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QUANTUM COMPUTING: UNLOCKING NEW POSSIBILITIES IN FINANCIAL SERVICES

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ELEVANDI

Contents

Foreword

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In an era marked by rapid technological advancement, quantum computing stands out as one of the most transformative developments of our time. Its potential to revolutionise industries is vast, and nowhere is this more evident than in the financial services sector. As the demands on financial institutions continue to grow—driven by the need for faster processing, more accurate predictions, and enhanced risk management-quantum computing offers a new frontier of possibilities.

This report, "Quantum Computing: Unlocking New Possibilities in Financial Services," explores the significant impact that quantum technology is set to have on the financial industry. It examines how quantum computing may help to solve some of the toughest challenges in finance today, from optimising large portfolios, to enhancing cryptographic security, and transforming risk management.

As we approach this new era of quantum innovation, it's important to understand both the opportunities and the challenges that this technology presents. The insights provided in this report not only highlight the current state of quantum computing in finance, but also encourage forward-thinking and innovation as we navigate this exciting landscape.

Quantum computing is no longer a distant dream but an emerging reality. Its integration into financial services promises to reshape the industry, enhancing efficiencies and unlocking possibilities once deemed unimaginable. This report offers valuable insights for those seeking to leverage quantum computing to unlock new opportunities and stay ahead in the rapidly evolving financial landscape.

Introduction

Quantum technologies can be broadly divided into three main sectors: **quantum sensing, quantum communication, and quantum computing**. While all three have potential applications in financial services, the most explored area so far has been quantum computing. Investigations have delved less, by contrast, into the applications in the financial services industry of quantum sensing and quantum communication. This report, therefore, focuses primarily on quantum computing and its potential impact on financial services.

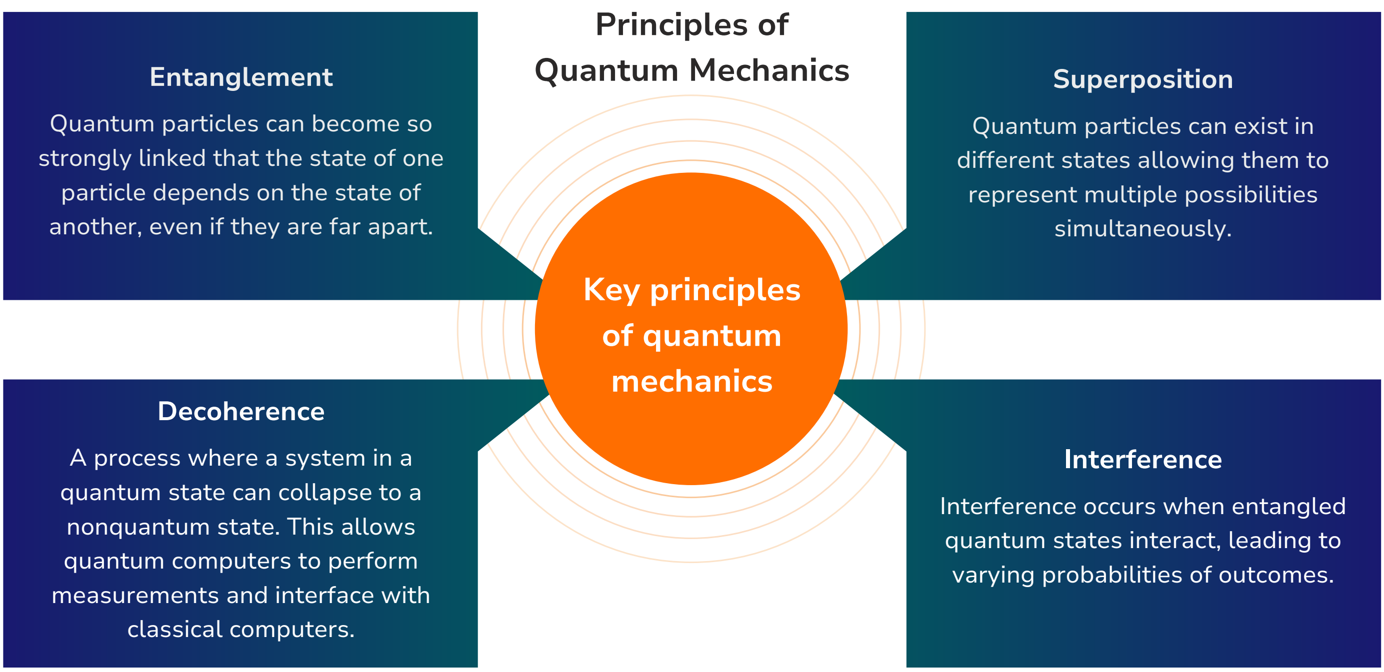
The report analyses quantum computing and its implications for the financial services sector in-depth. It covers three key areas:

1. The current state of quantum computing technology and its ongoing development
2. Potential applications of quantum computing in the financial services industry
3. Challenges and risks associated with the adoption of quantum computing in financial services

By focusing on quantum computing, the report aims to offer a comprehensive understanding of how this emerging technology can revolutionise the financial services industry and the key considerations for its adoption.

What are Quantum Technologies

Quantum technologies include three key areas: quantum sensing, quantum communication, and quantum computing. The report goes deep into 'quantum computing,' but we'll start with a summary of all three fields.



Quantum Sensing

This is the field of quantum technology in which researchers are working to develop ultra-sensitive devices that measure minuscule movements and changes in electromagnetic fields (CSIC, 2023). These devices will allow highly accurate measurements.

The applications of the field can be primarily divided into five categories—electromagnetic sensors, imaging, gravimeters and gradiometers, thermometers and barometers, and transversal applications.

In financial services, **research shows potential in utilising this technology to synchronise time across financial systems, ensuring consistency, compliance, and efficiency** (Capgemini, 2023). However, the adoption and concrete implementations of these synchronisation solutions in real-world financial environments remains nascent.

