



The Benefits of Quantum Forecasting

Harnessing quantum power to demystify
uncertainty



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Mounting uncertainty defines today's business landscape. Climate change, geopolitical changes, and rapid technological disruption create unprecedented volatility and unclear objectives force leaders to make critical decisions based on estimates and assumptions.

What separates organisations that thrive in chaos from those that merely survive? The ability to make sound decisions when the path forward is unclear. Mastering this skill enables better risk management, sharper resource allocation, and more accurate pricing strategies—turning volatility into competitive advantage.

And the stakes are rising. The World Uncertainty Index (WUI) reached its highest level since records began in 1990. Kristalina Georgieva, Managing Director of the International Monetary Fund (IMF), warned us to “buckle up: uncertainty is the new normal and it is here to stay.” Our latest CEO surveys confirm this reality—global turbulence has become business as usual. Enterprises are no longer striving to eliminate uncertainty; instead, they need stronger capabilities to quantify, simulate, and manage uncertainty. This is precisely where quantum computing: especially hybrid quantum-classical approaches, shows its potential value in risk modelling, optimisation, and forecasting. (PwC Czech Republic CEO Survey, 2026)

The question is no longer whether this volatility can be eliminated—it can't. The real question is: how can organisations build stronger capabilities to quantify, simulate, and manage it? This is where quantum computing, especially hybrid quantum-classical approaches, shows its potential value in risk modelling, optimisation, and forecasting.



Could quantum computing unlock new ways to navigate these challenges at scale? Beyond the business imperative, its relevance lies in its mathematical foundations. Quantum computing is built on principles such as superposition, probability amplitudes, and formal treatments of uncertainty. (Heisenberg's uncertainty principle, 1927; Dirac, 1930 and von Neumann, 1932). While quantum uncertainty differs fundamentally from economic or operational uncertainty, the associated mathematical framework, refined over 125 years, offers powerful tools for modelling complex, high-dimensional systems. As software and hardware mature, these tools may enable new approaches to large-scale risk modelling, optimisation, and forecasting that are computationally infeasible today. Quantum computing has evolved from academic theory into a commercial imperative, capturing the attention of governments, industry, and academia alike. Major technology giants like IBM, Google, Microsoft, and Fujitsu alongside emerging players such as Rigetti, D-Wave, Quantinuum, IonQ, QuEra, Pasqal, Planqc, Riverlane, PsiQuantum, and Xanadu are taking the field by storm. These companies are pursuing various approaches including superconductors, quantum annealers, trapped ions, neutral atoms, topological qubits, and photonics, making the ecosystem increasingly crowded and competitive. In fact, leading universities worldwide are conducting quantum computing research alongside numerous start-ups competing in the field. Many countries are investing in quantum technologies—China currently leads with \$138bn in planned government funding for emerging technologies including quantum computing (thequantuminsider.com, 2025). The aim for all parties is to demonstrate quantum advantage and economic benefits that justify this investment.

Progress is accelerating. According to a June 2025 article published in MIT Technology Review, IBM announced the development of Starling, a significantly more computationally efficient quantum computer with error correction capabilities. The company intends to make Starling available to users via the cloud by 2029.

Navigating the NISQ era

Despite its theoretical promise, quantum advantage for uncertainty quantification applications faces significant near-term barriers. We are currently in the Noisy Intermediate-Scale Quantum (NISQ) era, where quantum computers are limited to the low thousands of physical qubits with error rates too high for real world application. Success depends heavily on how efficiently a problem can be mapped to these constraints. Without error correction, errors accumulate rapidly, making it impossible to accurately run the complex algorithms required for large-scale systems such as climate or disaster forecasting.

Meanwhile, classical computing continues to improve through better algorithms, and we are witnessing a growing convergence between High Performance Computing (HPC) and AI. GPU (Graphics Processing Units)/TPU (Tensor Processing Units) acceleration, combined with machine learning-enhanced sampling methods, continue raising the bar for quantum advantage. Quantum Machine learning (QML) offers promising techniques such as Quantum Support Vector Machine, Quantum Neural Network, Quantum Decision Trees, and hybrid quantum-classical models. While the potential for exponential speedups and enhanced efficiency is evident, the field faces significant challenges, including hardware constraints and limited qubit coherence. (Tomar et al, 2024)

Given these hardware constraints, the most realistic near-term opportunity lies in hybrid approaches. In this model, quantum processors handle specific high-value calculations—such as tail probability estimation or complex correlations—while classical systems manage data preprocessing and model evaluation.

In practice, many organisations are already exploring quantum strategies to assess where hybrid quantum-classical capabilities could deliver incremental value. This is particularly relevant for Quantum Amplitude Estimation (QAE), a promising algorithm for financial risk (Value at Risk (VaR) and Conditional Value at Risk (CVaR)), insurance modelling, and reliability engineering.

