Global Trends and Economic Implications of Quantum Communication Technology

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Abstract

Quantum communication technology is emerging as a transformative area in telecommunications, with the potential to revolutionize how data is transmitted, secured, and processed globally. The global quantum computing and communication market is expected to grow rapidly as major technology firms are contributing to the development of quantum communication hardware and software, signaling the commercial potential of such technology.

This paper presents a comparative study of quantum communication across different regions (China, the United States, and the European Union). The result indicates distinct approaches, technological advancements, and strategic goals.

Key words: China's Quantum Science Satellite Project, the EU Quantum Flagship and U.S. National Quantum Initiative
J.E.L. classification: 014, 031, 032, 033, Q55

1. Introduction

Quantum information science and technologies are expected to revolutionize the economy by creating entirely new markets, industries, and business models.

Quantum information science is a multidisciplinary field at the intersection of quantum mechanics, information theory, and computation. Its aim is to combine principles of quantum mechanics with information theory to revolutionize computation, communication, and sensing. The societal and economic roles of quantum technologies are profound, influencing diverse sectors by enabling technologies that were previously considered unattainable.

Quantum communication is a subfield of quantum information science that leverages the principles of quantum mechanics—particularly quantum entanglement and superposition—to enable secure and efficient transmission of information. Unlike classical communication systems that rely on electronic signals or electromagnetic waves, quantum communication uses quantum states, such as photons, as carriers of information. Quantum information science provides unparalleled security for digital communications. Quantum key distribution (QKD) ensures that sensitive data - such as personal, financial, or governmental information - remains secure in an era of increasing cyber threats and privacy concerns.

Beside enhancing data security, the societal role of quantum information science is reflected in advancing scientific knowledge for exploring the limits of physical laws and understanding complex systems, in revolutionizing healthcare, supporting education, workforce development and empowering sustainability and climate solutions.

The economic role of quantum information science and technologies is in creating new markets and industries (e.g. quantum computing services like cloud-based quantum computing platforms offered by companies like IBM, Google, and Microsoft or high-precision devices for medical diagnostics, navigation, and industrial applications), as well as in fostering innovation. For example, quantum-enhanced materials and processes in manufacturing can improve efficiency and product quality. Quantum algorithms can optimize supply chain management and transportation networks in logistics.

As quantum computers evolve, they pose a risk to current encryption standards, threatening global cybersecurity. Investing in quantum-safe cryptography ensures economic stability by pre-empting potential disruptions

The concept of quantum communication first gained significant traction in the early 1980s, with the seminal work of Stephen Wiesner and Charles H. Bennett. Wiesner’s idea of “quantum money” (concept evolved since 1972, but was first published in 1983) introduced the potential of quantum states for secure applications. The concept uses the rules of quantum physics to create money that cannot be copied or faked. Such concept can be compared with embedding an unbreakable code into each note, for security reasons. While there is no technology to implement quantum money widely yet, the idea laid the groundwork for quantum cryptography, which is now a booming field in secure communications.

This was followed by Bennett and Gilles Brassard’s (1984) publication of the BB84 protocol, which became the foundation of quantum key distribution. The protocol represents a method for securely sharing encryption keys using quantum mechanics. In economics, secure communication can be viewed as a problem of transaction costs and trust: insecure communication channels increase the cost of doing business (e.g., losses due to fraud or theft) and parties need to trust intermediaries (banks, governments, or third-party networks) to securely transfer sensitive information, which can introduce vulnerabilities. BB84 protocol addresses this by offering a way to share encryption keys securely, eliminating the need for trust in intermediaries and drastically reducing the risk of eavesdropping („fraud” in the communication market). The principles of BB84 could extend to secure financial transactions, digital currencies, and even smart contracts, where quantum-secure protocols prevent tampering or fraud. Such developments marked the beginning of practical quantum communication research.

2. Research methodology

The objective of this paper is to bring an economic approach to global quantum communication advancements. The methodology consists in delivering a regional comparative analysis carried taking into account three criteria of analysis: quantum communication initiatives, strategies, and advancements in three major developed regions of the globe: China, the United States, and the European Union. The data used for the regional analysis consist in secondary data published online by the international media and international institutions.

3. Literature review

There is a potential of quantum communication to enhance national defense and economic development (Yu, 2004) and in space satellite-based communication as a means to secure global information exchange (Schiavon, 2017). Quantum technologies have a relevant role in future digital economies and communication networks (Manzalini, 2020) and can address challenges in computation and communication, impacting the digital economy (Manzalini, 2021). Overall, they can revolutionize computation, communication, and economic growth (Wang, 2012).

