



(REVIEW ARTICLE)



Space commerce and its economic implications for the U.S.: A review: Delving into the commercialization of space, its prospects, challenges, and potential impact on the U.S. economy

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World Journal of Advanced Research and Reviews, 2023, 20(03), 952–965

Publication history: Received on 28 October 2023; revised on 04 December 2023; accepted on 06 December 2023

Article DOI: <https://doi.org/10.30574/wjarr.2023.20.3.2494>

Abstract

This study provides a comprehensive analysis of the commercialization of space and its economic implications for the United States. The primary objective was to assess the scope, significance, and dynamics of space commerce, focusing on its historical evolution, current status, and future prospects. The methodology involved a systematic review of literature from academic journals, reports, and publications, employing a strategic search approach with specific inclusion and exclusion criteria. The selection of literature was based on relevance to the study's objectives, encompassing economic contributions, challenges, and potential policy recommendations for space commerce. Key findings indicate that space commerce has become a significant contributor to the U.S. economy, offering substantial revenue generation, job creation, and technological advancements. However, the sector faces challenges, including technological complexities, regulatory uncertainties, and economic risks. The study also highlights the transition from government-led space exploration to a more commercialized and competitive industry, opening new economic frontiers for the U.S. The study concludes that space commerce presents both significant opportunities and notable challenges for the U.S. economy. Strategic insights for U.S. stakeholders emphasize embracing technological innovation, fostering public-private partnerships, and developing strategies to mitigate inherent risks. Recommendations for future research include exploring the direct and indirect economic impacts of space commerce, the evolving role of policy and regulation, and the long-term sustainability of the sector. This study contributes to a deeper understanding of the economic implications of space commerce and offers guidance for future strategic planning and policy-making in this dynamic field.

Keyword: Space Commerce; Economic Implications; U.S. Economy; Commercialization of Space

1. Introduction

1.1. The Emergence of Space Commerce: A New Frontier in Economic Development

The dawn of the 21st century has witnessed the burgeoning of space commerce, marking a pivotal shift in economic development and technological innovation. This new frontier, characterized by the increasing involvement of private entities in space activities, has redefined the landscape of space exploration and utilization, heralding a new era in economic development (Mazzucato & Robinson, 2016). The transformation from a predominantly government-led

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domain to a more diverse and dynamic ecosystem of private, not-for-profit, and public actors signifies a paradigm shift in the approach to space activities and their economic implications.

Historically, space activities were primarily driven by governmental agencies, with NASA being a prominent example in the United States. However, recent years have seen a significant shift in this dynamic. The U.S. space policy has evolved from NASA-directed developments in low-Earth orbit (LEO) to fostering an ecosystem that includes a mix of private, not-for-profit, and public actors (Mazzucato & Robinson, 2016). This shift has not only changed NASA's role from an orchestrating to a facilitating one but has also opened up new avenues for economic growth and innovation.

The emergence of space commerce as a new economic frontier can be likened to the evolution observed in other sectors, such as the maritime industry. Just as the second industrial revolution led to a transformation in port cities and their economic activities (Van den Berghe & Boelens, 2016), the advent of space commerce is reshaping the economic landscape of space. The entry of private players has introduced new dynamics, akin to the rise of powerful multinationals in traditional industries, altering the governance and operational paradigms of space activities.

Furthermore, the rise of space commerce reflects broader trends observed in global markets, such as those in the Asian ICT sector. The interplay of geopolitics, economics, and technology in these markets offers valuable insights into the complexities and potential of emerging sectors like space commerce (Kawamata, 2018). The lessons learned from these markets can inform strategies and policies for nurturing and sustaining the growth of space commerce.

The economic implications of this shift are profound. Space commerce opens up a plethora of opportunities, ranging from satellite communications and Earth observation to space tourism and asteroid mining. These ventures not only promise substantial revenue streams but also have the potential to spur technological advancements and catalyze ancillary industries. The involvement of private entities in space commerce introduces market-driven efficiencies and innovations, fostering a competitive environment that can accelerate technological development and reduce costs.

However, the transition to a space economy driven by commercial interests also presents challenges. Regulatory frameworks need to evolve to address the unique aspects of space activities, including issues related to space traffic management, orbital debris, and the use of extraterrestrial resources. Moreover, the integration of private and public interests in space endeavors necessitates new models of collaboration and partnership, ensuring that the benefits of space commerce are widely distributed and aligned with broader societal goals. The emergence of space commerce represents a significant shift in the economic exploitation of space. It heralds a new era of economic development, characterized by innovation, collaboration, and competition. As this sector continues to evolve, it will undoubtedly play a crucial role in shaping the future of global economic development and technological progress.

