Comprehensive Review of Quantum Computing Applications in Finance:

Derivative Pricing, Risk Management, and Portfolio Optimization

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***Abstract*—Quantum computing has emerged as a transformative computational paradigm, offering novel capabilities to tackle complex problems in finance—most notably in derivative pricing, risk management, and portfolio optimization. This review synthesizes recent advances in quantum algorithms and hybrid quantum–classical frameworks as applied to financial services, examining how technologies such as quantum-annealing, quantum amplitude estimation, and variational quantum circuits can improve efficiency, accuracy, and scalability over classical methods. The study provides a systematic assessment of key use-cases: (1) derivative pricing and greeks computation via quantum Monte Carlo and amplitude estimation; (2) risk management enhancements, including Value-at-Risk (VaR) and conditional VaR through quantum gradient estimation; and (3) portfolio optimization via QUBO (quadratic unconstrained binary optimization) mapping, the Quantum Approximate Optimization Algorithm (QAOA) and quantum annealing approaches. In addition to reviewing technological potential, the paper addresses critical barriers—hardware noise, coherence limitations, data integration, regulatory considerations—and outlines future research directions, including quantum-resilient cryptography in finance and industry coupling. By bringing together algorithmic, financial and regulatory perspectives, this review seeks to guide academics and practitioners toward the next frontier in financial computing.**

The modern financial ecosystem is characterized by deep interconnections, high dimensionality, and increasing computational demands [1]. From exotic derivative pricing to systemic risk assessment and global portfolio reallocation, financial models must process large data volumes, account for nonlinear dependencies and tail-risk events, and deliver decisions under strict time constraints. Classical computing architectures—though significantly advanced—are reaching limitations when confronted with the combinatorial explosion and complexity of such tasks [4]. In this context, quantum computing emerges as a promising paradigm capable of delivering new algorithmic performance and structural breakthroughs.

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Unlike classical bits that exist in one of two states, quantum bits (qubits) exploit superposition and entanglement, allowing quantum algorithms to explore many states simultaneously [6]. This attribute has motivated researchers to investigate quantum Monte Carlo simulation, quantum amplitude estimation, and novel optimization schemes such as QAOA and quantum annealing for finance. For example, derivative pricing often relies on Monte Carlo methods, which can be computationally burdensome in high