Challenges to Unlocking Quantum Sensing's Full Potential

Case for change

In some industries, limited attractiveness compared with existing sensors stemming from:

- High setup costs
- High operating costs
- Unclear performance advantages

Sensitivity

Extreme sensitivity of the sensors is their greatest strength and weakness:

- Results can be corrupted by unfiltered noise when devices are used outside the laboratory
- Regulators expect accuracy and safety to be proven before deployment

Integration

Integration with other processes can be difficult, often requiring:

- Customisation (systems may not have been designed for quantum sensing)
- Production-scale miniaturisation

Scalability

Scaling up production is currently hampered:

- Niche applications account for most current applications
- Complex manufacturing processes require numerous specialised experts to produce few units

Awareness

General lack of awareness and knowledge hinders understanding of benefits, affecting financing and adoption by potential:

- Investors
- Users
- Customers

Barriers to standardisation

Source: Boston Consultancy Group (July 2023)

Quantum Communication

Quantum communication is an area that **explores the use of quantum technologies to securely exchange information or keys to encrypt information** (Richdale, PZF, 2024). The area could be used to secure payment infrastructures or establish new ways of communication between financial institutions, thus, enhancing interoperability. This field focuses on improving the performance of Quantum Key Distribution (QKD).

"Quantum communication is an area that explores the use of quantum technologies to securely exchange information or keys to encrypt information"

Kelly Richdale
Venture Partner,
Amadeus Capital Partners and Senior Advisor,
SandboxAQ at Point Zero Forum 2024, Zurich.

QKD can serve as a foundational technology for future quantum internet applications. Notably, potential applications of the quantum internet that may be relevant for banks include timing synchronization for transaction settlements or smart contracts (Capgemini, 2023).

Definition: Quantum Key Distribution

A Quantum Key Distribution (QKD) is a secure communication method which uses quantum physics principles to create and share encryption keys between two parties. To put it in even simpler words, a QKD works by sending individual light particles or photons over a fiber optic cable from one party to another.

The major advantage of a QKD is its security based on fundamental laws of Physics, rather than complex mathematical problems - making it 'unhackable' in theory.

Quantum Computing

Quantum computing is an area that leverages the principles of quantum mechanics to develop a much faster and more efficient quantum computer to solve complex problems. During the Point Zero Forum 2024, Dr. Philip Intallura, Head of Quantum Technologies at HSBC, described Quantum Computing as **not just a faster computer, but a completely different and new way of processing information.** Unlike classical computing, this technology relies on quantum bits or qubits. The t**echnology uses atomic and subatomic matter like photons, electrons, superconductors, and ions.** These qubits can exist in superposition states, unlike classical computers, in which bits can only exist in either 0 or 1 state. By using quantum theory, the amount of information that can be encoded on a quantum computer is much larger than on classical computers.

Definition: Qubit

A qubit is short for a quantum bit. These are constructed from photons, atoms, or ions. Unlike classical bits, qubits can exist in a superposition, meaning existing in multiple states simultaneously. In simpler words, a qubit can be in a state of 0, 1, or both simultaneously. This property of a qubit differentiates them from classical bits and underpins the power of quantum computing.

This system of control is referred to as 'quantum control'. It is a vital enabler of quantum computing as it allows quantum algorithms to be performed with optimal efficiency and effectiveness.

The chart on next page shows global investment in the three fields as of 2023, where Quantum computing has attracted the most capital from 2022-2023 globally.

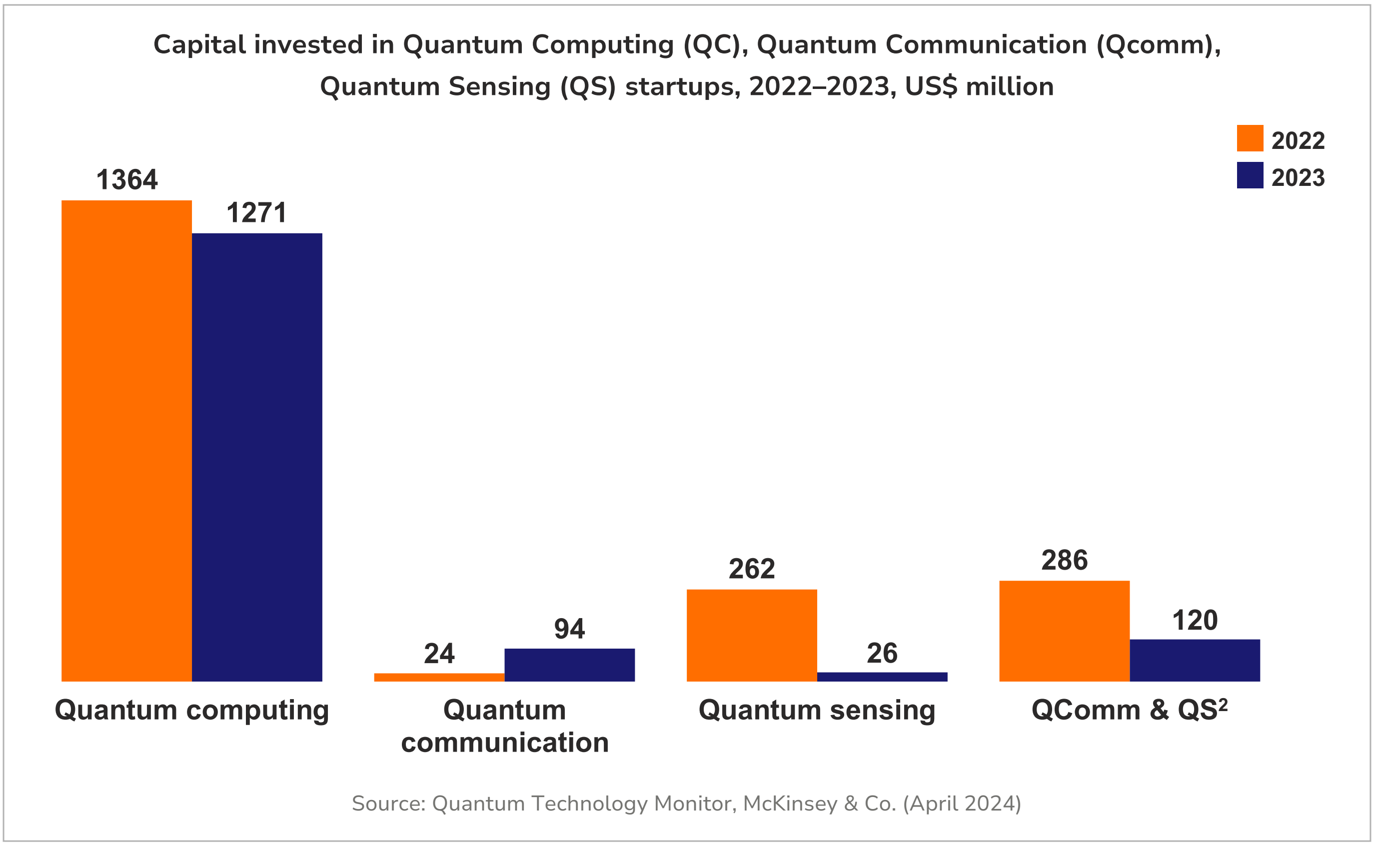
Deep Dive into Quantum Computing

From the Early 20th Century to the 2020s

Quantum computing dates back to the early 20th century, and divided into four time periods.