1.2. Delving into the Commercialization of Space: Scope and Significance

The commercialization of space, a concept that once belonged to the realm of science fiction, has now become a tangible and rapidly evolving aspect of the global economy. This transformation is marked by a shift from space being an exclusive domain of government agencies to a burgeoning industry driven by private enterprises and entrepreneurial ventures. The scope and significance of this transition are profound, reshaping not only the space industry but also the broader economic landscape.

Historically, space activities were primarily the purview of national governments, with the United States playing a leading role through agencies like NASA. The Cold War era, particularly the late 80s and early 90s, saw space policy becoming a critical element in international relations and technological advancement (Zhuravlova & Honchar, 2017). The development of astronautics during this period, spurred by the arms race, laid the groundwork for today's commercial space sector. This historical context is essential in understanding the evolution of space from a geopolitical tool to an economic opportunity.

The commercialization of space encompasses a wide array of activities, including satellite communications, Earth observation, space tourism, and potentially, resource extraction from celestial bodies. This diversification of space-related activities signifies a shift towards a knowledge-based global economy, where technological innovation plays a pivotal role (Reid, 2016). The dynamics of economic spaces in this context are characterized by rapid technological advancements and the emergence of new markets and industries.

One of the key aspects of space commercialization is the role of entrepreneurship and innovation. The space industry has seen a surge in private companies and startups, driven by a combination of technological advancements and decreasing costs of space access. This entrepreneurial spirit is akin to the developments observed in other high-tech

industries, where innovation and risk-taking have led to significant economic growth (Sheppard et al., 2015). The education and preparation of a new generation of engineers and entrepreneurs, capable of navigating and shaping this new economic space, are crucial for the sustained growth and development of the space industry.

The economic significance of space commercialization is multi-faceted. On one hand, it represents a substantial market opportunity with the potential for high returns on investment. On the other hand, it is a catalyst for technological innovation, driving advancements in areas such as telecommunications, materials science, and robotics. Furthermore, the commercialization of space has broader economic implications, including job creation, the development of new supply chains, and the stimulation of ancillary industries.

However, the commercialization of space also presents challenges. Regulatory frameworks need to evolve to keep pace with the rapid developments in the industry. Issues such as space traffic management, orbital debris, and the use of space resources require international cooperation and the establishment of clear and fair rules. Additionally, the integration of commercial and public interests in space endeavors necessitates new models of collaboration and partnership. The commercialization of space represents a significant shift in the economic exploitation of space. It heralds a new era of economic development, characterized by innovation, entrepreneurship, and competition. As this sector continues to evolve, it will undoubtedly play a crucial role in shaping the future of global economic development and technological progress.

1.3. Historical Journey: From Space Exploration to Economic Opportunity

The journey from space exploration to economic opportunity represents a remarkable evolution in the way humanity perceives and utilizes the final frontier. This transformation has been characterized by a shift from viewing space primarily as a domain for scientific discovery and national prestige to recognizing its vast potential for economic development and commercial exploitation.

In the early stages of space exploration, activities were predominantly driven by governmental agencies with objectives centered on scientific research, technological demonstration, and geopolitical competition. The European Space Agency's (ESA) strategy, for instance, was initially focused on scientific missions and technological development, with economic considerations playing a secondary role (Iacomino, 2017). This approach was mirrored by other space-faring nations, including the United States, where NASA led the charge in pioneering space exploration.

However, as the space sector matured, a paradigm shift occurred. The realization that space could offer more than just scientific knowledge began to take hold. The European space sector, as highlighted by Iacomino (2017), began to evolve, with innovation mechanisms being developed to support broader economic goals. This shift was not unique to Europe; it was a global phenomenon, with countries around the world starting to recognize the economic potential of space.

The economic potential of space is vast and multifaceted. As noted by Bamigboye (2021), the global space industry is projected to generate significant revenues, potentially reaching over \$1 trillion by 2040. This growth is driven by several factors, including declining launch costs, technological advancements, and increasing public and private sector interest. The space economy encompasses a wide range of activities, from satellite communications and Earth observation to space tourism and potential resource extraction from celestial bodies.

The transition from space exploration to economic opportunity has also been marked by the increasing involvement of the private sector. The traditional model of space activities being funded and operated by governments has given way to a more diverse ecosystem. Private companies, driven by profit motives and entrepreneurial spirit, have entered the space arena, bringing with them innovation, efficiency, and new business models. This shift has been particularly evident in the United States, where companies like SpaceX and Blue Origin have become key players in the space industry.

The implications of this shift are profound. The commercialization of space has led to the creation of new markets, job opportunities, and technological innovations. It has also raised new challenges, including the need for regulatory frameworks to manage commercial activities in space and address issues such as space traffic management and the use of space resources. The historical journey from space exploration to economic opportunity represents a significant evolution in our relationship with space. What began as a quest for knowledge and national prestige has transformed into a dynamic and rapidly growing economic sector. As we continue to explore and utilize space, it is clear that its potential for economic development and commercial exploitation will play a crucial role in shaping the future of humanity's endeavors beyond Earth.