Building quantum readiness now. The question isn't whether quantum computing will deliver advantage, but when—and whether your organisation will be ready. While hardware maturity remains years away, the strategic groundwork must begin now. Organisations that wait for “quantum-ready” hardware will find themselves years behind competitors who are already mapping their problems, building expertise, and testing hybrid approaches. To manage risk, organisations quantify it to inform mitigation strategies and exposure decisions. Well-established classical computing approaches already exist across industries—the insurance sector being a prime example. With advances in quantum computing, we explore whether this technology can meaningfully enhance these capabilities, particularly for decision-making under uncertainty where classical methods face computational limits. For example, the wildfires raging in California destroyed 521,988 acres of terrain in 2025 and with that, 16,479 structures, estimated to be \$45bn in insured losses, with total economic losses potentially exceeding \$250bn. Many scientists agree that climate change contributed to the grand scale of the fires in 2025.

According to the Insurance Journal, \$4.2bn of claims have been paid out in total to wildfire victims. However, about 30% of claims submitted could not be paid due to policy limits and financial strain to some insurance companies. The Guardian quoted a US Senate Budget Committee Staff report on insurance, stating that “climate-related extreme weather events will become both more frequent and more violent, resulting in ever-scarcer insurance and ever-higher premiums. This is predicted to cascade into plunging property values in communities where insurance becomes impossible to find or prohibitively expensive, potentially leading to a collapse in property values. Climate change is no longer just an environmental problem. It is a looming economic threat.” (The Guardian, 2025 and US Senate Budget Committee Staff Report, 2024)

The Swiss Reinsurance Group had published statistics stating that natural catastrophe insured losses were \$137bn in 2024, where economic losses for disaster events amounted to \$318bn, of which 57% were uninsured, leaving a global protection gap of \$181bn (Swissre.com, 2025).

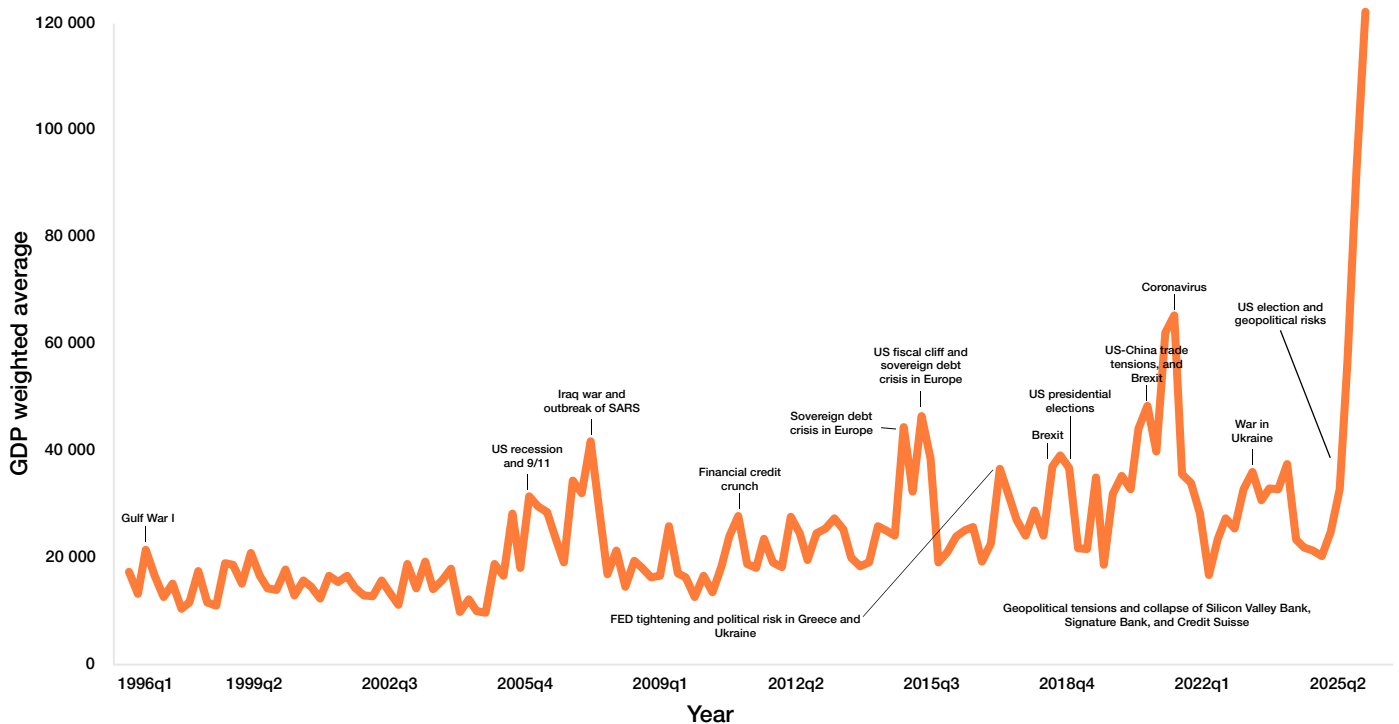
By using appropriate probability forecasting techniques, organisations can explore the likelihood of future outcomes—from climate catastrophes to financial shocks—to inform better decisions. Uncertainty quantification methods typically rely on Monte Carlo (MC) simulations or rare-event probability estimation to calculate key risk measures, including:

