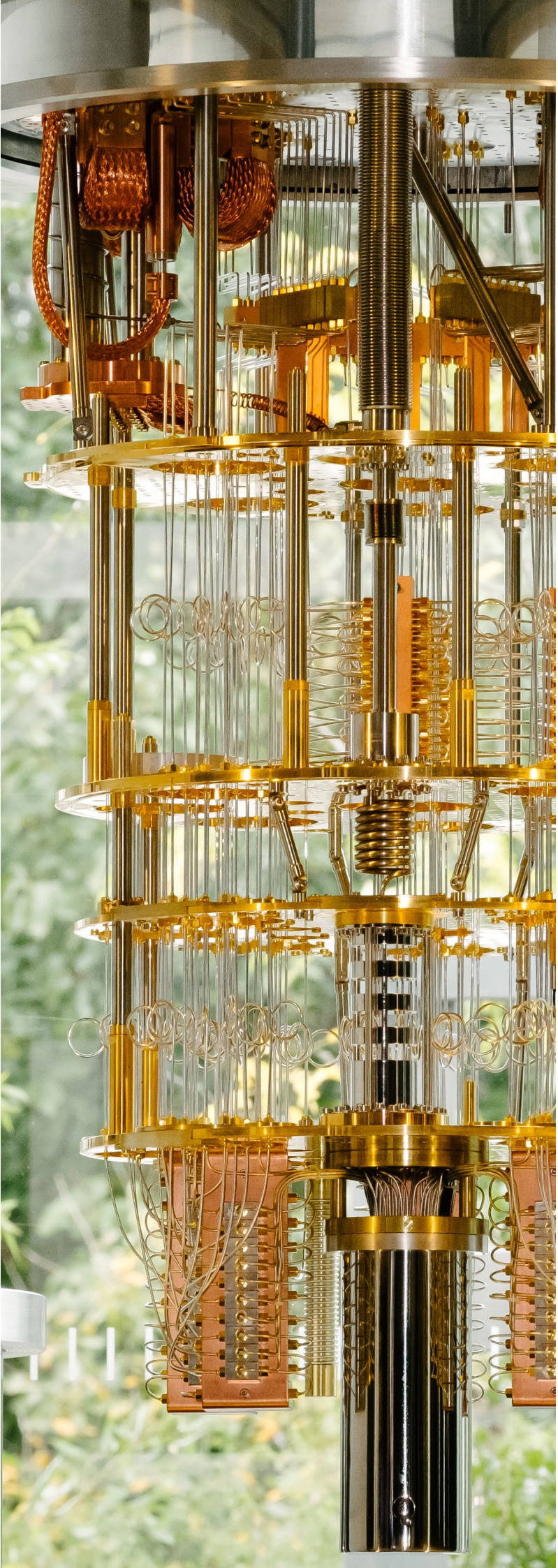

Expert Insights

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Getting your financial institution ready for the quantum computing revolution

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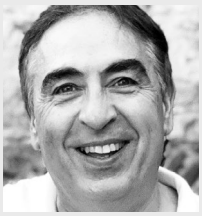
Experts on this topic



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There are compelling reasons to begin assessing the role and potential of quantum for your business now.

Talking points

Quantum for speed, accuracy
Financial institutions are exploring quantum computing, both to dramatically speed up immensely complicated calculations and to improve their accuracy.

Experimental systems
Experimental quantum systems are already being used on quantum risk analysis problems.

The time is now
Engaging now is important, as use cases are being identified and proprietary ecosystems are being formed.

The best of times

In 1748, American statesman and inventor Ben Franklin wrote "time is money." The origin of that axiom dates back to Greece 2,000 years ago.[1] Nowhere is that phrase truer than in the global financial services sector (FSS), where gaining an advantage in milliseconds can translate into outsized profits.

The upside opportunity is massive. The 28 largest banks worldwide manage more than USD 54 trillion combined.[2] The US stock and bond markets alone are capitalized at more than USD 70 trillion.[3] In markets this large, creating new algorithms to optimize portfolios, price derivatives, analyze risk, or calculate more accurate default probabilities, can have a massive and widespread impact on the long-term success of global financial institutions and their customers.

Quantum advantage

Today's financial services environment embodies the philosophy of survival of the fittest. Institutions battle for tiny competitive advantages using the best technologies available. At the same time, some are already exploring next-generation "quantum computing" to dramatically reduce the time required for immensely complicated calculations and to improve accuracy significantly.