1.4. Review Objectives: Assessing Prospects, Challenges, and Economic Impacts

The commercialization of space represents a significant shift in the economic landscape, akin to the transformative effects of digitalization and major economic paradigm shifts observed in various regions globally. Drawing analogies from the digital economy and regional economic transformations, this review seeks to provide a comprehensive understanding of the multifaceted nature of space commerce.

The prospects of space commerce are vast and diverse, mirroring the opportunities presented by the advent of digital innovations in the financial sector (Gomber et al., 2017). Just as digitalization opened new avenues for economic growth and innovation, space commerce is poised to create new markets, drive technological advancements, and foster economic development. The potential for revenue generation, job creation, and technological progress in sectors such as satellite communications, space tourism, and resource extraction is significant. The U.S., with its robust technological base and entrepreneurial ecosystem, is particularly well-positioned to capitalize on these opportunities.

However, the path to realizing these prospects is not without challenges. The transition to space commerce can be compared to the challenges faced during the digitalization of financial services, where issues such as market concentration, regulatory uncertainties, and technological risks were prevalent (Hua & Huang, 2021). In the context of space commerce, challenges include the development of regulatory frameworks for space activities, management of space traffic and debris, and ensuring sustainable and responsible use of space resources. Additionally, the high costs of space missions and technological complexities pose significant barriers to entry, necessitating continued innovation and investment.

The economic impacts of space commerce can be profound, as seen in other large-scale economic shifts. The study of Hyderabad's transformation through economic development provides a relevant analogy (Singh, 2019). Just as Hyderabad's evolution into a high-tech hub had significant regional economic impacts, the growth of the space sector is likely to have wide-ranging effects on the U.S. economy. These include direct impacts such as revenue generation and job creation in the space sector, as well as indirect impacts through the stimulation of related industries and technological spillovers. The long-term economic implications could be as transformative as those observed in the aftermath of major technological and economic paradigm shifts, such as those brought about by climate change (Gomber et al., 2017).

From the foregoing, the commercialization of space presents a complex mix of prospects, challenges, and economic impacts. While the potential for economic growth and technological advancement is significant, realizing these benefits will require navigating a range of challenges, including regulatory, technological, and sustainability issues. The economic impacts of space commerce are likely to be far-reaching, affecting not just the space sector but the broader economy as well. As the U.S. and other nations venture further into this new economic frontier, a comprehensive understanding of these dynamics will be crucial for maximizing the benefits and mitigating the risks associated with space commerce.

1.5. Research Gap

Despite the growing body of literature on space commerce and its economic implications, there exists a notable research gap in comprehensively understanding how these dynamics specifically impact the U.S. economy. While previous studies have extensively explored the technological and scientific aspects of space exploration and commercialization, there is a lack of in-depth analysis focusing on the economic dimension, particularly in the context of the U.S. Most existing research tends to either broadly discuss global space commerce or concentrate on specific technological innovations and policy frameworks without delving into the direct and indirect economic impacts on the U.S. economy. Furthermore, there is a scarcity of studies that integrate the historical evolution of space commerce with its current economic realities and future prospects in the U.S. context. This study aims to fill this gap by providing a detailed examination of the economic contributions, challenges, and future economic scenarios of space commerce, specifically in relation to the U.S. economy. It seeks to bridge the divide between the general discourse on space technology and the specific economic implications for the U.S., offering a comprehensive understanding of the role of space commerce as a driver of economic growth and innovation in the U.S. context. This includes an analysis of policy recommendations tailored to enhancing the U.S. economic benefits derived from space commerce activities.

1.6. Aim and Objectives of the Study

The primary aim of this research is to comprehensively analyze the commercialization of space and its economic implications for the United States. The study seeks to understand the scope, significance, and dynamics of space commerce, focusing on its historical evolution, current status, and future prospects. It aims to provide a detailed

assessment of the economic contributions, challenges, and potential policy recommendations to enhance the U.S. economy through space commerce activities.

The research objectives are to;

- To assess the current scope and significance of space commerce and evaluating their current economic impact.
- To identify and analyze the key players in space commerce and understanding their roles and contributions.
- To identify the challenges in space commerce and their implications for future growth.

2. Methodology

The methodology section outlines the systematic approach employed in this study to review and analyze the economic implications of space commerce in the U.S. It details the data sources, search strategy, inclusion and exclusion criteria, selection criteria, and data analysis methods used.

2.1. Sources of Data

The primary data sources for this study were academic journals, reports, and publications focusing on space commerce, its economic implications, and related technological and policy developments. These sources included peer-reviewed articles from databases such as JSTOR, ScienceDirect, and Google Scholar, as well as reports from governmental organizations like NASA and industry analyses from space commerce entities. Additionally, data from news articles, industry blogs, and white papers provided supplementary insights.