1. The foundation period

Many renowned scientists at the time contributed to the theory of quantum mechanics, which would later form the principles of quantum computing. These scientists included Max Planck, Albert Einstein, Niels Bohr, Werner Heisenberg, John von Neumann, and more (Salim, 2022). The scientific research delved into ground-breaking developments in topics central to quantum mechanics – for example, concepts of quantised energy levels, the photoelectric effect, the Bohr model of the atom, the phenomenon of entanglement in quantum mechanics, and a mathematical framework for quantum mechanics.



2. The emergence

In the early 1980s, the concept of quantum computing started to gain momentum. Researchers and scientists began to explore the potential of the technology to increase computational competencies.

3. The development stage

During the mid-1990s, there was significant progress in quantum algorithms. Peter Shor, an American mathematician, and Lov Grover, an Indian-American computer scientist, developed algorithms with significant implications for computing. Shor's algorithm offered an efficient method of factoring large numbers, while Grover's algorithm provided a more effective approach to searching unsorted databases (Shor, 1999) (Grover, 1996). The development of these algorithms was groundbreaking in the field of quantum computing, generating profound interest from both researchers and investors. Furthermore, these demonstrated the potential impact and benefits of quantum computing. The success of these algorithms and proven benefits spurred developments in the field.

4. The race to build quantum computers

Up until the late 20th century, research had explored the potential of quantum technology. However, the race began only twenty years ago in the early 21st century. Tech giants, startups, and researchers started to build practical machines. Two notable events: 1) In 2011, D-Wave One was claimed to be the first commercially available quantum computer, built by D-Wave Systems. However, researchers speculated about the nature of this computer. Many argued that these computers only enhanced the speed of classical computers (Zeeya, 2011). 2) In 2019, Google achieved "quantum supremacy" by building a 53-qubit Sycamore processor. The computer was claimed to have solved a problem in 200 seconds that would take around 10,000 years to complete on a classical computer (BBC News, 2019).

5. The 2020s

In the last 3 – 4 years, the technology surrounding quantum computing has seen tremendous progress. The research is continuously focusing on bringing down complexity through quantum computing, which classical computing is unable to address. **Quantum computing is expected to reach mass adoption in the early 2030s** (Deloitte, 2023).

The transformative power of the technology lies in its **ability to increase the performance of a computational unit exponentially,** explained Dr. Alessandro Curioni during the Point Zero Forum 2024. For example, adding one processor to a classical computing unit increases performance by 10%, whereas **adding one unit to a quantum computer system of an existing ten units will double the performance for certain applications** (Intallura, 2024).

IBM, a leading computer manufacturer, has recently announced that the world has entered the **'era of quantum utility',** marking a transition from quantum computing research being predominantly academic to becoming a valuable and usable technology in industries, where quantum computing hardware and algorithms are applied to solve meaningful and practical large-scale problems.

"The transformative power of the technology lies in its ability to increase the performance of a computational unit exponentially"

Dr. Alessandro Curioni
IBM Fellow, Vice President, Europe & Africa and Director, IBM Research at Point Zero Forum 2024, Zurich.

6. What next?

In the next decade or so, the quantum universe will focus on expanding toolkits to enhance algorithms to correct errors. Eventually, businesses will be able to extract commercial value from these systems.

Critical Challenges for Quantum Computing

The major challenges in quantum computing revolve around (1) making the hardware a reality and (2) bringing error rates down.

As quantum computers use atomic and subatomic particles to solve complex problems, it is necessary to prevent them from interacting with the environment (Intallura, 2024). A quantum computer qubit is highly fragile and any disturbance, including slight changes in light, vibrations, and increased temperatures, can lead to discrepancies in calculations. This is referred to as **quantum decoherence.**

"As quantum computers use atomic and subatomic particles to solve complex problems, it is necessary to prevent them from interacting with the environment."

Dr Philip Intallura
Head of Quantum Technologies, HSBC, Point Zero Forum 2024, Zurich.

Currently, the size and cooling equipment are beyond the capabilities of existing commercially available systems, making the commercialisation of quantum computers a distant prospect.

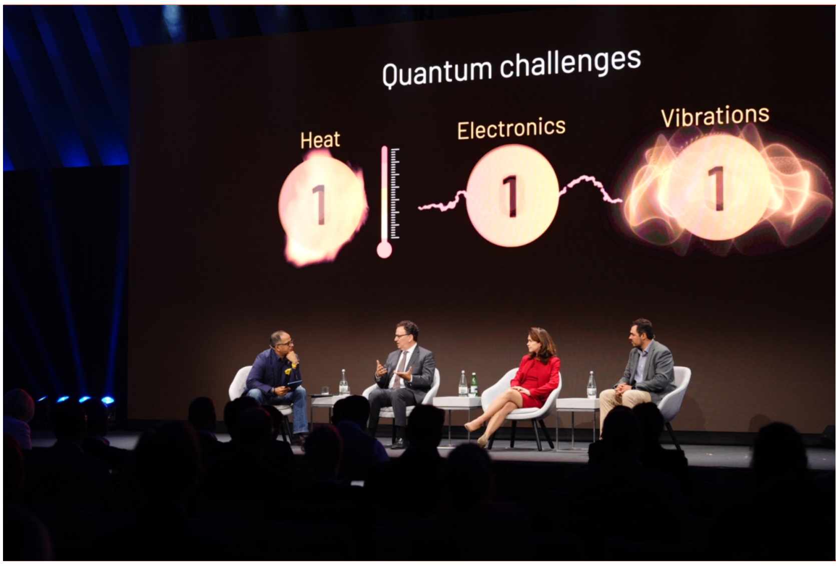
In order to bring scalability to quantum computing, it is vital to increase the number of qubits efficiently. The more qubits, the greater the potential for handling complex problems. However, introducing more qubits increases the number of error sources. Thus, the density of errors must be low for logical performance to improve with increasing code size (Google Quantum AI, 2023).

