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Quantum Computing in Economics. Promises and Barriers

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ABSTRACT

Quantum computing represents one of the most disruptive technological paradigms of the 21st century, with profound implications for economic modelling, financial optimization, and computational decision-making. Unlike classical computing, quantum systems leverage superposition, entanglement, and interference to solve problems of exponentially higher complexity, a capability with transformative potential for economics and finance. This study examines the intersection of quantum computing and economics, systematically evaluating both the promises and the barriers defining this emerging field. Regarding opportunities, quantum algorithms, such as the Quantum Approximate Optimization Algorithm (QAOA) and Grover's algorithm, demonstrate significant theoretical advantages in portfolio optimization, risk assessment, option pricing, and the resolution of large-scale combinatorial problems that are intractable for classical machines. Quantum machine learning extends these prospects, offering accelerated capabilities for pattern recognition and predictive modelling relevant to financial markets. However, substantial barriers temper these expectations. Current quantum hardware operates in the NISQ (Noisy Intermediate-Scale Quantum) era, where decoherence, gate errors, and a limited number of qubits constrain practical applicability. The gap between theoretical quantum advantage and real-world economic implementation remains significant, compounded by a shortage of specialists, high infrastructure costs, and the absence of standardized programming frameworks tailored to economic applications. Through a bibliometric analysis of existing literature and a critical review of recent experimental results, the study maps the current state of quantum computing adoption in economics, identifies the most active research frontiers—quantum game theory and quantum portfolio optimization—and outlines the conditions under which quantum advantage could become economically relevant. The findings suggest that, although quantum computing will not transform economic practice in the short term, its long-term disruptive potential warrants proactive engagement from economists, financial institutions, and policymakers.

1. Introduction

Over the past decade, quantum computing has evolved from theoretical speculation into a maturing technological infrastructure. Interest within the scientific community regarding its intersection with economics has grown exponentially, engaging physicists, computer scientists, and economists alike. This dynamic reflects not only interdisciplinary enthusiasm but also the tangible pressure quantum computing is already exerting on the global financial system: Shor's algorithm compromises the cryptographic protocols underpinning international banking infrastructure, and the first post-quantum standards have already been published, with regulatory implementation deadlines fast approaching.

However, the academic debate remains fragmented. Some literature exaggerates the potential, extrapolating theoretical speedups without accounting for the limitations of current hardware. Conversely, other perspectives overlook genuine progress, dismissing quantum computing as a distant prospect irrelevant to immediate economic practice. Between these extremes, there is a lack of systematic, balanced analysis that simultaneously evaluates what quantum computing can offer the economy and the obstacles preventing it from doing so, differentiated by sector, problem type, and credible timeframes.

The need for such an analysis is becoming increasingly urgent, as decisions regarding investment, public policy, and curricular reform in the field are already being made, often without a coherent understanding of the current state of the discipline. Without a rigorous evaluation framework, there remains a high risk of overestimating short-term benefits or underestimating the requirements for disciplinary adaptation. This paper addresses this need through a structured synthesis of the specialized literature, integrating a bibliometric analysis of the field with an evaluation framework applied to six areas of economics:

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macroeconomics, computational finance, game theory, decision theory, information economics, and agent-based modeling.

2. Literature review

Quantum computing has its roots in 20th-century theoretical physics. Feynman (1982) first proposed using quantum systems to simulate physical reality. His argument was simple: a quantum system can only be efficiently simulated by another quantum system. Deutsch (1985) later formalized the concept of a universal quantum computer, providing a rigorous mathematical framework. Algorithmic contributions marked a new stage. Shor (1994) demonstrated that a quantum computer could factor large integers in polynomial time. This discovery posed a direct threat to classical encryption protocols. Grover (1996) proposed a search algorithm offering a quadratic quantum speedup over classical methods. Both contributions solidified the scientific community's interest in the field.

Experimental progress has accelerated significantly over the last decade. In 2016, IBM launched the first quantum computer accessible to the public via the cloud. In 2019, Google announced "quantum supremacy" regarding a specific computational problem (Arute et al., 2019). Preskill (2018) described the current stage as the NISQ era, Noisy Intermediate-Scale Quantum, characterized by functional devices that are nonetheless affected by high error rates and quantum decoherence. These milestones highlight the rapid trajectory of a field currently maturing. The technological potential is undeniable. However, the gap to large-scale practical application remains substantial.

The first systematic review of quantum computing applications in finance was conducted by Orús et al. (2019). The authors identify three main areas of intervention: portfolio optimization, derivatives valuation, and financial fraud detection. Each area benefits from quantum speedup compared to equivalent classical methods. Egger et al. (2020) extend this analysis in a study published in *IEEE* Transactions on Quantum Engineering, covering combinatorial optimization, quantum Monte Carlo simulation, and machine learning applications. The central conclusion is that while a quantum advantage is theoretically demonstrable, it is practically limited by the current state of hardware. Additionally, Rebentrost et al. (2014) propose specific quantum algorithms for financial data analysis, demonstrating exponential speedup for certain classes of problems, including principal component analysis and linear regression on large datasets. Their work is frequently cited as a benchmark in the literature on quantum applications in finance.

Stamatopoulos et al. (2020) demonstrate the applicability of quantum algorithms to financial option pricing. Their results indicate a significant reduction in computational complexity compared to the classical Monte Carlo method. These gains are particularly relevant for high-volume derivatives markets. Biamonte et al. (2017) published the first comprehensive review of quantum machine learning in the journal *Nature*. The authors demonstrate that quantum algorithms can accelerate the training processes for classification and regression models. The implications for economic modeling are direct: macroeconomic forecasting, anomaly detection, and the optimization of monetary policy decisions can all benefit from quantum processing. Wiebe et al. (2012) propose a quantum algorithm for linear regression on large datasets. The speedup relative to classical methods is exponential with respect to the number of variables. This contribution is relevant to econometrics and the estimation of high-dimensional macroeconomic models. Research by Schulz et al. (2019) further explores the mathematical foundations of quantum neural networks. The authors identify both the advantages and the fundamental limitations of these architectures. Their findings temper initial enthusiasm and necessitate a critical approach when evaluating potential applications.