2.2. Search Strategy

The search strategy involved a comprehensive and systematic approach to identify relevant literature. Keywords such as "space commerce", "economic implications", "U.S. space economy", "commercialization of space", and "space industry technology" were used. The search was conducted across multiple databases and sources to ensure a wide coverage of relevant literature. Boolean operators like "AND" and "OR" were used to refine and broaden the search results.

2.3. Criteria for Inclusion and Exclusion of Relevant Literature

2.3.1. Inclusion criteria

- Publications from 2010 to 2023 to ensure the relevance and recency of data.
- Studies focusing on the commercial aspects of space activities, economic impacts, policy implications, and technological innovations in space commerce.
- Articles published in English.

2.3.2. Exclusion criteria

- Non-peer-reviewed articles and sources without clear authorship or institutional affiliation.
- Publications focusing solely on technical aspects of space exploration without direct relevance to economic implications.
- Articles not available in full-text format.

2.4. Selection Criteria

The selection of literature for review was based on relevance to the study's objectives. Abstracts and summaries of identified articles were initially reviewed to assess their applicability. Full-text articles were then scrutinized for detailed information on space commerce's economic impacts, challenges, and future prospects. Priority was given to studies with comprehensive data, clear methodologies, and those that provided unique insights into the U.S. space commerce sector.

2.5. Data Analysis

Data analysis involved a qualitative synthesis of the selected literature. Key themes, patterns, and findings were identified and categorized under relevant topics such as economic contributions, challenges, and future trends in space commerce. The analysis also involved comparing and contrasting different perspectives and findings from the literature to provide a comprehensive understanding of the topic. The synthesized information was then used to inform the discussions and conclusions of the study.

3. Literature Review

3.1. Overview of Space Commerce: Defining Components and Key Players

Space commerce, an increasingly significant sector of the global economy, encompasses a wide range of activities from satellite communications to deep space exploration. This section provides an overview of the key components and players in space commerce, drawing on recent research and industry trends.

The commercial satellite industry forms a cornerstone of space commerce. Christensen et al. (2022) provide a comprehensive analysis of this sector, highlighting its current size, revenue drivers, and evolving dynamics. The satellite industry is not just about launching and operating satellites; it also includes the manufacturing of satellites and components, ground-based infrastructure, and a range of services from telecommunications to Earth observation. This industry is a primary revenue generator in space commerce, with its growth fueled by advancements in satellite technology and increasing demand for satellite-based services.

Another critical component of space commerce is the development of space infrastructure, which includes launch services, spaceports, and in-space platforms. These elements are essential for both governmental and commercial space missions. The expansion of launch services, including reusable launch vehicles, has significantly reduced the cost of accessing space, thereby opening up new opportunities for commercial exploitation.

Space commerce is a global endeavor with several key players. While the U.S. and Russia have been traditional leaders in space, emerging space countries are also making significant strides. Brichta (2022) discusses the development of the space industry in countries like Slovakia, emphasizing the role of spin-in capabilities and procurement support. These emerging players are contributing to the diversification and growth of the global space economy, bringing new perspectives and capabilities.

The Russian space industry, as analyzed by Shiryayeva and Rozhanskaia (2020), is another significant player in the global space market. Russia's expertise in rocket and space technology, along with its long history in space exploration, positions it as a key competitor and collaborator in the international space commerce arena.

3.2. The U.S. in the Global Space Commerce Arena

The United States has long been a dominant force in space exploration and commerce, shaping the trajectory of the global space industry. The U.S. space industry has been a pioneer in many aspects of space commerce, from satellite communications to deep space exploration. Its leadership is underpinned by significant investments in space technology, a robust industrial base, and a conducive policy environment that encourages private sector participation. The U.S. has also been instrumental in driving global trends in space commerce, including the commercialization of low Earth orbit (LEO) and the development of new space markets.

The global space market is experiencing rapid growth and transformation, with countries like Russia also playing significant roles. Groshev & Koblov (2021) highlights the development of space tourism in Russia, indicating a growing global interest in commercial space activities. This development underscores the increasingly competitive nature of the global space market, where the U.S. faces both opportunities and challenges.

Bamigboye (2021) projects that the global space industry could generate revenues exceeding \$1 trillion by 2040. This growth is driven by factors such as declining launch costs, technological advancements, and increasing public and private sector interest. The U.S., with its advanced space technology and entrepreneurial ecosystem, is well-positioned to capitalize on these opportunities.

The U.S. space industry's contribution to global economic development is significant. de Waal (2018) explores the potential role of the modern global space industry in establishing an advanced global economy. The U.S., with its extensive space capabilities, is expected to play a key role in systems in space that contribute to sustainable development on Earth. This includes the development of space-based solar power, asteroid mining, and other in-space activities that could have far-reaching economic and environmental impacts.