For context, IBM at Point Zero Forum in July 2024 revealed that the expected error rate is 1 over 1 trillion, which is the error rate of a classical computer. However, currently, a quantum computer's error rate is only reaching 1 over 10,000 (Alessandro, 2024). Therefore, it is important to find the right balance between the number of qubits and error rates.

Research is ongoing on developing new algorithms to enhance the quality of qubits and to improve error correction. Governments and the private sector are investing heavily in the rapidly advancing technology. For instance, China has invested a total of more than US$15 billion in the technology, whereas the US has invested over US$3 billion (McKinsey, 2024).

Finally, the existing talent gap in the quantum workforce is a challenge to creating business value. Projections indicate that only half of the available quantum computing job openings will be filled by 2025. Furthermore, there is only one qualified candidate for every three job openings in the field (McKinsey, 2022).

In the current state, only 29 out of 176 quantum research programs at universities worldwide offer graduate-level degrees in the subject (McKinsey, 2022). By focusing on crucial areas, such as defining a clear talent need, investing in translators to bridge technical and business knowledge, and creating pathways for a diverse talent pipeline, organisations can ensure timely access to the quantum computing talent they require.



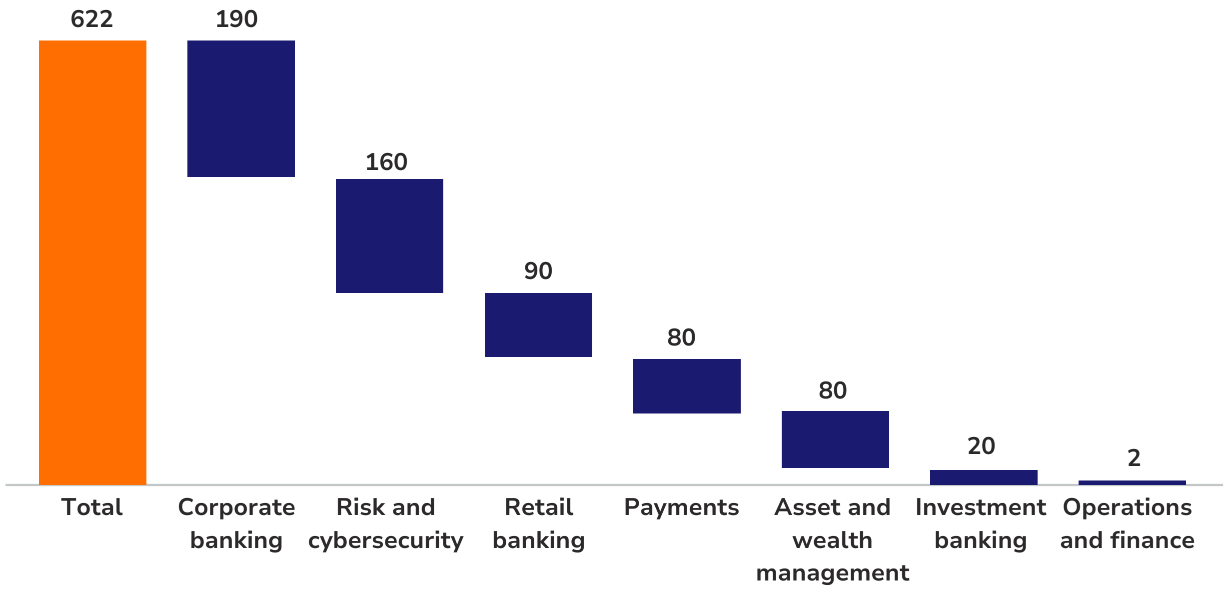
Masterclass on quantum technologies: Decoding the future of computing, Point Zero Forum 2024, Zurich.

Applications of Quantum Computing in Financial Services

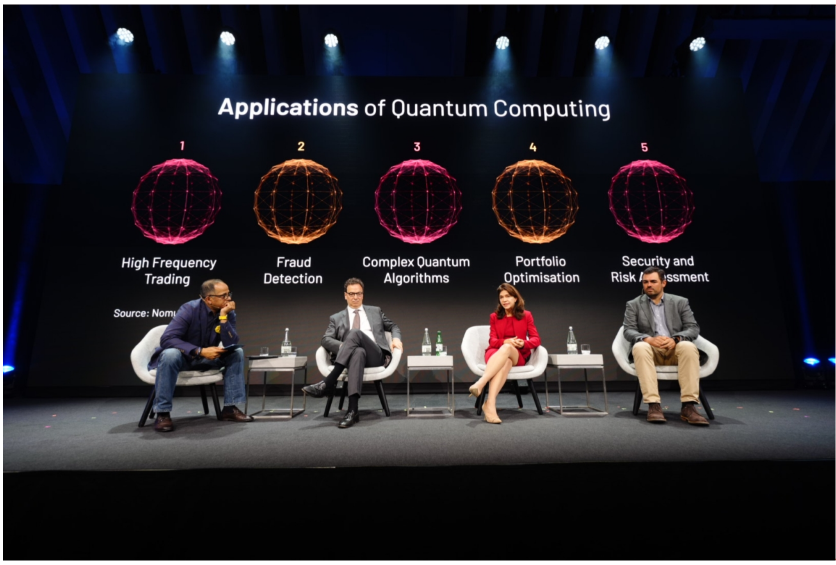
Experts believe that a full-scale fault-tolerant quantum computer could be in operation by 2035 (McKinsey, 2023). Indeed, **McKinsey estimates that applications of a quantum computer in financial services could generate more than US$622 billion in economic value by that year** (McKinsey, 2023). *(Chart on next page)*

The technology holds immense potential to revolutionize the financial sector. There is anticipation of tech convergence at the infrastructure level, wherein specific tasks will be run on quantum computers while others will still run on classical computers. Ultimately, Graphics Processing Units, Central Procession Units, and Quantum Processing Units will coexist to enhance efficacy and productivity in the financial sector (Richdale, PZF, 2024).