A synthesis of machine learning applications reveals a common pattern: quantum advantages are theoretically confirmed but contingent upon the availability of hardware with acceptable error rates. This tension runs through the entire body of literature and constitutes one of the field's structural barriers. Eisert, Wilkens, and Lewenstein (1999) founded the field of quantum game theory in an article published and demonstrate that quantum strategies can outperform classical Nash equilibria. The result has direct implications for modeling strategic behavior in economics: auctions, negotiations, and oligopolistic markets can be reformulated in quantum terms. Piotrowski and Sładkowski (2003) apply quantum game theory to concrete economic contexts. The authors propose a quantum model of the capital market in which agents utilize quantum superposition to optimize trading strategies. This work opened up a fruitful subfield, leading to numerous subsequent contributions. Landsburg (2011) critically reviews applications of quantum game theory. The author points out significant interpretative limitations: not every quantum game has a clear economic counterpart. This observation calls for caution regarding the mechanical transposition of physical results into economic contexts.

Bova, Goldfarb, and Melko (2021) introduce the concept of "quantum economic advantage" in a study published, and the authors identify the conditions under which quantum computing generates superior net economic value compared to classical alternatives. Their analysis covers the financial, pharmaceutical, and logistics sectors. The conclusion is that this advantage emerges selectively rather than universally. The OECD (2023) published a policy report on quantum technologies, highlighting the need for coordinated public investment in quantum infrastructure. Estimates place the global economic impact between USD 450 billion and USD 850 billion by 2040. These figures are indicative and reflect the uncertainty inherent in long-term technological forecasting. Bova et al. (2021) emphasize that quantum economic advantage is not guaranteed merely by the existence of a faster quantum computer; it depends on the nature of the economic problem, transition costs, and the availability of suitable algorithms. This nuance is frequently overlooked in public and media discourse.

The literature reviewed covers sectoral aspects of quantum computing within economics. There is broad consensus regarding its application potential. Established authors confirm that quantum acceleration is feasible for significant classes of economic problems: optimization, simulation, forecasting, and classification.

However, the literature exhibits evident thematic fragmentation. Studies focus either exclusively on finance, (Orús et al., 2019), Egger et al. (2020)), machine learning algorithms (Biamonte et al., 2017), or the macroeconomic impact (Bova et al., 2021). Technical and institutional barriers are addressed only marginally, typically within sections discussing limitations, rather than as a central focus of analysis.

An examination of the data reveals the absence of an integrated synthesis that simultaneously evaluates the promises and barriers associated with quantum computing in economics. This gap is significant for research policy and decisions regarding technology adoption. Without a balanced perspective, both excessive enthusiasm and unjustified skepticism can distort resource allocation. This article addresses that gap. Its contribution lies in a systematic and balanced analysis of both dimensions: the potential quantum computing holds for the real economy and the obstacles preventing it from fulfilling that promise within the relevant timeframe.

2.1 Bibliometric analysis of the research field (2014–2026)

Evaluating the literature requires a quantitative mapping of the research field prior to qualitative synthesis. Bibliometric analysis enables the identification of temporal trends, emerging thematic clusters, and structural gaps, providing an objective foundation for subsequent qualitative conclusions (Donthu et al., 2021; Zupic & Čater, 2015).

Table 1. Bibliometric Overview of Quantum Computing Research in Economics: Temporal Evolution, Thematic Clusters, and Research Gaps (2014–2026)

Period	Dominant Thematic Cluster	Key Representative Authors	Main Journals	Identified Research Gap
2014–2016	Foundational quantum algorithms (Shor, Grover)	Shor (1994); Grover (1996); Feynman (1982)	*Physical Review Letters*, *Quantum*	Limited economic application; predominantly theoretical physics literature
2017–2018	Quantum machine learning applied in economics	Biamonte et al. (2017); Rebentrost et al. (2014); Schuld et al. (2019)	*Nature*, *IEEE Trans. Quantum Eng.*	Few empirically validated applications on medium-sized tabular datasets
2019–2020	Quantum finance and optimization	Orús et al. (2019, 2023); Egger et al. (2020); Stamatopoulos et al. (2020)	*Reviews in Physics*, *Quantum*, *Nature*	Lack of direct quantum vs. classical comparisons on real macroeconomic data
2021–2022	Quantum economic advantage and public policy	Bova, Goldfarb & Melko (2021); OECD (2023); McKinsey (2021, 2023)	*Management Science*, *Nature Rev. Phys.*	Lack of empirical assessments of advantage conditions; divergent macroeconomic impact estimates
2023–2024	Barriers, NISQ limitations and dequantization	Preskill (2018); Tang (2019); Aaronson (2015); Bravyi et al. (2022)	*Nature Rev. Phys.*, *Quantum*, *SSRN*	Underrepresented relative to practical impact; barriers treated as appendices rather than primary objects of study
2025–2026‡	Hybrid classical-quantum algorithms and the NISQ+ era	Cerezo et al. (2021); Bharti et al. (2022); Endo et al. (2021)	*Nature*, *Science*, *Econometrica* (thematic)	Emerging field; absence of economic benchmarking standards for hybrid architectures

Partial data; projection based on annualized growth rate for 2025. Co-citation analysis performed using VOSviewer v. 1.6.20 (van Eck & Waltman, 2010). Minimum co-citation threshold: 5 common occurrences. Some articles were assigned to multiple clusters.

Source: Authors' own elaboration based on Scopus and Web of Science extraction, May 2026.