The U.S. continues to be a central player in the global space commerce arena. Its leadership in space technology, policy, and industry dynamics significantly influences the global space market. As the space industry evolves, the U.S. is poised to play a pivotal role in shaping its future direction, contributing to global economic development, and harnessing the potential of space for the benefit of humanity. The U.S.'s engagement in space commerce not only drives economic

growth but also fosters international collaboration and innovation, underscoring its strategic importance in the global space economy.

3.3. Comparative Analysis: U.S. and International Space Commerce

The global space commerce arena is a dynamic and multifaceted environment, with various countries contributing to and shaping its landscape. The development of the space industry in the United States has been marked by significant technological advancements and a strong entrepreneurial spirit. This contrasts with the approaches seen in other countries. For instance, Dzbur and Dzbur (2020) examine the space industry in Ukraine, highlighting the challenges and potential in a context that differs markedly from the U.S. model. The U.S. space industry benefits from a combination of government support, private investment, and a well-established technological base, factors that are less pronounced in Ukraine's space sector.

Koshova et al. (2022) explore investment trends in the space industry, focusing on the EU and Ukraine. Their findings, while centered on Europe, offer valuable insights into the investment landscape that can be applied to the U.S. context. The U.S. space industry has seen a surge in private investment, particularly in areas like commercial launch services, satellite manufacturing, and space tourism. This trend is indicative of a broader global movement towards increased private sector involvement in space commerce.

The U.S. space commerce sector, when compared with its international counterparts, demonstrates a unique blend of technological leadership, entrepreneurial culture, and robust investment. While facing competition from countries like Russia and China, the U.S. continues to play a pivotal role in shaping the global space commerce landscape. The comparative analysis underscores the diverse approaches and strategies employed by different countries in advancing their space industries, reflecting the complex and competitive nature of global space commerce.

3.4. Technological Innovations Driving Space Commercialization

The commercialization of space has been significantly driven by technological innovations, reshaping the industry and creating new opportunities. The intersection of intellectual property rights and technology transfer plays a crucial role in the space industry. Habiba, Kazemi, and Sadeghi (2022) delve into this aspect, highlighting the conflict between the commercialization of space activities and the tight control over technology transfer. Developed countries, including the U.S., often impose restrictions on technology transfer in the space industry, which can hinder the development of space activities in less developed countries. This dynamic creates a complex landscape where intellectual property rights become a pivotal factor in the commercialization and global spread of space technologies.

Satellite technology has been a cornerstone of space commercialization, with its applications spanning telecommunications, geological surveys, and more. Sivaraks, Maliswan, and Kaewphanuekrungsi (2021) discuss the evolution of satellite businesses, emphasizing how technological advancements have created a variety of new business opportunities. The development of satellite technology has enabled internet access in remote areas, demonstrating the far-reaching impact of these innovations. The paper also addresses the challenges and legal limitations associated with space-based internet services, underscoring the complexities involved in commercializing satellite technologies.

Technological innovations are at the heart of space commercialization, driving the industry forward and opening up new possibilities. From the complexities of intellectual property and technology transfer to the evolution of satellite technology and the identification of key industry trends, these innovations play a pivotal role in shaping the future of space commerce. As the space industry continues to evolve, staying abreast of these technological advancements and their implications will be crucial for stakeholders looking to capitalize on the opportunities presented by space commercialization.

4. Discussion of Findings

4.1. Economic Contributions and Challenges of Space Commerce

The commercialization of space has brought about significant economic contributions along with a set of unique challenges. The economic impact of space commerce is multifaceted, encompassing direct and indirect contributions. The direct economic contributions are evident in the revenue generated from satellite communications, launch services, and space tourism. According to Jaehnichen (2020), the commercial use of outer space, while presenting ecological challenges, also offers substantial economic benefits. These benefits extend beyond the immediate financial gains, contributing to technological advancements and innovation.

The role of electronic commerce in space-related activities cannot be overlooked. Burinskienė (2011) provides a parallel to space commerce, where digital platforms and technologies play a crucial role in enabling and expanding commercial activities. This is particularly relevant in the context of satellite-based internet services and space data analytics, where digital commerce mechanisms are integral.

Despite its economic potential, space commerce faces several challenges. One of the primary challenges, as highlighted by Jaehnichen (2020), is the ecological impact and the ethical considerations associated with the exploitation of outer space. The accumulation of space debris and the potential for environmental damage pose significant concerns, necessitating sustainable practices and regulatory measures.

The integration of Information and Communication Technologies (ICTs) in space commerce, while beneficial, also presents challenges. Joseph (2019) discusses the role of ICTs in economic development, shedding light on the challenges related to technological integration and digital divide issues. These challenges are pertinent to space commerce, where advanced technologies are essential but not uniformly accessible.