Value Of Quantum-Computing Use Cases, by Business Unit (US$ billion)



Note: Assumes that 50% of the full potential in the finance industry will be realised by 2035.
Source: McKinsey & Company, 2023.



Masterclass on quantum technologies: Decoding the future of computing, Point Zero Forum 2024, Zurich.

Here are some potential use cases of quantum technology in finance:

1. The most significant applications of quantum computing in financial services are expected to be in investment and corporate banking. In corporate banking, quantum computing could assist with **portfolio optimisation and securities lending collateral optimisation.** These optimisation problems become increasingly complex with more variables and constraints. While a quantum computer may not solve the entire problem, specific parts of the process could be deployed to a quantum computer for higher precision calculations. The results would then be integrated into the overall problem-solving.

In investment banking, quantum computing **could impact pricing strategies and portfolio optimisation,** which are essential yet challenging tasks. This could affect a range of financial products from insurance to options, derivatives, stocks, digital assets, and more. Quantum computing has the potential to significantly enhance high-dimensional Monte Carlo simulations, which could be particularly impactful in fields such as financial risk analysis, where large-scale simulations are essential for predictive modelling and informed decision-making. This, in turn, could increase customer satisfaction and profitability through more accurate pricing and portfolio optimisation.

Overall, the ability of quantum computers to handle large amounts of data and complex problems makes them well-suited for optimising portfolios and pricing strategies in investment and corporate banking.

2. The financial services sector invests heavily in risk management, and quantum computing has the potential to transform existing machine learning models to enhance credit scoring and overall risk management. By leveraging its capacity to process large datasets and perform complex calculations, quantum technology can improve risk analysis methodologies. For example, it can enhance calculations of Value-at-Risk, facilitate more sophisticated scenario analyses, and provide more accurate probability assessments.

   Additionally, quantum computing will impact fraud detection, an increasingly critical area as the incidence of fraud, phishing, and scams in financial services rises with technological advancements. Quantum technology can enhance fraud detection capabilities by rapidly identifying deceptive activities, thereby improving the sector's overall security.

   The integration of improved risk analysis and fraud detection capabilities will empower financial institutions to make better-informed investment and business decisions. This, in turn, will lead to increased profitability and resilience. By adopting quantum computing in their risk management practices, firms can gain a competitive edge in navigating the complexities of financial markets, ultimately transforming how they operate and respond to challenges.

3. Blockchain technology has demonstrated its potential to enhance payment speeds at both customer and inter-bank levels. Quantum computing is set to further improve security and accelerate payment processes. According to McKinsey, quantum computing could effectively address money laundering issues on blockchain platforms (McKinsey, 2023). Additionally, this technology could bolster security for intra- and interbank system interfaces, facilitating faster payment settlements (Quantum Zeitgeist, 2024).

4. Financial institutions will also reap the benefits of quantum computing by making more accurate predictions. Quantum computers can offer real-time analysis of financial market data, which will greatly impact investment strategies and revenues for the financial services industry. Furthermore, quantum computing will be able to solve complex problems such as faster and more accurate investment decisions by enhanced Monte Carlo simulations that could translate into billions of revenues from higher profits (Spiceworks, 2024).

"If you accept that there is a finite probability that a quantum computer capable of breaking asymmetric cryptography will exist, say within the next ten years, how long will it take you to upgrade your cryptographic infrastructure, and what is the expected lifetime of your data? If you do not yet know the answers to these questions, the time to act is now! Once you know these answers, you can start to prioritize your efforts and be better prepared once standards are finalized."
— Colin Soutar, Managing Director, Deloitte & Touche LLP

Key Risks of Quantum Computing

As interest, investments, and exploration of quantum computing use cases in the financial services sector intensify, it is crucial to address the potential threats posed by this emerging technology.

The first and most significant risk posed by quantum computing is its potential to break existing encryption codes. Currently, online data is secured using encryption standards such as Rivest–Shamir–Adleman (RSA) and elliptic curve cryptography (ECC), which utilise key sizes ranging from 1,024 to 2,048 bits. However, these key sizes may not be entirely secure against quantum computers. **Research indicates that a quantum computer could potentially crack a 2,048-bit RSA key in as little as eight hours** (Gidney & Ekerå, 2021). This implies a great threat to entire encryption standards today.

Moreover, attackers could employ a 'harvest-now, decrypt-later' strategy, allowing them to steal encrypted files and store them until more advanced quantum computers become available. Notably, operational quantum computers capable of breaking existing cryptographic methods don't exist today, and significant investment is still required to develop a quantum computer that can effectively do so. Consequently, for now, such technology remains largely out of reach for misuse (MIT Technology Review, 2019). **In anticipation of when quantum computers are available, attackers could employ a 'harvest-now, decrypt-later' strategy, allowing them to steal encrypted files and store them until more advanced quantum computers become available.** Cybersecurity experts have expressed concerns that nation-states and cybercriminals may already be engaging in harvest-now, decrypt-later attacks, hoarding encrypted data with the intent to decrypt it once quantum computers become powerful enough. Notably, Deloitte's Colin Soutar indicated that adversaries are targeting organizations with this strategy, although he did not confirm specific instances of such attacks occurring (Tech Monitor, 2023).

Time for Action: Quantum-Proofing IT systems

Given the risks posed to existing encryption standards, the importance of post-quantum cryptography cannot be overstated. Post-quantum cryptography encompasses cryptographic algorithms specifically designed to withstand the threats posed by quantum computers. This field of research aims to create new cryptographic systems that ensure the security of sensitive data and communications in a future dominated by quantum technologies.

Financial institutions must recognize the potential threats that quantum computing presents to their operations. **To maintain a competitive edge, these institutions need to develop a quantum-proof IT ecosystem that addresses vulnerabilities associated with this emerging technology.** However, this transition is lengthy and costly. Implementing quantum-proof systems will ultimately free the financial sector from the burden of securing multi-million-dollar budgets for quantum computing resources (Mohanty, PZF, 2024).

National Strategies for Quantum Technologies

Globally, quantum investments by governments are estimated to be around US$42 billion as of June 2024 (Qureca, 2024) (McKinsey, 2024). The primary nations investing in quantum technologies are China, Germany, the United Kingdom, and the United States, collectively accounting for 68% of total investments in this field.