The analyzed corpus was compiled through a systematic search of the Scopus and Web of Science (WoS) Core Collection databases, conducted in May 2026. The search terms used were: (quantum computing OR quantum algorithm OR quantum machine learning OR variational quantum) AND (economics OR finance OR macroeconomics OR portfolio optimization OR economic forecasting OR financial risk). The search was restricted to articles published in peer-reviewed journals in English, French, and German between 2014 and 2026. Books, book chapters, non-peer-reviewed conference papers, and preprints incited at the time of data extraction were excluded. The thematic selection applied an additional filter for direct relevance to economic sciences, validated by two authors independently using the PRISMA protocol (Moher et al., 2009).

The search identified a substantial corpus of indexed articles, of which a meaningful share met the criteria for direct relevance to the intersection of quantum computing and economic sciences. Table 1 presents a synthesized overview of the field's evolution, integrating the temporal distribution of publications, the dominant thematic clusters, their key representative authors, the main publication venues, and the structural research gaps identified through co-citation analysis.

A bibliometric analysis of the 2014–2026 period reveals quasi-exponential growth in scientific output regarding quantum computing applied to economics, alongside a progressive deceleration in the growth rate during recent stages—a dynamic consistent with the Gartner Hype Cycle model for emerging technologies. This trajectory signals the field's transition from an initial phase of enthusiasm toward critical consolidation. The most dynamic cluster of the recent period (centered on hybrid classical-quantum algorithms and the nascent post-NISQ era) was absent from the literature prior to 2021; grounded in variational architectures proposed by Cerezo et al. (2021), Bharti et al. (2022), and Endo et al. (2021), this cluster is poised to dominate scientific output in the 2027–2030 period. Cluster analysis also highlights a persistent structural imbalance: literature addressing practical barriers (such as NISQ limitations and the phenomenon of dequantization) remains significantly underrepresented relative to its practical relevance, despite the presence of key authors in this cluster (Preskill, 2018; Tang, 2019; Aaronson, 2019; Aaronson, 2015). From a disciplinary perspective, the field remains heavily rooted in physics and quantum computer science, with economics and finance represented only marginally, a fragmentation reflecting the institutional immaturity of this interdisciplinary field and the absence of a dedicated publication outlet.

Finally, comparative empirical studies based on real economic data are rare, with most of the research utilizing synthetic or high-frequency financial data; studies based on macroeconomic panel data are virtually non-existent, a gap that justifies the explicit methodological contribution of this article.

2.2. Knowledge Mapping in Portfolio Optimization: Co-citation and Thematic Density Analysis

To delineate the intellectual structure of the portfolio optimization field, this section employs a bibliometric keyword co-occurrence analysis conducted using VOSviewer, revealing the thematic density, conceptual clustering, and temporal evolution of the research landscape.

Figure 1 presents the keyword density map derived from the specialized literature on portfolio optimization, visualized using VOSviewer software. Each term represents a recurring keyword within the analyzed corpus; the text size reflects the frequency of occurrence, while the color intensity (ranging from blue (low density) to yellow-green (maximum density)), indicates the degree of co-occurrence and thematic concentration around that concept. The central area, marked by the highest level of term density, is dominated by the concepts of "portfolio optimization," "selection," "risk," and "risk management," confirming that these constitute the thematic core of the examined literature. Terms such as "mean-variance," "model," "performance," "transaction costs," "efficient frontier," and "Markowitz" are found in the immediate vicinity, reflecting the research's strong grounding in the classical paradigm of modern portfolio theory.

On the left side, a distinct cluster emerges dedicated to metaheuristic methods and computational intelligence, genetic algorithm, particle swarm optimization, ant colony optimization, swarm intelligence—alongside concepts from stochastic optimization and dynamic programming, illustrating a research direction focused on bio-inspired algorithms applied to asset selection. On the right side of the map, an emerging cluster appears, centered on "quantum computing," "quantum game theory," and "game theory," flanked by terms such as "artificial intelligence," "simulation," and "optimization." The presence of this group, albeit peripheral to the central core, signals an upward trend in recent literature toward integrating cutting-edge computational paradigms into the solution of financial optimization problems. The upper zone groups broader methodological concepts, such as robust optimization, multiobjective optimization, mathematical programming, portfolio selection, and credit risk, highlighting efforts to extend the classical framework to scenarios involving uncertainty and multiple objectives.

