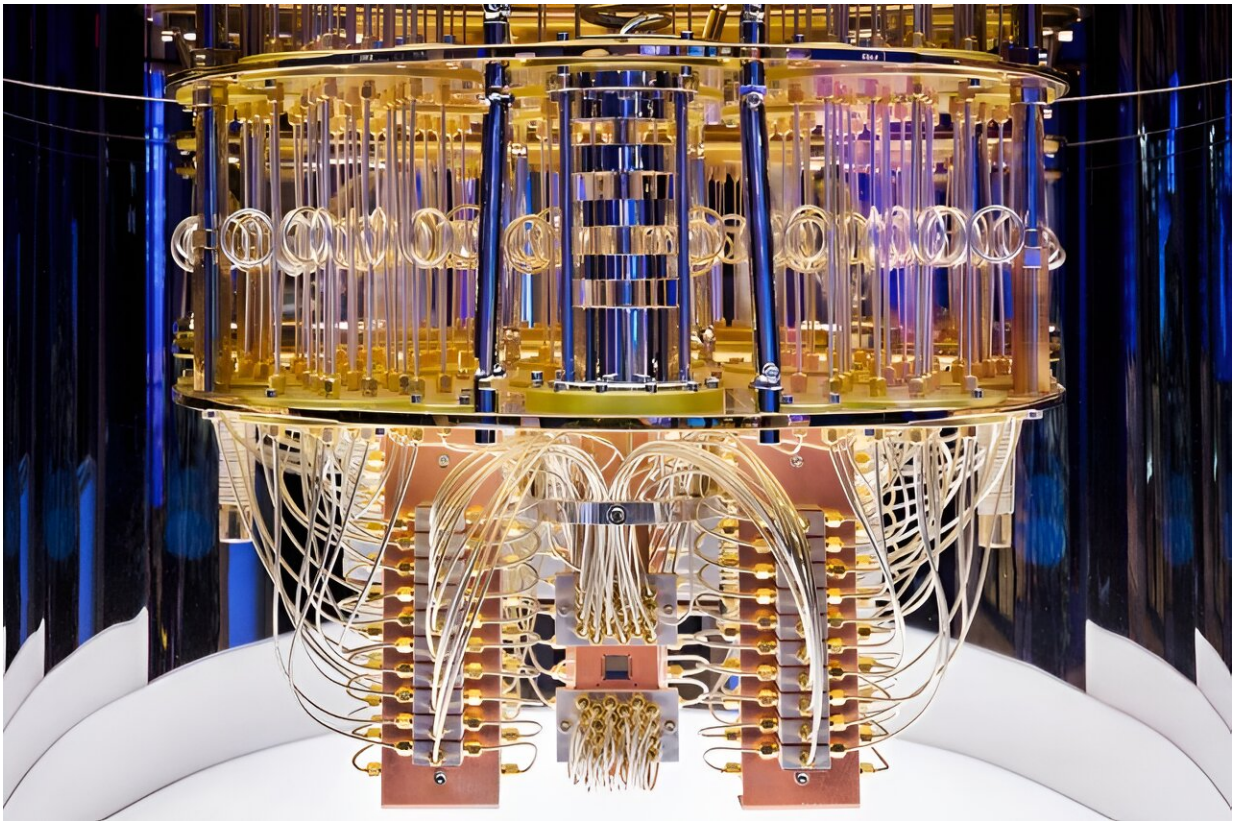


Q&A: How to introduce quantum computing without slowing economic growth

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The Quantum System One is a quantum computer made by the technology corporation IBM. Credit: IBM ([CC BY-ND 2.0](#))

In a recent commentary article [published](#) in *Nature*, Chander Velu, Professor of Innovation and Economics at the Institute for

Manufacturing (IfM) and Fathiro H. R. Putra, Lecturer in Industrial Engineering and Engineering Management at the Bandung Institute of Technology, explore the potential impact of quantum computing on growth and productivity.

We spoke to IfM's Chander Velu to find out more.

How would you describe the key differences between quantum and traditional digital computers?

Quantum computers work by being able to both store and analyze information more efficiently compared to conventional digital computers. The advantage of quantum computers over digital computers comes from [quantum information](#) processing in which information is encoded in the quantum state of physical systems such as atoms, electrons and photons.

Digital computers work essentially using on-off switches and use binary bits that can only depict either a "0" or "1." Digital computers are inefficient for certain problem classes where there is a need to select the best option among a large set of possibilities. This is because a digital computer solves such problems by iteration by considering them one by one sequentially.

Quantum computers have a significant advantage over traditional digital computers in solving complex problems more quickly and efficiently. This advantage is known as the "quantum advantage." Quantum computers use qubits, which can exist in a superposition of states, representing both "0" and "1" simultaneously or any combination of these states. Furthermore, qubits can be entangled, meaning they can be interconnected as a single system.

These unique properties of qubits enable quantum computers to process information simultaneously and efficiently. As a result, quantum computers excel in optimizing and solving combinatorial problems that are at the core of many business and commercial operations. They can also simulate quantum mechanical phenomena, which are inherently complex and difficult for classical computers to handle.