NATIONAL STRATEGIES FOR QUANTUM TECHNOLOGIES

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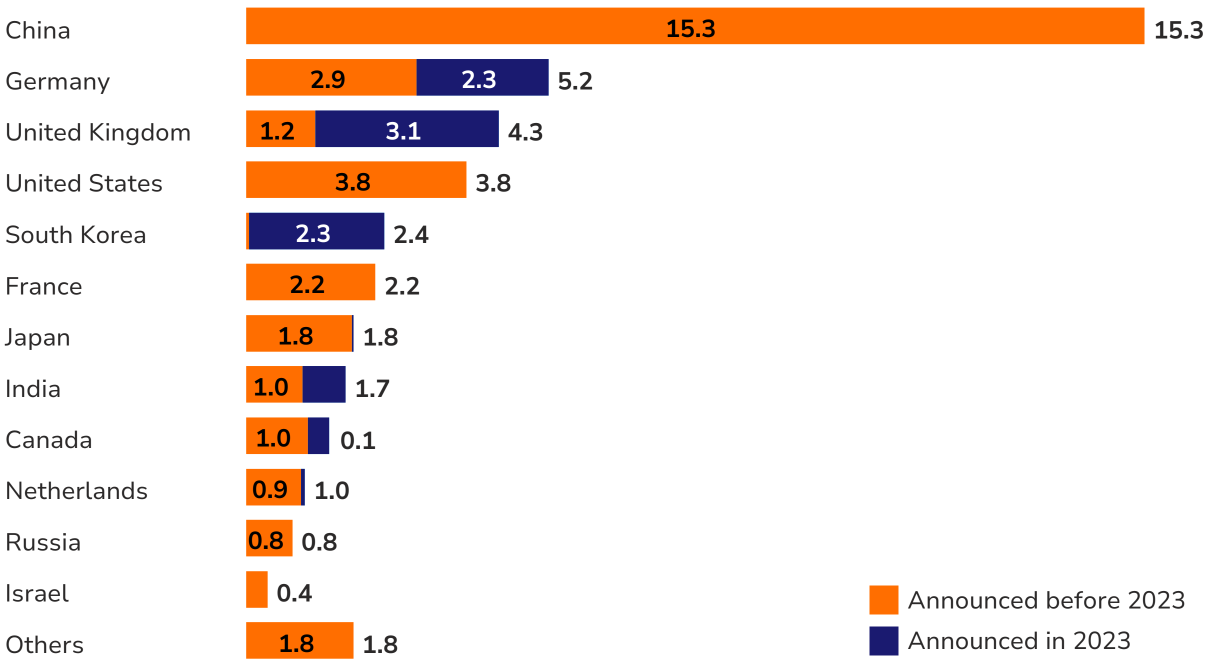
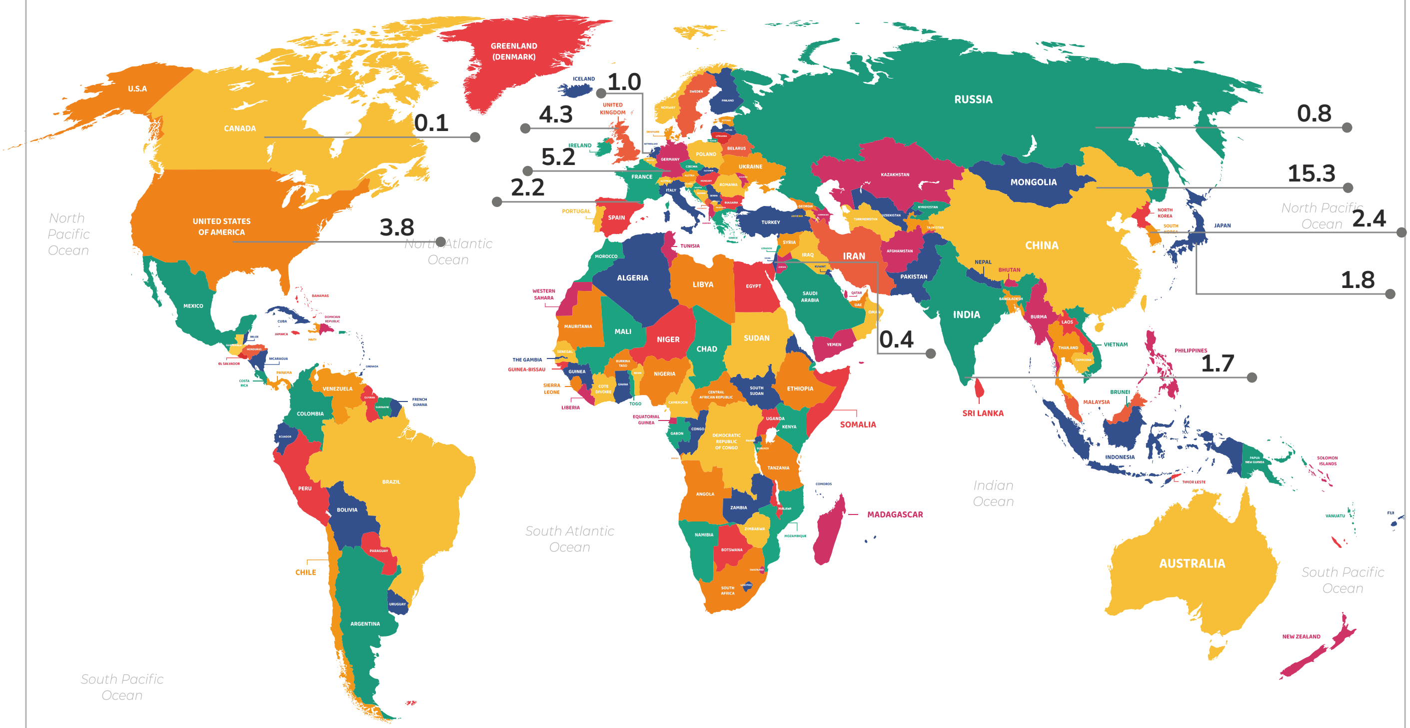
Global Public Investments in Quantum Technology in 2023