Space commerce contributes significantly to the economy, offering new revenue streams, technological advancements, and innovation opportunities. However, it also faces challenges, including ecological impacts, ethical considerations, and technological integration issues. Addressing these challenges effectively is crucial for the sustainable growth and development of space commerce. As the sector continues to evolve, a balanced approach that considers both the economic potential and the associated challenges will be essential for its long-term success.

4.1.1. Direct Economic Contributions: Revenue, Employment, and Investment

The direct economic contributions of space commerce are substantial and multifaceted, encompassing revenue generation, employment creation, and investment stimulation. Space commerce has become a significant revenue generator in the global economy. The study of Toh (2021) on the economic impact of e-commerce in Singapore provides a useful parallel for understanding the revenue potential of space commerce. The study found that e-commerce accounted for a considerable portion of the nation's gross output and GDP, supporting the idea that space commerce, similarly, contributes significantly to economic output. This is particularly relevant considering the increasing commercial activities in satellite communications, space tourism, and exploration.

The employment opportunities created by space commerce are another vital aspect of its economic contribution. Zhang (2021) analysis of tourism employment based on regional Internet of Things technology offers insights into the employment dynamics in the digital age. The study's findings on employment flexibility and comprehensive employment effects can be extrapolated to space commerce, where new technologies and commercial ventures are creating diverse job opportunities, ranging from engineering and scientific roles to administrative and support positions.

Investment in space commerce not only generates direct economic benefits but also serves as a catalyst for broader economic growth. The study by Torres Castaño et al. (2022) on the impact of industry and commerce tax on business organizations highlights the role of investment in stimulating economic development. This is particularly relevant for space commerce, where investments in technology, infrastructure, and research have far-reaching implications for economic growth and innovation.

Revenue generation, employment creation, and investment stimulation are key aspects of these contributions, each playing a crucial role in the broader economic landscape. As space commerce continues to expand and evolve, its impact on the global economy is likely to increase, underscoring the importance of understanding and leveraging these contributions for sustainable economic growth.

4.1.2. Broader Economic Effects: Indirect and Induced Impacts

The economic implications of space commerce extend beyond direct financial gains, encompassing a range of indirect and induced impacts. Indirect economic effects are those that occur as a consequence of the direct activities of space commerce but are not directly associated with it. Delphine et al. (2019) in their critical reflection on large transport projects, provide insights into the complexity of assessing these indirect effects. They argue that the broader economic implications, often overlooked, include enhanced accessibility and potential solutions to social problems. In the context of space commerce, similar indirect effects can be seen in the form of technological spillovers, infrastructure development, and enhanced global connectivity, all of which contribute to broader economic development.

The interconnected nature of modern economies means that the impacts of one sector can significantly influence others. The study of Su et al. (2021) on the impacts of network power and knowledge spillovers on urban green economic efficiency is particularly relevant. They found that higher network resource dominance and better-performing partners lead to higher efficiency. Translated to space commerce, this implies that advancements and innovations in space technology can have spillover effects on other sectors, enhancing overall economic efficiency and productivity.

The economic impacts of space commerce also extend to related industries. Stougiannidou et al. (2020) discuss the economic impacts of forest fires on agriculture, highlighting the importance of considering both direct and indirect costs. Similarly, space commerce affects related industries such as telecommunications, manufacturing, and even education, through the demand for specialized skills and technologies.

The broader economic effects of space commerce, including indirect impacts and induced implications, are significant. These effects manifest in various forms, such as technological spillovers, network effects, and impacts on related industries. Understanding these broader economic effects is crucial for comprehensively assessing the economic potential and challenges of space commerce. As the sector continues to grow, its indirect and induced impacts on the global economy will likely become more pronounced, necessitating a nuanced understanding of these effects for policy-making and strategic planning.

4.1.3. Challenges in Space Commerce: Economic, Technological, and Regulatory

Space commerce, while offering significant economic opportunities, is not without its challenges. These challenges span economic, technological, and regulatory domains, each presenting unique hurdles to the growth and sustainability of space commerce.

Economic Challenges

The economic challenges in space commerce are multifaceted. The high costs associated with space missions, the uncertainty of returns on investment, and the competitive nature of the global space market are significant economic challenges. These factors necessitate substantial financial resources and risk management strategies to ensure the viability and profitability of space ventures.

Technological Challenges

Technological advancements are at the heart of space commerce, yet they also pose significant challenges. The rapid pace of technological innovation requires continuous research and development, which can be resource-intensive. Moreover, the complexity of space technologies, such as satellite design and launch systems, demands a high level of expertise and poses challenges in terms of reliability and safety. Ensuring the sustainability of space activities, including addressing space debris and ensuring the long-term operability of satellites, is another critical technological challenge.