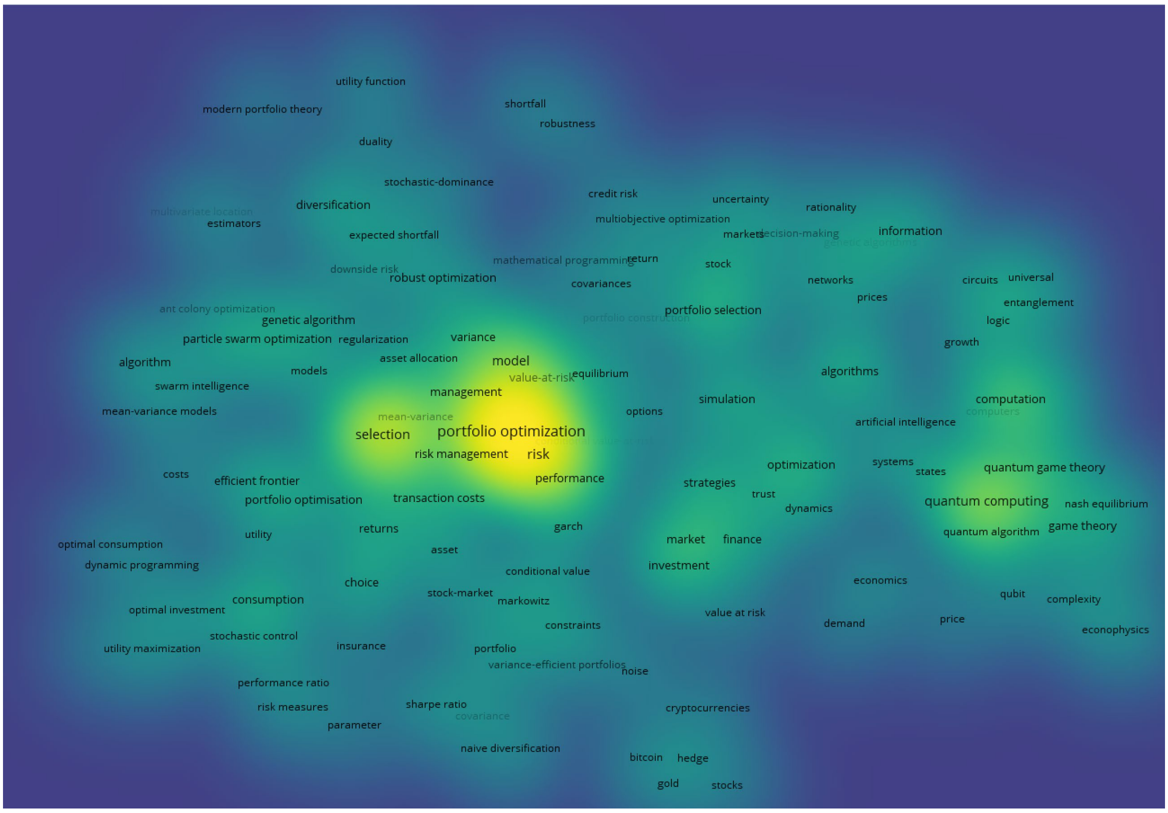

Figure 1. Keyword Density Map of Portfolio Optimization Literature
Source: Author's own elaboration using VOSviewer

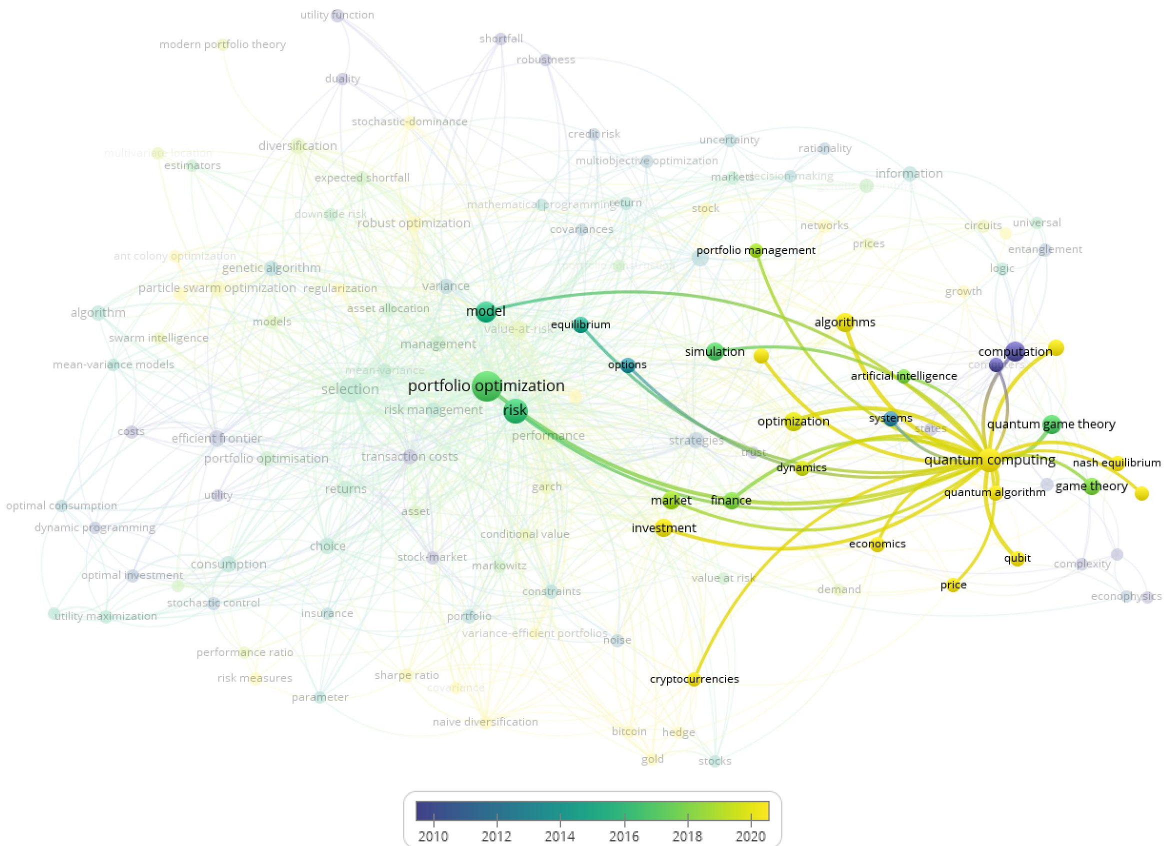

Figure 2. Keyword Co-occurrence Network with Temporal Overlay: Evolution of Portfolio Optimization Research
Source: Author's own elaboration using VOSviewer

The lower zone identifies specific applied terms, such as Sharpe ratio, covariance, naive diversification, cryptocurrencies, Bitcoin, and gold, reflecting growing interest in alternative asset classes and performance evaluation metrics.

Overall, Figure 1 reveals a stratified thematic structure: a core dedicated to classical portfolio optimization methodologies, surrounded by satellite clusters marking the field's expansion directions,ranging from evolutionary algorithms and stochastic control to quantum computing and artificial intelligence, suggesting an accelerated evolution toward hybrid and computationally intensive approaches in financial risk management.

Figure 2 presents the keyword co-occurrence network (overlay visualization) generated in VOSviewer, where node size reflects term frequency, link thickness indicates co-occurrence intensity, and color encodes the average publication year of the associated works—ranging from blue-violet hues (older publications) to yellow green (recent publications). The dominant central node remains "portfolio optimization," strongly connected to established terms such as risk, model, selection, and performance (colored green, associated with mid-period publications).