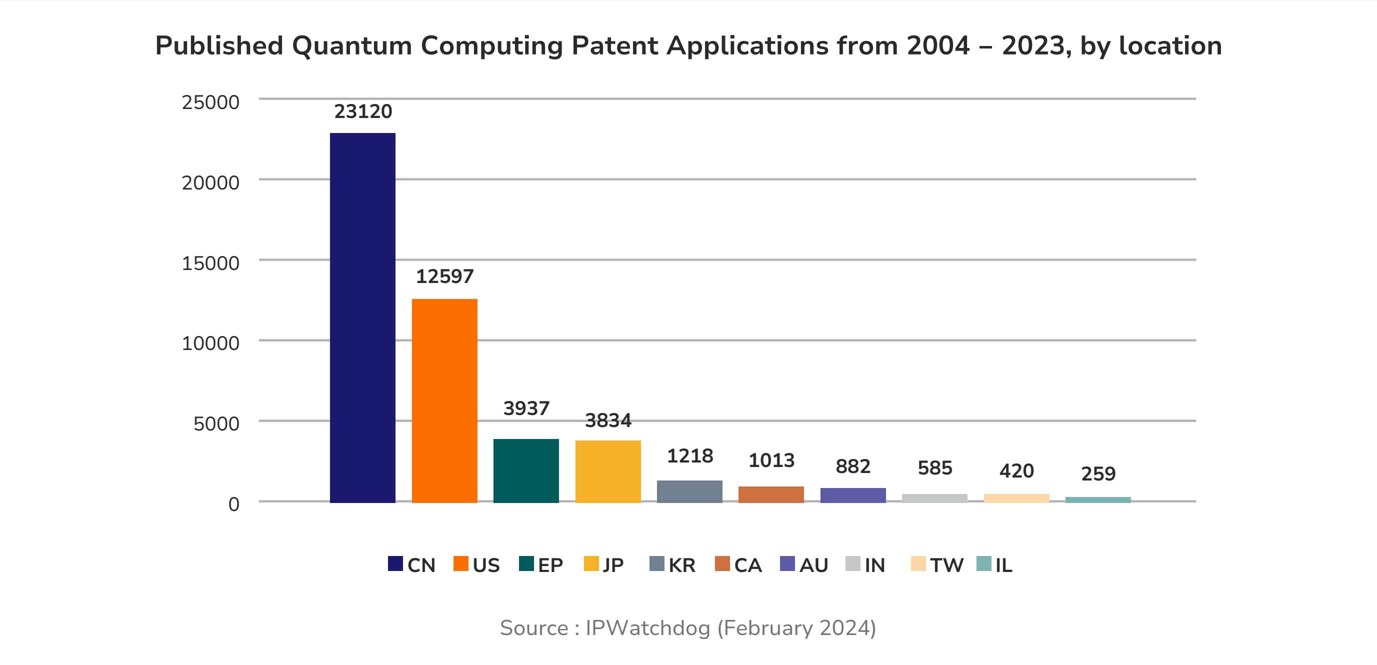
Announced government investment, US$ billion



Source: Quantum Technology Monitor, McKinsey & Co. (April 2024)

Global Public Investments in Quantum Technology in 2023





China

China has invested most (US$15.3 billion) in quantum technology as part of its 14th five-year plan from 2021–2025. This is more than double the European Union's commitment (US$7.2 billion), and eight times the United States' (US$1.9 billion). China also has the highest number of patents from 2004–2023, followed by the United States, the European Union, and Japan.

Germany

The country's public investments have totaled US$5.2 billion in quantum technology as of 2023. It plans to build a 100-qubit universal quantum computer by 2026, that sees potential to grow up to 500 in the medium-term (IOT World Today, 2023). In June 2024, Leibniz Supercomputing Centre and IQM Quantum Computers integrated a 20-qubit quantum computer into a supercomputer in Germany, making it the first hybrid (HPC Wire, 2024).

United Kingdom

According to the UK's National Quantum Strategy, the country's vision is to create a coherent government, industry, and academic quantum technology community that will position the UK as a world leader in emerging multi-billion-pound new quantum technology markets, enhancing the value of major UK-based industries (UK Research and Innovation, 2015). As of 2023, the UK ranks as the third-largest investor in quantum technologies globally.

United States

The United States has established itself as a global leader in quantum technology development and implementation. In 2018, the U.S. government passed the National Quantum Initiative Act, allocating $1.2 billion over five years to accelerate quantum research and development. This initiative has led to the creation of several national quantum research centers, including those at major institutions like the University of Chicago, MIT, and Harvard. The U.S. quantum ecosystem is characterized by strong collaboration between academia, industry, and government agencies. Tech giants such as IBM, Google, and Microsoft are heavily invested in quantum computing research, with IBM and Google both claiming quantum supremacy milestones.

Japan

Japan's public investment stands at US$1.8 billion (McKinsey, 2024). Fujistu, the largest Japanese IT services provider, and RIKEN, a national scientific research institute in Japan unveiled a new 64-qubit superconducting quantum computer at the RIKEN RQC-Fujitsu Collaboration Center. The collaboration revealed a new hybrid platform that leveraged the 64-qubit quantum computer to accelerate research and development for quantum financial algorithms (Fujitsu, 2024).