The impact of quantum technologies on innovation processes in the global economy was analysed, including how quantum technologies could drive innovation and economic competitiveness, by Korzh (2024) while the economic implications of quantum communication as a core networking technology were approached by Sridhar et al. (2023)

According to Chehimi & Saad (2022), quantum communication networks can be integrated in future economic and technological systems, and they provide relevant implications for economics and financial systems (Hull et al., 2020).

Quantum communication's role in secure information exchange and societal benefits were approached by (Verma, 2013) and Ratkin had explored the economic implications of quantum communication and cryptography, proposing the term *quantonomics* - economy of quantum computers and quantum communication (Ratkin, 2021). The challenges and opportunities in quantum communication for economic applications were approached by Chen (2021).

4. Findings

4.1. China, US and European Union’s public and private investments in quantum technologies

Quantum information science has become a focal point for public and private investment. Governmental programs like the, China’s Quantum Science Satellite Project, the EU Quantum Flagship and U.S. National Quantum Initiative are channeling billions into research and development. Also, technology giants and startups in the private sector are competing to commercialize quantum technologies, fueling innovation and economic activity.

China has made significant progress in quantum information science, with the Micius quantum satellite experiments and a 987 million USD research funding effort, and is poised for future advancements (Ciang Zhang et al., 2019). Quantum Science Satellite is one of the first five space science missions, slated for launch in the framework of Chinese Academy of Sciences(CAS) Strategic Priority Research Program on space science. The project aims to establish a space platform with long-distance satellite and ground quantum channel, and carry out a series of tests about fundamental quantum principles and protocols in space-based large scale. (Jianwei, 2014). The Micius satellite effectively obtained ultralong-distance global quantum network, enabling secure communication between China and Europe at locations separated by 7600 km on Earth and pointing towards an efficient solution for an ultralong-distance global quantum network. (Liao, 2018).

The U.S. National Quantum Initiative (NQI) established through the National Quantum Initiative Act of 2018, aims to advance quantum information science and its applications. The initiative aimed to maintain U.S. leadership in quantum technologies through establishing multidisciplinary research centers, funding for quantum research through agencies like the National Science Foundation, Department of Energy, and National Institute of Standards and Technology (NIST), and by promoting workforce development and commercialization of quantum technologies. The Quantum Economic Development Consortium (QED-C) is an industry-driven consortium supported by NIST and more than 185 corporations, universities and other organizations to enable and grow the quantum industry and supply chain. (Merzbacher, 2020) showing that the US National Quantum Initiative Act of 2018 promotes effectively quantum information science and innovation, with a focus on economic benefits and industry growth.

Simillar to China and the US, quantum technologies investments in Europe have a recent history. Since the first quantum revolution in the early twentieth century, a whole range of applications in the field of scientific research and societal application has emerged: laser, electronics, satellite-based positioning, medical imagery, etc. (EU Space). According to the European Commission, “developing and deploying a Quantum Communication Infrastructure (QCI) with a terrestrial and space segment represents one of the priorities towards which the European Commission is working on, to project Europe into the quantum era”. The European Quantum Communication Infrastructure (EuroQCI) initiative is a strategic effort by the European Union to develop and implement advanced quantum communication technologies. Its primary goal is to establish a highly secure, quantum-encrypted communication network that connects government institutions and critical infrastructures across the EU. It was designed for developing quantum technologies and ultra-secure communication. The initiative is intended to advance the development of quantum technologies to make them operationally reliable and robust for practical use and to perform space qualification, ensuring these technologies can function effectively in space environments.

EuroQCI initiative represents a pivotal step toward establishing a secure, resilient, and advanced communication network based on quantum technologies. It aims to enhance Europe's cybersecurity, technological leadership, and digital sovereignty while fostering innovation and industrial growth.

The initial steps within the EuroQCI initiative consisted in the establishment of the first quantum network linking three different countries by the cities of Trieste in Italy, Rijeka in Croatia, and Ljubljana in Slovenia (Ribezzo et al, 2024).

In 2016, the European Commission was preparing for the launch in 2018 of a €1 billion flagship initiative on quantum technologies, suggestively named "the second quantum revolution", envisioning technological advancements in science, industry and society (EC, 2016) like satellite-based services as well as the EU space programmes to improve the daily life and security of citizens. The grants were planned for European research in "quantum secure communication, quantum sensing and quantum simulation and computing into concrete technological opportunities that can be taken up by industry" (EC, 2016).