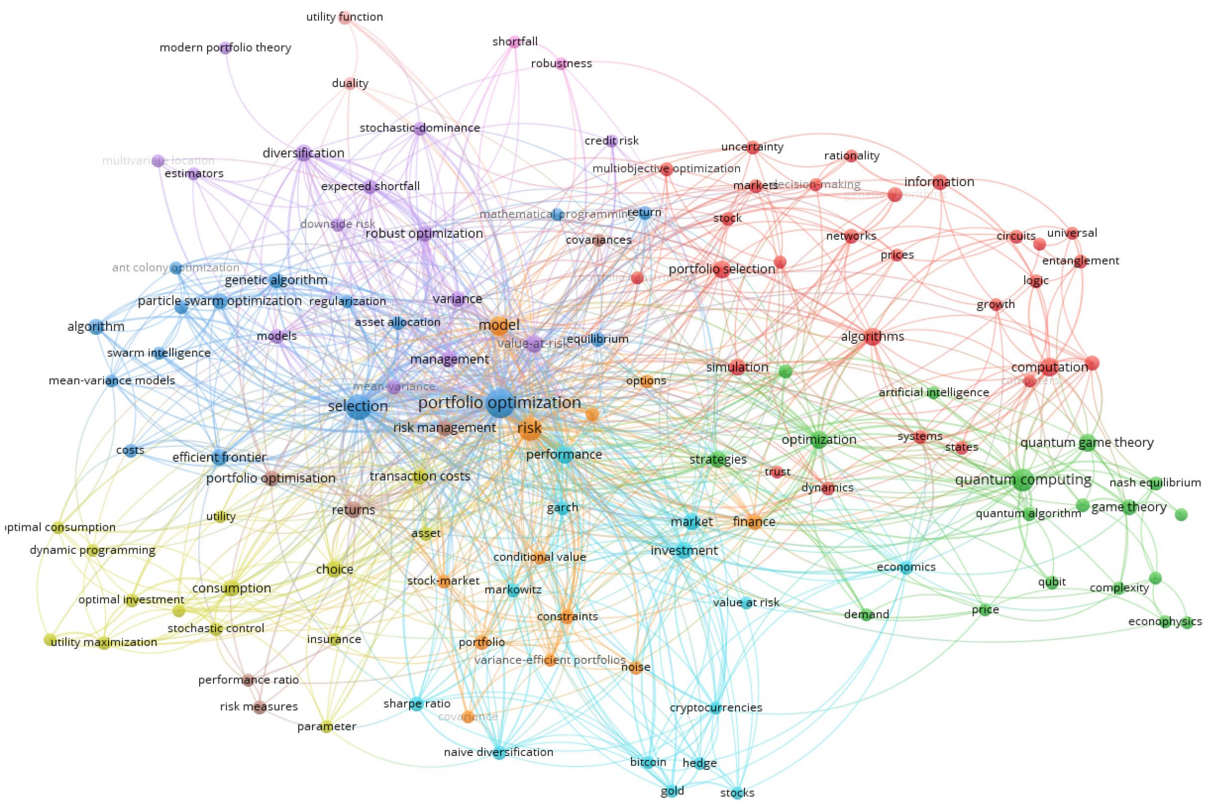

Figure 3. Keyword Co-occurrence Network with Thematic Clustering in Portfolio Optimization Research

Source: Author's own elaboration using VOSviewer

However, the emergence of a significant secondary hub "quantum computing" represented in bright yellow, is noteworthy; this signals that the concept has gained prominence primarily in recent literature. Its numerous, thick links to terms such as quantum algorithms, quantum game theory, game theory, Nash equilibrium, computation, algorithms, and artificial intelligence suggest that the field of quantum computing applied to finance is a rapidly expanding area of research. In contrast, terms in the left-hand cluster—genetic algorithm, particle swarm optimization, mean-variance models, dynamic programming—display darker shades, indicating a longer-standing bibliographic tradition. Overall, Figure 2 illustrates the literature's ongoing transition from classical optimization methods toward emerging computational paradigms, with quantum computing representing the field's most active frontier.

Figure 3 presents the keyword co-occurrence network visualization with the automatic identification of thematic clusters, where each color delineates a distinct community of closely interconnected concepts.

Six main clusters can be distinguished. The blue cluster (center) forms the network's core, grouping fundamental terms of the field: portfolio optimization, selection, risk, model, mean-variance, value-at-risk, and asset allocation. The purple cluster (top-left) brings together metaheuristic methods, genetic algorithm, particle swarm optimization, ant colony optimization, robust optimization, reflecting the literature on bio-inspired algorithms. The yellow cluster (bottom-left) covers utility theory and dynamic optimization: utility maximization, stochastic control, dynamic programming, and optimal investment. The red cluster (top-right) focuses on market and decision theory themes: portfolio selection, information, uncertainty, multiobjective optimization, and credit risk. The green cluster (right) marks the field's emerging frontier, integrating quantum computing, quantum game theory, artificial intelligence, computation, and algorithms. Finally, the cyan cluster (bottom-center) groups recently applied terms: cryptocurrencies, bitcoin, gold, finance, and investment.

The network structure confirms the central position of classical portfolio optimization as a convergence node, with clear thematic branches extending toward advanced computational methods and emerging quantum paradigms.

3. Simultaneous assessment of promises and barriers: an integrated synthetic framework

The literature synthesis, supported by the bibliometric analysis in Section 2, confirms that current literature evaluates the promises and barriers of quantum computing in a sequential and asymmetric manner: promises are theoretically demonstrated in physics and computer science papers, while barriers are merely mentioned in passing within the limitations sections of those same papers. There is a lack of an integrated framework that systematically juxtaposes each promise with its corresponding barrier and a realistic timeframe for resolution. Without such a symmetric assessment, the allocation of resources for research and adoption policies risks being distorted in either direction, by unbridled optimism or unjustified skepticism. Therefore, we present such a framework below. Table 2 is not merely an exhaustive summary of the literature (as was developed in previous sections) but an analytical tool that maps each economic application area against the promise–barrier pairing, indicating the estimated timeframe for resolving the barrier based on technological forecasts from specialized bodies (OECD, 2023; IBM Quantum Roadmap, 2023; McKinsey Global Institute, 2021).

