions and private industry, accelerating the adoption of innovative solutions. This approach not only strengthens the economic and technological resilience of various sectors but also enhances the global competitiveness of industries involved in space research and technology transfer.

7.3. Recommendations for future policy development processes

In order to ensure the continuity of the contributions of space research to other sectors, there are a number of recommendations that should be taken into consideration in future policy development processes. First, investments in research and development activities of space technologies should be increased. Policymakers can ensure that innovative projects are implemented by creating funding mechanisms that encourage investments in this field. Investments in space research will positively affect not only the space industry but also other related sectors.

Second, training and awareness programs should be developed for the integration of space technologies into other sectors. Policymakers can encourage businesses to benefit from the potential of these technologies by organizing training on how to use space technologies. Training programs will facilitate access to space technologies, especially for small and medium-sized enterprises, and increase their competence in this field.

Thirdly, encouraging international cooperation stands out as an important strategy. In future policy development processes, strategies should be developed to strengthen cooperation with different countries and increase knowledge sharing. Such collaborations will ensure that innovative solutions obtained in space research reach a wider audience. In this context, policymakers should develop policies that encourage participation in international projects.

Fourthly, public participation should be encouraged in order to increase the social benefits of space research. Policymakers should organize campaigns that inform the public about the effects of space research on society and encourage their participation. In this way, public interest in space research can be increased and awareness in this area can be increased. Public participation will help the benefits provided by space research reach a wider audience. Policymakers need to adopt a flexible and adaptable policy development process. Rapid developments in space technologies and research can affect policy development processes. Therefore, policymakers should constantly monitor developments and update their policies when necessary. A flexible policy framework will facilitate the integration of space research with other sectors and enable the implementation of innovative solutions.

7.4. Strategic recommendations for policy makers

Technology policymakers should develop a strategic approach to maximize the benefits of innovative solutions offered by space research. First of all, policymakers should create a strong technology transfer ecosystem to support the integration of technologies developed in space research into the local economy. This will ensure rapid dissemination of innovation and its effective use in other sectors. In addition, cooperation between local manufacturers and research institutions should be encouraged.

Another strategic recommendation is to increase state-supported research and development (R&D) activities. The cost of space research is generally high, but the return on this cost can be more than offset by technological contributions provided to other sectors. By increasing R&D investments, policymakers can ensure the spread of space research to wider sectors and enable faster commercialization of innovative solutions. Public-private partnerships in particular offer great opportunities in this area.

Integrating technological gains from space research into sustainable development goals should be another priority for policymakers. Renewable energy technologies developed in space, solutions that increase agricultural productivity, and applications that improve health systems are critical for a sustainable future. Policymakers should develop long-term strategies on how to use these technologies in line with sustainable development goals.

Education and talent development should be another focus of policymakers. In order to fully benefit from the technological solutions offered by space research, an expert and qualified workforce is needed. Policymakers can accelerate the technology transfer process by supporting education programs and talent development projects in this field. In addition, the orientation of young generations to space technologies and other innovative areas should be encouraged. Policymakers can ensure that the gains from space research are disseminated on a global scale by increasing international cooperation and knowledge sharing. Space research is generally a study that transcends borders and has global impacts. Therefore, cooperation should be developed in the international arena to ensure that technologies obtained from space research are shared and implemented among different countries.

7.5. Recommendations for future policy development processes

Space research provides long-term innovative contributions, thus presenting important strategic implications for technology policy makers. In this context, the development of space technologies ensures integration with other sectors and thus supports economic growth. The efficiency gains and cost

reductions achieved in space research can serve as an example for other industries. This situation provides an opportunity for policy makers to develop strategies that support and encourage space research.

The results of space research can be a source of inspiration for innovative solutions in various industries. For example, the applications of materials and technologies used in space in sectors such as health, energy and communication provide competitive advantages to local industries. Policy makers can increase the competitiveness of local businesses by adopting such innovative solutions. Therefore, the knowledge and technologies obtained from space research should be considered as a strategic resource.

The integration of the results of space research into other sectors also plays an important role in achieving sustainable development goals. For example, space technologies can be applied in areas such as environmental monitoring, agricultural productivity and natural disaster management. By encouraging the use of such technologies, policymakers can both find solutions to environmental problems and support economic development. Therefore, there is a strong link between space research and sustainable development.

The long-term innovative contributions provided by space research also encourage international collaborations. Technology-producing policymakers can increase the sharing of knowledge and experience by establishing collaborations with different countries. This allows for the acceleration of innovation at the global level and the development of more effective solutions. Supporting these collaborations by policymakers strengthens.

Ethical approval

Not applicable.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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