Regulatory Challenges

Regulatory challenges are particularly pronounced in space commerce due to the unique nature of space as a domain and the rapid evolution of space activities. Simanjuntak (2019) highlights the complexities of regulatory frameworks in rapidly evolving industries, which is applicable to space commerce. The lack of comprehensive international regulations governing space activities, the need for national regulatory frameworks to keep pace with technological advancements, and issues related to space traffic management and the use of space resources are key regulatory challenges. Additionally, Teixeira and Teixeira de Carvalho (2019) discuss the tax challenges in technological contexts, underscoring the need for updated laws and policies to address the unique aspects of industries like space commerce.

Addressing these challenges requires a coordinated approach involving stakeholders from industry, government, and academia. Developing effective strategies to overcome these challenges is crucial for the sustainable growth and success of space commerce, ensuring its continued contribution to economic development and technological advancement.

4.2. Prospects and Future Directions in Space Commerce

4.2.1. Emerging Trends and Innovations

The space commerce sector is rapidly evolving, driven by emerging trends and innovations that are reshaping its landscape.

Technological Innovation Trends in Aerospace

Technological advancements are a key driver of change in space commerce. Pelicioni et al. (2018) utilized bibliometric analysis to identify innovation trends in the aerospace sector, highlighting developments in space technology, satellites, and launch vehicles. The study revealed a focus on new low-cost technologies and small satellites, indicating a shift towards more accessible and versatile space solutions. This trend is significant for space commerce, as it opens up new opportunities for smaller companies and startups to enter the market and innovate.

Role of Big Data in Identifying Business Trends

The application of big data analytics is becoming increasingly important in identifying and capitalizing on business trends. Saritas et al. (2021) demonstrated the use of big data in mobile commerce to identify emerging business trends. This approach is highly relevant for space commerce, where analyzing vast amounts of data from satellites and other space missions can provide valuable insights into market trends, customer needs, and potential areas for innovation.

E-commerce Trends and Their Applicability to Space Commerce

The evolution of e-commerce offers parallels for understanding trends in space commerce. Khan and Sagar (2015) study on emerging trends in e-commerce in the Indian context provides insights into the dynamics of digital marketplaces. Similar trends, such as the increasing importance of digital platforms, the integration of advanced technologies like AI and IoT, and the focus on customer-centric solutions, are likely to influence space commerce. These trends suggest a future where space commerce is more integrated, data-driven, and responsive to market demands.

These developments are creating new opportunities, driving competition, and necessitating continuous innovation in the sector. As space commerce continues to evolve, staying attuned to these trends will be crucial for companies and policymakers to harness the full potential of this dynamic industry.

4.2.2. Economic Forecast: Opportunities and Risks

The economic forecast for space commerce is a complex interplay of opportunities and risks, shaped by technological advancements, market dynamics, and global economic trends.

The opportunities in space commerce are vast and varied. The sector is poised for significant growth, driven by advancements in technology, increasing demand for space-based services, and the expansion of commercial space activities. The development of new markets such as space tourism, satellite broadband services, and asteroid mining presents substantial economic opportunities. Additionally, the increasing involvement of private companies and international collaboration is likely to spur innovation and competition, further boosting the sector's growth.

However, the economic forecast for space commerce is not without risks. The report on the former Soviet states Oxford Analytica (2020) highlights the economic impact of external factors like the COVID-19 pandemic, which can be extrapolated to understand the vulnerabilities in space commerce. Economic downturns, geopolitical tensions, and global crises can adversely affect investment, supply chains, and market demand in the space sector. Furthermore, technological risks, such as launch failures or satellite malfunctions, pose significant challenges and can have far-reaching economic implications.

The future of space commerce also depends on how the sector adapts to changing global dynamics. Thorpe and Rogers (2018) discuss the future of the Global Weather Enterprise, focusing on opportunities and risks arising from changes such as technological advancements and climate change. Similar dynamics are at play in space commerce, where the sector must navigate evolving technological landscapes, regulatory environments, and market demands. The ability to adapt to these changes, mitigate risks, and capitalize on emerging opportunities will be crucial for the long-term success and sustainability of space commerce.

The sector's growth potential is underpinned by technological innovation and market expansion, but it also faces challenges from external economic factors and inherent risks in space activities. Navigating this complex landscape requires strategic planning, robust risk management, and continuous innovation. As space commerce continues to evolve, understanding and addressing these opportunities and risks will be key to harnessing its full economic potential.

4.2.3. Policy Recommendations for Enhancing U.S. Economic Benefits

The burgeoning field of space commerce presents unique opportunities for economic growth. To maximize these benefits, strategic policy recommendations are essential. Odularu, Adetunji, and Odularu (2020) emphasize the

importance of creating an enabling business ecosystem for fostering trade opportunities in the digital age. This approach is equally applicable to space commerce. Policies should aim to create a conducive environment for innovation and entrepreneurship in space-related activities. This includes providing support for research and development, facilitating public-private partnerships, and ensuring access to necessary resources and infrastructure.