By addressing these challenging problems with unprecedented speed, quantum computing has the potential to redefine competitive advantage and revolutionize entire industries. It can dramatically transform [business models](#) and open new possibilities for solving problems that were previously infeasible with classical computing methods.

In summary, quantum computing's problem-solving capabilities have the potential to create a significant impact on various aspects of business and technology, promising a new era of computational power and innovation.

What are some of the potential opportunities emerging with the advent of quantum computers?

Quantum computers offer exciting possibilities for various fields, such as materials science, optimization, and machine learning. These advancements could bring about significant benefits and positive impacts in multiple areas.

For example, improved simulation of materials could enable better development of low-carbon technologies to address climate change, such as catalysts for carbon capture or electrolytes for batteries. Simulating molecules better could also speed up drug development. Improved optimization might enable a delivery logistics firm to reschedule its vehicle routes more rapidly to respond better to customer demand for pickups of returned goods or enable a financial services firm to optimize

its portfolio of securities for improved risk management. Finally, the enhancement of machine learning could be applied to various areas where artificial intelligence is being used to find better customer solutions.

In light of the economic gains brought about by the digital revolution, do you anticipate a similar trajectory for quantum computing?

We believe that quantum computers will bring enormous economic gains just like digital computers but might initially slow productivity growth before the benefits accrue. When digital computers spread in the 1970s and 1980s, rather than delivering efficiencies, for a decade, they stalled growth in productivity, the value added relative to inputs such as labor.

Such a dip is known as the productivity paradox. It arose because businesses had to invest in new equipment and learn how to program the devices, as well as work out what to do with them.

Firms also did not invest at first in other innovations needed to change core processes and business models. Only after many sectors had adjusted in the 1990s did productivity growth rise again. We believe quantum computers could face a similar productivity paradox but even more severe.

As quantum computing strives to become commercially viable, what are some of the potential challenges or obstacles that need to be addressed?

There are three major challenges that need to be addressed in adopting quantum computers.

First is the high integration costs and low short-term rewards. Businesses may adopt quantum computers initially to solve existing business problems, where improvements are likely to be incremental, while the costs of integration with digital computers are likely to be high.

Second is the difficulty in translating quantum concepts for business managers and engineers. In particular, quantum mechanics that underpin these technologies operate on counterintuitive principles, often unfamiliar to engineers and business managers.

Third is the cryptographic threat of quantum computers. In particular, quantum computers could unlock information encrypted by conventional computers very quickly which could render existing cryptography methods obsolete and potentially open to hacking.

As businesses, researchers and governments plan for the future of quantum computing, what specific traps or hurdles should they be prepared to tackle?

To overcome the specific hurdles in adopting quantum computers, the first crucial step is to demonstrate their practical value in tackling real-world industrial or societal challenges. This means showcasing their capabilities and effectiveness in solving complex problems that are currently difficult or infeasible for classical computers to handle.

These include weather forecasting or enhancing the resilience of the financial system among others. Second is the need to agree on a common language and build understanding between business managers, engineers and scientists. The third is to integrate quantum computers and quantum communication technologies into a coordinated network with secure encryption, also known as the quantum internet, which would enable new business models through enhanced privacy.

The implementation of quantum computing may come with a steep learning curve and possible economic losses. What measures or strategies could help alleviate the economic burden during this transition?

One way to ease the economic strain is for the government to promote private investment towards the implementation of quantum computing. This could be framed as a mission to tackle significant challenges faced by society and industry. Once the proof of concept is shown, then researchers should set out what firms need to do in practice to adopt quantum technologies, including how they may need to change their business models and practices, as well as work with others along their value chains.

Second, a common semantic and syntactic language for quantum computers needs to be developed. This could take the form of a quantum unified modeling language, similar to the standardized Unified Modeling Language used for digital computer programming, which could facilitate effective communication, simplify the process of software development, and help shorten development times. Strategies for communicating about [quantum computing](#) with the public are also needed to build trust in these new technologies and ensure benefits accrue to all parts of society in a responsible manner.

Third is to help firms invest in new mathematical approaches or adopt quantum-based communications systems such as quantum key distribution. This would overcome security threats and enable new business models to develop, for example, through improved supply chain flexibility.

Tell us a bit more about your work at the IfM and how this is helping us to understand the landscape of quantum computing better.

The Cambridge Business Model Innovation Group examines how and why business model innovation enables productivity growth.

Productivity is the engine that drives economic growth. The U.K. and other major economies have experienced a significant slowdown in economic growth despite the prevalence of digital technologies. A significant number of research studies have attempted to better understand this "productivity puzzle." However, many of these studies have tended to focus on past technological adoption or current challenges in firms adopting digital technologies to improve performance.

One of the major areas where we lack understanding is how firms and policymakers need to prepare to adopt technologies that are emerging from research in science and engineering but which are only likely to be adopted in the future.

We believe that quantum technologies are suitable for such a study. That's why my research group is examining both technologies that are mature as well as early stage emerging technologies, such as quantum technologies to better understand how business model innovation might help firms and governments prepare to adopt them in order to lessen the burden on the economy and spur growth sooner.

In doing so, we hope to contribute to a better understanding of the theories of business model innovation and technology transitions.

More information: Chander Velu et al, How to introduce quantum computers without slowing economic growth, *Nature* (2023). [DOI:](#)

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