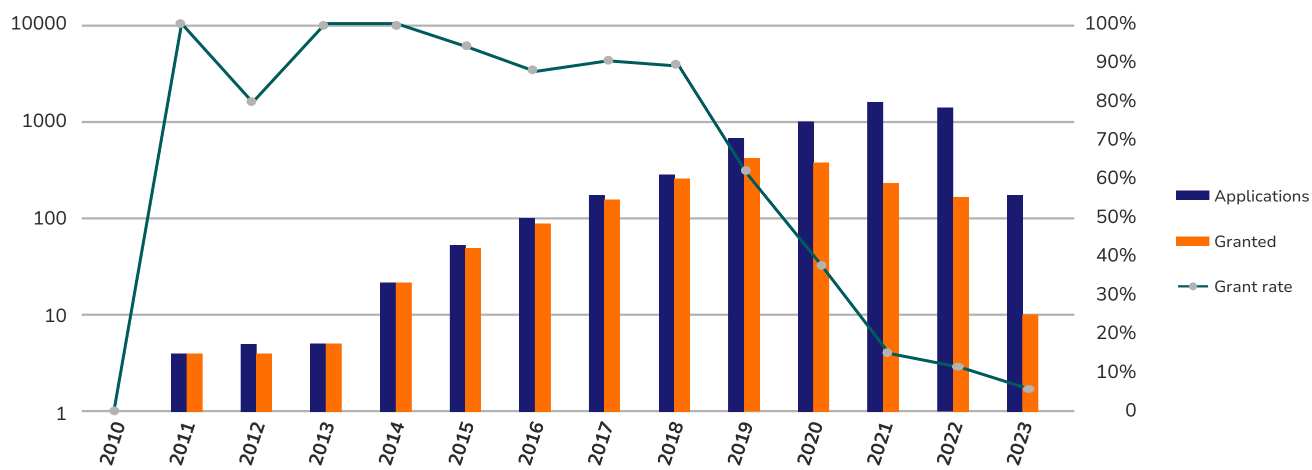
Singapore

The Monetary Authority of Singapore (MAS) committed an additional S$100m in July 2024, bringing the total investment over the next five years in quantum technology research and talent development to S$400m (Straits Times, 2024). The investment supports building quantum capabilities that in turn will support financial institutions in Singapore. MAS announced its National Quantum Strategy in May 2024 to establish a quantum track under FSTI 3.0, launched during the Singapore FinTech Festival 2022 with an initial investment of S$150m. The country's National Quantum Strategy is focused on four different cores: scientific excellence (Centre for Quantum Technologies), engineering capabilities (Quantum Engineering Programme), talent development (National Quantum Scholarships Scheme), and innovation and industrial partnerships (National Quantum Office).

India

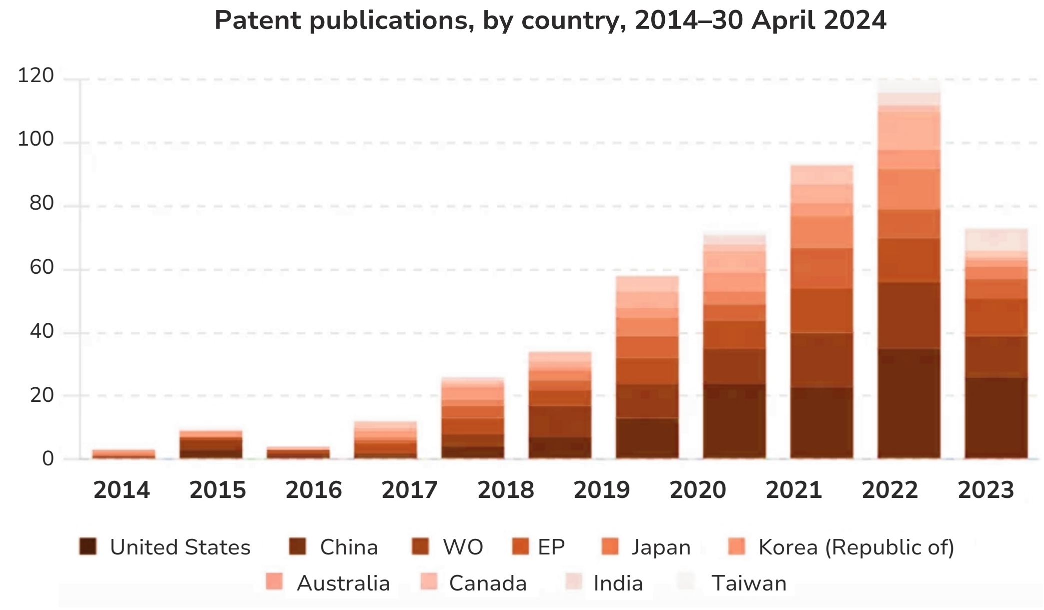
In early August 2024, Q-CTRL, a global leader in quantum infrastructure software, partnered with Quantum AI Global, India's foremost quantum communication and technology company, to enhance the skills of the emerging workforce. This initiative is the first globally to advance quantum education. It will require mandatory quantum computing education in technical universities. The drive aims to address the wide talent gap in the industry (Times of India, 2024).

Number of Applications, Patents, Grant Rate in Quantum Computing, 2010–2023



Note: The applications and patents trends of the technology are identified by the IPC group "G06N 10" which encompasses quantum computing technologies. These include "Quantum computing", its "Physical realisations", "Models", and "Algorithms", "Quantum error detection/correction", and "Quantum programming".

Source: Murgitroyd (January 2024). An Introduction to Quantum Computing and Patent Trends.



WO = World Intellectual Property Organization, EP = European Patent Office.
Source: The Quantum Insider.

Project Leap

A joint project by the BIS Innovation Hub, the Bank of France, and Deutsche Bundesbank aims to quantum-proof the financial system. The initiative also aims to raise awareness among central banks about threats of quantum computing. The first phase of the project investigated solutions that exemplify cryptographic agility. It demonstrated the feasibility of implementing new quantum-resistant schemes (BIS, 2023). Future phases of the project include testing post-quantum cryptography in a more complex environment. It might address central banking use cases to enhance security among central bank communications.

Conclusion

The evolution of quantum computing is a transformative leap in technology, promising to revolutionize many sectors, particularly financial services. Its potential applications range from optimizing financial portfolios to enhancing risk management and improving payment systems. However, these advancements pose significant challenges, including issues related to encryption, talent shortages, and regulatory frameworks.

The global landscape features substantial investments and initiatives to harness the power of quantum technologies. Countries like China, Singapore, India, Japan, and the United States are leading the charge, establishing robust frameworks to support research and development while addressing the inherent risks associated with quantum advancements.

The successful integration of quantum computing into mainstream applications, however, will depend on overcoming these challenges and fostering collaboration among governments, academia, and the private sector. The journey toward a quantum-enabled world is just beginning, and the next decade will be crucial in shaping this groundbreaking technology.

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Coverage at the Singapore FinTech Festival 2024

Come join us from November 4–8, 2024 at the [Singapore FinTech Festival](#) and engage in exhilarating conversations with industry leaders about the transformative impact quantum computing will have on financial services.

Festival Themes

- Roadmap for AI & Quantum
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- Next-gen Transactions
- Sustainability in Action
- Bridging the Financial Gap
- Talent of Tomorrow

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