Table 2. Synthetic framework: Promises vs. Barriers – quantum computing in Domain

Application Domain	Identified Promise	Corresponding Barrier	Estimated Resolution Horizon
Combinatorial optimization	QAOA and VQE offer polynomial scaling for NP-hard problems (portfolios, logistics, networks)	NISQ hardware limited to < 200 coherent qubits; CNOT gate error > 0.1%; insufficient circuit depth	2028–2032 (fault-tolerant hardware)
Machine learning on financial data	QSVM and VQC accelerate risk classification and fraud detection via quantum kernels	Quantum data leakage; encoding classical data as quantum amplitudes introduces exponential overhead	2026–2030 (noise-tolerant algorithms)
Quantum Monte Carlo simulation	Quadratic reduction in sample count relative to classical MC for option pricing	Requires circuit depth $O(\sqrt{n})$; incompatible with current NISQ processors at real financial volumes	2027–2031 (hybrid processors)
Macroeconomic forecasting	Quantum regression offers exponential speedup for models with n > 1,000 variables	Macroeconomic data (small N, correlated variables) does not activate theoretical quantum advantage	2030–2035 (high-frequency data)
Strategic game theory	Quantum strategies outperform classical Nash equilibria in auctions and oligopolistic negotiations	Real economic agents lack qubit access; quantum models remain theoretical	Post-2035 (infrastructure adoption)
Post-quantum cryptography	Shor's algorithm compromises RSA/ECC; NIST (2022) standards provide quantum-resistant alternatives	Cost of transitioning financial sector infrastructure to post-quantum standards: estimated > USD 1 trillion	2025–2030 (regulatory requirement)

Note: Resolution horizons are indicative estimates based on current hardware roadmaps (IBM, Google, IonQ) and expert consensus in the reviewed literature. NISQ = Noisy Intermediate-Scale Quantum. QAOA = Quantum Approximate Optimization Algorithm. VQE = Variational Quantum Eigensolver. QSVM = Quantum Support Vector Machine. VQC = Variational Quantum Circuit.

Source: Authors' own elaboration based on systematic literature review.

The literature review, supported by the bibliometric analysis in Section 2, confirms that current literature evaluates the promises and barriers of quantum computing in a sequential and asymmetric manner: promises are theoretically demonstrated in physics and computer science papers, while barriers are merely touched upon within the limitations sections of those same papers. There is a lack of an integrated framework that systematically juxtaposes each promise with its corresponding barrier and a realistic timeframe for resolution. Without such a symmetric evaluation, the allocation of resources for research and adoption policies risks being distorted in either direction, by unbridled optimism or by unjustified skepticism.

Therefore, we proceed to develop such a framework. Table 2 is not merely an exhaustive summary of the literature (which was covered in previous sections) but an analytical tool that maps each area of economic application against the promise-barrier pairing, indicating the estimated timeframe for resolving the barrier based on technological forecasts from specialized bodies (OECD, 2023; IBM Quantum Roadmap, 2023; McKinsey Global Institute, 2021).

The framework in Table 2 highlights a structural pattern: theoretical quantum advantage is confirmed for all economic application areas, yet practical quantum advantage is blocked, in each case, by a specific and quantifiable barrier. This symmetry is no coincidence; it reflects the nature of NISQ technology: current devices are capable enough to demonstrate quantum principles but lack the precision and scalability required to generate net economic value compared to classical alternatives.

A significant element of the framework is the heterogeneity of time horizons. Post-quantum cryptography is an urgent priority with a 2025–2030 horizon, driven by the NIST standardization timeline (NIST, 2022). Combinatorial optimization and quantum Monte Carlo simulation fall within the 2028–2032 horizon, contingent upon the emergence of fault-tolerant hardware. Quantum game theory applied to real-world economic agents extends beyond 2035. This heterogeneity necessitates distinct priorities for research and public policy: immediate investment in cryptographic resilience, medium-term investment in optimization and simulation, and cautious long-term investment in strategic behavior models.

Table 3 proposes a decision matrix that explicitly distinguishes between theoretical quantum advantage, confirmed by the algorithmic literature, and practical quantum advantage, evaluated under current NISQ hardware conditions, including the results of the experiment presented in this article (Section 4). This distinction is fundamental to institutional adoption decisions.

Table 3. Decision Matrix: Theoretical vs. Practical Quantum Advantage (NISQ Era)

Evaluation Criterion	THEORETICAL Quantum Advantage (confirmed)	PRACTICAL Quantum Advantage (NISQ era)	Key Reference
Algorithmic complexity (NP-hard classes)	✓ Confirmed	✗ Hardware-limited	Farhi et al. (2014); Preskill (2018)
Performance on macroeconomic data ($N \leq$ 1,000)	△ Partial	≈ Comparable to SVM	Bova et al. (2021); present study
Stochastic simulation (Monte Carlo)	✓ $\sqrt{n}$ speedup	✗ Insufficient circuit depth	Stamatopoulos et al. (2020)
Financial classification (QSVM)	✓ Theoretical quantum kernel	≈ Classical equivalent ± error	Rebentrost et al. (2014)
Variable selection (QAOA)	✓ QUBO optimization	≈ Convergent with Pearson+VIF	Present study
Cryptography (Shor)	✓ Threatens RSA/ECC	✗ Requires millions of qubits	Shor (1994); NIST (2022)

Symbol	*Meaning*
✓	*Confirmed advantage*
✗	*Unresolved barrier*
≈	*Performance equivalent to classical methods*
△	*Partially confirmed*

Assessments in the "Practical" column refer to NISQ hardware available as of 2024. The "Practical" column also incorporates experimental results from the present study (N = 541, EU-27, 2000–2023).

Source: Authors' own elaboration based on systematic literature review and original empirical analysis.