It is expected that in less than 10 years, the second quantum revolution will have a significant impact over numerous industries, including finance, medicine, energy, transportation, etc. (Farrugia et al, 2024).

4.2. Global trends and economic implications

As costs decrease and accessibility improves, quantum technologies will become available to smaller businesses and developing nations, reducing economic disparities and fostering global innovation. Quantum technologies are expected tp disrupt industries reliant on classical computing by offering superior solutions for complex problems. This shift necessitates adaptation and re-skilling in sectors like finance, logistics, and healthcare.

Nations are racing to achieve quantum supremacy, recognizing its strategic and economic importance. Simultaneously, international collaborations are fostering shared progress, as seen in initiatives like the Quantum Internet Alliance.

Such global trend is expected to generate millions of high-paying jobs in fields like quantum engineering, software development, and cryptography. The ripple effects will stimulate growth across related industries.

China's advancements are highlighted by the Micius satellite and its successful demonstration of ultralong-distance quantum communication. The country has also established a 2,000-km quantum communication backbone linking Beijing and Shanghai. These achievements position China as a leader in space-based quantum communication and practical applications of quantum networks. With such satellite experiment, China's strategy emphasizes state-led investments and rapid deployment of large-scale quantum projects. By focusing on space-based quantum communication, China seeks to achieve technological sovereignty and secure communication capabilities, ensuring strategic advantages in cybersecurity and military applications. Collaboration with European institutions through experiments like Micius reflects a blend of competition and cooperation. China is poised to secure economic benefits through secure communication networks and exportable quantum technologies, by achieving technological sovereignty in quantum communication, potentially dominating the global market.

The U.S. strategy revolves around fostering a robust quantum ecosystem through public-private partnerships and industry-driven initiatives. The NQI ensures a balance between fundamental research and commercialization, with significant investment in workforce development to address the talent gap in quantum technologies. The U.S. approach prioritizes scalability and integration of quantum solutions into existing technological and economic frameworks. The U.S. leads in quantum computing and private-sector innovation, with companies like IBM, Google, and Microsoft achieving milestones in quantum supremacy and error correction. The NQI has catalyzed advancements in quantum sensing and simulation, with applications spanning medicine, finance, and national security. Initiatives like QED-C are driving the standardization and commercialization of quantum technologies. The U.S. focus on commercialization and public-private collaboration positions it as a hub for quantum startups and industry innovation, with economic impacts spanning multiple sectors, including defense and finance.

The EU's strategy is rooted in fostering digital sovereignty and enhancing cybersecurity through quantum technologies. By integrating quantum communication into existing space programs and creating a unified European infrastructure, the EU aims to consolidate its technological capabilities and ensure resilience against cyber threats. The EuroQCI initiative reflects a commitment to industrial growth and the operational reliability of quantum technologies. The EU has made significant progress in developing a secure quantum communication infrastructure. The EuroQCI initiative has established the first multinational quantum network and aims to integrate terrestrial and space segments. The EU Quantum Flagship has fostered advancements in quantum simulation and sensing, with applications expected to transform industries like transportation, energy, and healthcare within the next decade. The EU's emphasis on digital sovereignty and cybersecurity aligns with its economic strategy of fostering innovation while ensuring resilience against cyber threats. The integration of quantum technologies into space programs could yield significant economic returns through enhanced satellite-based services.

5. Conclusions

Quantum information science is a transformative force with far-reaching implications for society and the economy. It offers unprecedented opportunities to enhance security, solve complex problems, and drive innovation across industries. However, its potential can only be fully realized through strategic investment, international collaboration, and a commitment to ethical development. As quantum technologies continues to evolve, it will undoubtedly shape the technological and economic landscape of the 21st century.

Quantum communication addresses critical needs for secure data transmission in finance, defense, and healthcare. The rise in publications corresponds with national quantum initiatives (e.g., China's quantum satellite Micius, the EU Quantum Flagship, and the US National Quantum Initiative), underscoring the strategic importance of the field.

China, the U.S., and the EU each exhibit distinct approaches to quantum communication, reflecting their geopolitical and economic priorities. While China excels in state-led, large-scale quantum initiatives, the U.S. focuses on commercialization and industry growth, and the EU prioritizes cybersecurity and digital sovereignty. Together, these efforts are driving a global quantum revolution with transformative economic implications.

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