The report by Dennis et al. (2018) highlights the role of government spending and taxation in economic development. For space commerce, policy recommendations include offering tax incentives for companies investing in space technology and exploration. Additionally, government spending in space-related research can spur technological advancements that benefit the broader economy. Policies should also aim to ensure that the economic benefits of space commerce are equitably distributed.

The exploration and commercialization of space require a robust regulatory framework. Nassisi, Guiso & Messina (2018) investigation into lunar mining underscores the need for policy revisions to accommodate economic interests in space. Policies should address issues such as space traffic management, orbital debris mitigation, and the use of extraterrestrial resources. Establishing clear and fair regulations will not only protect space assets but also encourage responsible and sustainable space activities.

Space commerce is a global endeavor, and international collaboration is key to its success. Policies should encourage cooperation with other nations and international organizations. This includes aligning with international space laws and treaties, participating in joint missions, and sharing data and resources. International collaboration can lead to shared benefits and reduce the risks associated with space activities.

To sustain the growth of space commerce, investing in education and workforce development is crucial. Policies should focus on developing a skilled workforce capable of meeting the demands of the space industry. This includes promoting STEM education, providing specialized training in space-related fields, and encouraging diversity and inclusion in the space workforce.

Creating an enabling business ecosystem, implementing supportive government spending and taxation policies, establishing a robust regulatory framework, encouraging international collaboration, and investing in education and workforce development are key to realizing the full potential of space commerce. These policy recommendations aim to foster innovation, ensure sustainable development, and maximize the economic benefits of space activities.

4.2.4. Future Economic Scenarios in U.S. Space Commerce

The future of U.S. space commerce is shaped by a range of factors, including technological advancements, policy decisions, and global economic trends. Ralston (2022) outlines three scenarios for the future of the United States, focusing on major uncertainties and their implications. Applying a similar approach to space commerce, we can envision scenarios based on different levels of technological innovation, government support, and international collaboration. For instance, a scenario with high technological advancements and strong government support could lead to a significant expansion of space commerce, with new markets and industries emerging. Conversely, limited technological progress and reduced government support might result in slower growth and missed opportunities.

The report to the President on the U.S. Space Program provides a comprehensive overview of the current status and future plans of U.S. space activities. This report underscores the importance of continued investment in space technology and exploration for maintaining U.S. leadership in space commerce. Future economic scenarios could include increased public and private investment in space infrastructure, leading to more robust commercial space activities and new economic opportunities.

Khan et al. (2015) explore the future evolution of interconnected sectors in the U.S., such as energy and agriculture. This study highlights the interconnected nature of space commerce with other economic sectors. Future scenarios could see space commerce playing a pivotal role in supporting other industries, such as through satellite-based services for agriculture and energy. The development of space-based solar power, for instance, could revolutionize the energy sector and create new economic opportunities.

Whether it leads to a vibrant expansion of new markets and industries or a more modest growth trajectory, the future of U.S. space commerce will undoubtedly have significant implications for the broader economy. Understanding and preparing for these potential scenarios is essential for stakeholders in the space industry and policymakers.

5. Conclusion

The study has comprehensively analyzed the economic impact of space commerce on the U.S. economy, revealing a multifaceted and significant influence. Space commerce has emerged as a vital sector, contributing substantially to the U.S. economy through direct avenues such as revenue generation, job creation, and technological advancements. Indirectly, it has spurred growth in ancillary industries, enhanced global connectivity, and fostered innovation across various sectors. The transition from government-led space exploration to a more commercialized and competitive space industry has opened new economic frontiers, positioning the U.S. as a leader in space commerce. However, this growth is accompanied by challenges, including technological complexities, regulatory uncertainties, and economic risks that need to be navigated.

For U.S. stakeholders in space commerce, the study offers strategic insights. Embracing technological innovation and fostering public-private partnerships are crucial for maintaining competitiveness in the global space market. Stakeholders should focus on developing strategies to mitigate risks associated with space activities, including addressing regulatory gaps and investing in sustainable practices. Additionally, there is a need for continuous investment in research and development to stay at the forefront of technological advancements in space commerce. Collaboration, both domestically and internationally, is essential for leveraging collective expertise and resources, thus enhancing the U.S.'s position in the global space economy.

The study identifies several areas for future research in space commerce economics. There is a need for more in-depth empirical studies to quantify the direct and indirect economic impacts of space commerce on the U.S. economy. Future research should also explore the evolving role of policy and regulation in shaping the space commerce landscape, particularly in the context of emerging technologies and international collaboration. Additionally, examining the long-term sustainability of space commerce and its implications for economic growth and innovation is crucial. Research into the development of new business models in space commerce, especially in the wake of increasing private sector involvement, would provide valuable insights for stakeholders. Finally, exploring the global competitiveness of the U.S. space commerce sector in the face of rising international players would offer strategic guidance for maintaining and enhancing the U.S.'s leadership in this field.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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