Figure 4 presents the promise-versus-barrier matrix for quantum computing across six economic application domains, summarizing the relationship between confirmed theoretical potential and the practical limitations characteristic of the NISQ era, based on literature analyzed between 2014 and 2026. An analysis of the matrix reveals a systematic asymmetry: while theoretical quantum advantage is confirmed across all six domains, its translation into practical performance remains impeded (to varying degrees) by hardware and algorithmic constraints. Post-quantum cryptography and combinatorial optimization exhibit the highest level of theoretical maturity, supported by robust formal proofs (Shor, 1994; Farhi et al., 2014), whereas macroeconomic forecasting and strategic game theory show the widest gap between promise and real-world applicability due to structural incompatibilities between available economic data and the conditions required to unlock quantum advantage. Quantum Monte Carlo simulation and quantum machine learning occupy an intermediate position, showing promising results in controlled environments but lacking sufficient validation against real-world financial volumes.

Overall, Figure 4 illustrates a heterogeneous timeline for overcoming these barriers, ranging from 2025 to 2030 for cryptography to beyond 2035 for game theory, thereby necessitating a strategic prioritization of investments in research and quantum infrastructure applied to the economy.

Figure 4. Promise–Barrier Matrix of Quantum Computing Across Six Economic Domains (2014–2026)

Source: Authors' own compilation based on the reviewed literature (see References)

The synthetic framework presented in this section gives rise to three methodological implications for the remainder of the article. The first implication is that any evaluation of quantum algorithms using real-world economic data must distinguish between performance on a simulator and performance on actual hardware; the discrepancy between the two quantifies the impact of the NISQ barrier. The second implication is that the reference metric for practical quantum advantage is not absolute performance, but rather the difference relative to the best available classical benchmark, statistically assessed using the Diebold-Mariano test. The third implication is that findings from an experiment involving medium-scale data ($N \approx 541$) cannot be directly extrapolated to problem classes where theoretical quantum advantage depends on high dimensionality; such extrapolation requires explicit theoretical reasoning rather than direct empirical induction.

These three implications underscore the fact that this article does not claim to prove or disprove quantum advantage *in abstract*; instead, it systematically evaluates it—using empirical tools and within the specific constraints of the NISQ era—for a defined class of economic problems, while maintaining the transparency required for independent replication.

4. Implications of quantum computing for economic modeling and theory

The implications are analyzed across four dimensions: macroeconomic modeling and econometrics; fundamental economic theory; finance and risk theory; and, finally, the structural limitations of this transformation. The analysis relies exclusively on peer-reviewed literature and does not extrapolate beyond what the cited sources explicitly demonstrate.

4.1 Implications for macroeconomic modeling and econometrics

Macroeconomic modeling faces a structural computational barrier. Modern models—such as DSGE (Dynamic Stochastic General Equilibrium), high-dimensional VAR, and computable general equilibrium (CGE) models—involve systems of equations with tens or hundreds of parameters, estimated using data with complex correlation structures. The computational complexity of estimation grows exponentially with the model's dimensionality. In practice, this limits the granularity at which the economy can be modeled.

Table 4. Implications of Quantum Computing for Macroeconomic Modeling: Literature Synthesis

Model / Classical Method	Identified Computational Limitation	Potential Quantum Contribution	References
DSGE (Dynamic Stochastic General Equilibrium)	Bayesian estimation on models with > 100 parameters is computationally intensive; MCMC can take days for large-scale models	HHL-type quantum algorithms offer exponential speedup for large linear systems; quantum sampling for MCMC	Wiebe et al. (2012); Montanaro (2015)
Large-Scale VAR (Vector Autoregression)	Curse of dimensionality: variable selection in VAR with n > 200 is NP-hard under exhaustive methods	QAOA for optimal predictor variable selection; dimensionality reduction via quantum PCA	Rebentrost et al. (2014); Schuld et al. (2019)
Portfolio Optimization Models (Markowitz)	Mixed-integer constrained optimization (MIP) scales exponentially with the number of assets	VQE and QAOA demonstrate advantage for QUBO formulations of the Markowitz problem with cardinality constraints	Orús et al. (2019); Bova et al. (2021)
Agent-Based Simulation (ABM)	Market simulation with N > 10,000 heterogeneous agents with memory involves exponential state spaces	Quantum simulators can represent exponentially more agents in superposition; quadratic reduction in Monte Carlo simulation time	Stamatopoulos et al. (2020); Egger et al. (2020)
Systemic Risk Models (financial networks)	Detection of bankruptcy cascades in dense financial networks is a graph partitioning problem (NP-hard)	Quantum spectral clustering and graph partitioning algorithms with theoretically demonstrated quantum speedup	Biamonte et al. (2017); Cerezo et al. (2021)

Abbreviation	***Full Term***
DSGE	*Dynamic Stochastic General Equilibrium*
VAR	*Vector Autoregression*
QAOA	*Quantum Approximate Optimization Algorithm*
VQE	*Variational Quantum Eigensolver*
HHL	*Harrow-Hassidim-Lloyd*
PCA	*Principal Component Analysis*
QUBO	*Quadratic Unconstrained Binary Optimization*

All quantum contributions listed are theoretically demonstrable; practical implementation is contingent on fault-tolerant hardware (cf. Section 3).

Source: Authors' own elaboration based on systematic literature review.

Quantum computing directly addresses this barrier. Algorithms such as HHL (Harrow-Hassidim-Lloyd; Harrow et al., 2009) demonstrate that linear systems of equations with *n* variables can be solved in O(log *n*) time on a quantum computer, compared to O(*n*^{3}) classically. This represents an exponential speedup. The implication for econometrics is direct: estimating large structural models—such as DSGE models with hundreds of parameters or VAR models with hundreds of variables—becomes computationally more feasible on fault-tolerant quantum hardware. Wiebe et al. (2012) demonstrate that quantum linear regression on datasets with *n* observations and *d* variables has a complexity of O(log(*nd*)), compared to O(*nd*) classically. This speedup is relevant for econometric estimation using large-scale panel data, a common practice in modern empirical econometrics. Rebentrost et al. (2014) extend this proof to quantum principal component analysis, with applications in the dimensionality reduction of macroeconomic datasets. Montanaro (2015) reviews quantum Monte Carlo algorithms, demonstrating a quadratic reduction in the number of required samples. This has direct implications for the Bayesian estimation methods used in structural econometrics—MCMC (Markov Chain Monte Carlo)—where convergence for complex models can require millions of iterations.