Quantum computing, a hot research area in technology research labs worldwide, remains a few years away from having a huge impact on the financial services industry. However, there are compelling reasons to begin assessing the role and potential of quantum for your business now. One easy way to get started is to join an emerging financial services quantum ecosystem.

What is quantum computing?

Superposition and entanglement are among the key factors behind the power of quantum computing.

"Classical" computers represent data as either a one or a zero via a bit. Quantum computers can represent data as a one or a zero, or as a combination of a one and a zero via a qubit. Qubits can be in multiple basis states at the same time, which is known as quantum superposition.

Next is the peculiar phenomenon of quantum entanglement. Due to entanglement, even though two or more quantum objects may be physically separated, their behavior is correlated. This behavior is true whether the separation is measured in millimeters or miles. So, while one qubit can be in a superposition of two basis states, 10 qubits, exploiting entanglement, can be in a superposition of 1024 basis states. This phenomenon leads to an exponential growth of the possible states that can be represented with respect to the number of qubits.[4]

Several quantum algorithms for financial applications are currently being developed and tested.[5] And while more research is required to successfully run these apps at the required scale and in real-life environments on emerging quantum machines, it's important to start to identify which high-value problems might profit from quantum algorithms in the future. Now is the time to begin navigating the technology's learning curve to be ready when quantum computers have sufficient scale and power to run them.

Several types of challenges face financial services firms that quantum computing may address. These challenges include: the classification and selection of assets, customers, and vendors by default risk; and the detection of fraud, money laundering or other criminal activities by finding complex variable relations.[6] A series of complex and often concurrent multi-disciplinary tasks is required to resolve such challenges. Quantum computers, with greater speed and accuracy, might provide new capabilities in these areas.

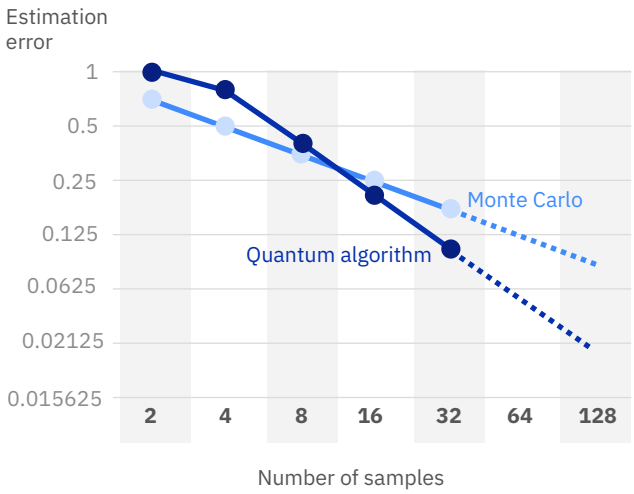
Quantum computing has the potential to be especially helpful in solving optimization problems, such as portfolio optimization, management, and diversification. It may even extend to complex risk measures, such as conditional value at risk (C-VaR), also known as "expected shortfall."[7]

Furthermore, it now appears possible that optimization of pricing/risk analysis might eventually be done on a quantum computer with a "quadratic speed-up" requiring significantly fewer samples. While a classical Monte Carlo simulation may require millions of samples, only a few thousand quantum samples might be sufficient on a quantum computer (see Figure 1).[8] Shortening cycles, such as for analyzing derivatives, from overnight to near real-time, might reduce risk and funding requirements. The result could be massive savings, given the billions of options contracts being traded worldwide every year.[9]

Financial institutions experienced 65 percent more cyberattacks than other organizations in 2016.

Figure 1

Quadratic speedup over Monte Carlo



Quantum risk analysis has already been used on real experimental quantum systems for very small problems and is being extended for larger, more realistic applications, including risk analysis on pricing assets such as bonds and options. Quantum risk analysis already is being tested on European-style options. IBM Q and Qiskit Finance have examples where the actual implementation of quantum algorithms for European option pricing and portfolio optimization can be found.[10]

While this test represents only an elementary case of quantitative finance, the approach can be extended to more sophisticated cases. Candidates include pricing of path-dependent derivatives under complex market dynamics, and some problems that are considered today as intractable, such as dynamic portfolio optimization and option pricing.[11] This quadratic speed-up can have a positive business impact by decreasing capital allocation needs, finding new investment opportunities, and reacting faster to market volatility.