- Expectations and probabilities
- Standard deviation and beta
- VaR and CVaR

Uncertainty quantification applications span numerous industries where decision-making under uncertainty is critical:

- **Financial services:** Credit risk, market volatility, portfolio optimisation
- **Insurance:** Catastrophe modelling, actuarial analysis
- **Manufacturing and supply chain:** Production planning, logistics optimisation
- **Energy and mining:** Resource estimation, operational risk
- **Aerospace and defence:** Reliability engineering, mission planning
- **Agriculture:** Yield forecasting, climate adaptation
- **Pharmaceuticals and chemistry:** Drug development, process optimisation

World Trade Uncertainty Index 1996Q1 to 2025Q3



— World Trade Uncertainty Index 1990Q1 to 2025Q3

The use of the data and figure should be cited as:

Note: The use of the data and figure should be cited as: Ahir, H, N Bloom, and D Furceri (2022), "World Uncertainty Index", NBER Working Paper.

The limits of classical simulation

Current risk modelling relies heavily on MC simulations to predict future outcomes. While this remains the industry standard, the method hits a computational wall (Glasserman, 2024) when attempting to accurately model rare, high impact “tail events” such as the extreme wildfires in California of 2025.

Insurers today face a compounding challenge with “nested stochastic” models—essentially simulations within simulations required for regulatory reporting (Society of Actuaries, 2016). This nested workload often forces risk managers to trade accuracy for speed. While the industry attempts to mitigate this using variance reduction techniques, even these advanced classical methods face diminishing returns when dealing with highly correlated, non-linear risk factors found in complex portfolios.

This is where QAE presents a theoretical pathway to greater efficiency. A generalisation of Grover’s famous search algorithm, QAE replaces random sampling with quantum interference to identify target outcomes. (Brassard et al, 2000)

Research by Ashley Montanaro (2015) demonstrates that this approach could theoretically achieve a “quadratic speedup” over classical MC methods. This does not solve uncertainty itself, but it implies a quantum computer could reach the same statistical precision with significantly fewer calculation steps.

Building on this mathematical foundation, researchers have applied QAE to specific financial problems: Woerner and Egger (2019) demonstrated applications to option pricing, Stamatopoulos et al. (2020) estimated resource requirements for scaling these algorithms, and Kaneko et al. (2021) explored optimisations for complex risk measurements (VaR/CVaR).

Turning computational limits into competitive advantage

Quantum computing is not a silver bullet, but it represents a promising frontier for organisations grappling complex risk modelling and decision-making under uncertainty. While we remain in the NISQ era with inherent limitations, the mathematical foundations of Quantum QAE suggest a path toward computational advantages that could transform industries reliant on MC simulations—particularly insurance, finance, and climate modelling.

Organisations do not need to wait for quantum perfection. Hybrid quantum-classical approaches being developed by major technology vendors offer a pragmatic pathway to explore quantum advantages today. As hardware matures, financial modelers could calculate higher confidence intervals on rare events that could lead to significant losses, potentially turning a computational bottleneck into a competitive advantage. Organisations that will thrive are those that act now:

- Investing in quantum literacy and building internal awareness.
- Identifying high-value use cases aligned with business priorities.
- Building foundational capabilities is needed to leverage quantum advantages when they arrive.

The IMF's warning that "uncertainty is the new normal" demands innovation in how organisations forecast and make decisions. Quantum computing may not eliminate uncertainty, but it could provide the computational power to navigate it more effectively, transforming financial surprises into manageable, quantified risk across any sector where risk management is critical.

PwC's role in quantum readiness

In this environment, PwC operates at the intersection of strategy, risk, data, and emerging technologies. Drawing on global quantum capabilities and alliance partnerships, PwC supports organisations in exploring areas of:

- **Assess materiality:** Where uncertainty is materially impacting decision-making.
- **Benchmark classical limits:** Understanding where current analytics reach computational boundaries.
- **Identify quantum potential:** Where quantum-enabled or quantum-inspired methods may offer incremental advantage.

This work typically involves readiness assessments, use-case prioritisations informed by business context, and controlled experimentation using hybrid classical-quantum platforms. These activities are designed to support informed exploration of quantum technologies within appropriate governance, risk management, and measurement frameworks.



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