What is a Monte Carlo simulation?

A Monte Carlo simulation is used in finance and other industries to measure risk and uncertainty in forecasting models. The simulation provides a visual representation of many or all potential outcomes, assisting users assess the relative risks of a decision.[12]

The urgency of security

Protecting data and communications is typically the first priority for enterprises that manage critical business, personal and governmental financial data. Even so, the average financial institution experienced 65 percent more cyberattacks than other organizations in 2016.[13] As quantum computing capabilities improve, malicious actors will sooner or later gain access to them. Quantum will present security risks as well as powerful new defenses to protect against future attacks.[14]

Quantum key distribution can help protect communication channels from traditional and quantum threats. By exploiting quantum principles, it can provide current and future secrecy of encryption keys, and help prevent eavesdropping by unauthorized parties. Organizations need to act now to adopt cryptographic techniques that can protect data on both classical and quantum computers. For example, some types of lattice-based cryptography are being explored that seem to be resistant to quantum computing attacks. So far, no known algorithms can break these methods of encoding data, which may help protect against both existing and new threats, today and into the future.[15]

Companies banking on quantum success

JP Morgan Chase (JPMC) and Barclays are among the banks experimenting with quantum computing to accelerate risk mitigation and improve performance modeling.

JPMC has established a quantum computing research group spanning corporate and investment banking, consumer and community banking, and asset and wealth management. The group includes two dedicated researchers with PhDs in physics, along with several researchers working part-time. The team focuses on problems of relevance to the business, such as portfolio optimization, option pricing and financial health classification. The goal is to explore and understand quantum advantage, its future potential and existing limitations to prepare for future real-world applications. The JPMC quantum team has worked in collaboration with others to develop and implement many algorithms of interest. These have been tested and evaluated on real and available quantum devices.

Barclays already has a working group for quantum computing that includes statistical modeling experts. The team codes straightforward quantum apps and, to test results, it runs them on a publicly available experimental quantum computer that is accessible on the cloud. The team is testing the apps for optimization problems—such as determining the correct sequencing and prioritization of activities—with a final outcome of settling thousands of trades every business day efficiently and accurately.[16] To help put this type of optimization problem in perspective, consider that selecting the optimal order of execution for 5,000 trades has more than $4.2 \times 10^{16,325}$ possibilities.[17]

Early adoption for early advantage

Programming a quantum computer is fundamentally different from programming a classical computer, meaning there is a non-trivial learning curve. Early quantum computing adopters in FSS are not just more likely to take advantage of the technology's diverse possibilities, they are also more apt to chart the direction of the industry by setting new standards. Although fully fault-tolerant universal quantum computers are years away, it is essential that organizations engage now as important and promising use cases are being identified, tools and algorithms are in development, and proprietary ecosystems are being formed. Such efforts will coalesce over time, providing first movers with a quantum advantage.

Ready, set, take the leap

There are straightforward steps an organization can take now to prepare for a "quantum leap":

- *Experiment with quantum computing* by using available, open prototypes. To get started, access an open source computing framework with learning material and ready-to-use algorithm libraries.
- *Explore quantum use cases* pertinent to your business, then qualify and prioritize them by seeing where your operating model aligns with strategic direction. Build a customized quantum roadmap.
- *Build, buy or rent required skills.* There already may be someone on your team who closely follows the progress and potential of quantum computing. Consider adding that as a requirement for future key technical hires. Supplement with specialists more deeply involved in state-of-the-art development of quantum financial services.
- *Ensure that the entire C-suite becomes conversant about quantum computing.* Customers and investors are sure to be asking about it soon, if they haven't started already.
- *Join an ecosystem* of established companies, startups, academic partners and national research labs focusing on building quantum computing solutions for financial services problems.[18]

Programming a quantum computer is fundamentally different from programming a classical computer.

Key questions to consider

» How is your organization preparing for the potential impacts of quantum computing?

» How can accelerating the ability to solve complex problems be a competitive advantage to your business?

» In what ways will you start to assess the potential impact of quantum computing on your organization's security posture?

About Expert Insights

Expert Insights represent the opinions of thought leaders on newsworthy business and related technology topics. They are based upon conversations with leading subject matter experts from around the globe. For more information, contact the IBM Institute for Business Value at iibv@us.ibm.com.

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