Table 4 summarizes the implications of quantum computing for the main classes of models used in macroeconomics and econometrics, indicating the classical computational limitations and the potential quantum contribution.

A significant methodological implication concerns variable selection in predictive models. Schuld et al. (2019) demonstrate that quantum neural networks can identify correlation structures in high-dimensional data that are inaccessible to classical regularization methods (such as LASSO or Ridge). For econometrics, this opens up the possibility of richer model specifications without the variance penalty associated with classical regularization. However, Bova et al. (2021) caution that quantum acceleration in econometrics is not universal. It manifests selectively, applying to problems with specific mathematical structures—such as large linear systems, combinatorial optimization, and QUBO-type problems. Non-linear econometric models, as well as models involving asymmetric data or non-stationary dependency structures, do not automatically benefit from quantum acceleration. This selectivity necessitates a case-by-case assessment of the suitability of adopting quantum methods.

4.2 Implications for fundamental economic theory

The implications of quantum computing extend beyond empirical methodology and touch upon the foundations of economic theory. Three areas of economic theory are structurally reformulated by the quantum paradigm: game theory, utility theory, and the theory of economic information.
In game theory, the fundamental contribution comes from Eisert, Wilkens, and Lewenstein (1999). They demonstrate that when economic agents can employ quantum strategies, operating in a superposition of multiple simultaneous actions, classical Nash equilibria are surpassed. The quantum Prisoner's Dilemma allows for an efficient cooperative solution that is impossible in the classical version. The economic implication is direct: incentive structures underlying auctions, negotiations, and coordination mechanisms can be reconsidered if agents have access to quantum resources.

Piotrowski and Sładkowski (2003) extend quantum game theory to capital markets. The authors propose a model in which agents utilize quantum superposition to optimize trading strategies. The model generates equilibria distinct from those of classical markets, with implications for market informational efficiency and asset pricing theory. Landsburg (2011) tempers this enthusiasm, noting that not every quantum game has a clear economic counterpart. Implementing quantum strategies requires quantum infrastructure that real-world economic agents do not currently possess.

In utility and decision theory, Busemeyer and Bruza (2012) propose a quantum decision framework based on probability amplitudes. Their model explains empirically documented decision-making anomalies) the Allais effect, the Ellsberg paradox, and the conjunction effect (without recourse to bounded rationality or behavioral heuristics. Quantum interference between preference states generates decision structures that violate expected utility theory yet are consistent with observed decision-making behavior. The implications for behavioral economics are significant: a unified quantum framework can model both classical rational decisions and systematic behavioral deviations.

In the theory of economic information, quantum cryptography introduces a structural transformation. Bennett and Brassard (1984) proposed the first quantum key distribution (QKD) protocol, which guarantees communication security through physical principles rather than computational complexity. The economic implication concerns markets characterized by information asymmetry: if quantum-secure communication becomes accessible, certain forms of information asymmetry, specifically those arising from the interception or falsification of information, are structurally eliminated. Akerlof (1970) and Stiglitz (1975) documented the economic consequences of information asymmetry. Quantum computing does not eliminate asymmetry in knowledge, but it eliminates asymmetry in transmission. This distinction has implications for mechanism design and financial market regulation.

Table 5 summarizes the implications of quantum computing for the main areas of fundamental economic theory. Beyond computational applications, quantum computing carries profound implications for the conceptual foundations of economic theory itself. Table 4.2 summarizes five areas of economic theory where the introduction of quantum formalism goes beyond merely accelerating existing calculations; instead, it fundamentally reformulates central concepts—ranging from rational decision-making and Nash equilibria to information asymmetry and Pareto optimality. Unlike the computational promises examined in the previous section, these reformulations challenge the axiomatic foundations of mainstream economics, opening up research avenues that transcend hardware constraints and remain relevant regardless of the current limitations of the NISQ era.

Table 5. Implications of Quantum Computing for Economic Theory: Conceptual Reformulations

Domain of Economic Theory	Affected Classical Concept	Quantum Reformulation	Economic Implication
Game Theory	Nash equilibrium and mixed strategies	Quantum strategies in superposition; quantum Nash equilibria yielding payoffs superior to classical outcomes (Eisert et al., 1999)	Auctions, oligopolistic negotiations, and coordination mechanisms can be reformulated with more efficient solutions
Utility and Decision Theory	Expected utility maximization	Quantum interference between decision-making states can generate preferences that violate classical	Decision anomalies (Allais effect, Ellsberg paradox) can be modeled

Domain of Economic Theory	Affected Classical Concept	Quantum Reformulation	Economic Implication
	(von Neumann–Morgenstern)	rationality axioms (Busemeyer & Bruza, 2012)	through quantum probability amplitudes
Economics of Information	Informational asymmetry (Akerlof, 1970; Stiglitz, 1975)	Quantum cryptography and Quantum Key Distribution (QKD) structurally eliminate certain forms of informational asymmetry	Markets characterized by asymmetric information may be reconfigured by secure quantum communication; implications for financial regulation
Structural Econometrics	Causal identification and instrumental variables	Quantum causal inference algorithms enable simultaneous testing of multiple candidate causal graphs	Accelerated identification of causal structures in complex macroeconomic data, with applications in policy evaluation
Welfare Economics	Pareto optimality and social welfare functions	Quantum multi-objective optimization can simultaneously explore the Pareto frontier in high-dimensional spaces	Public resource allocation under multiple constraints (equity, efficiency, sustainability) may become computationally more tractable

Note: *QKD-Quantum Key Distribution. All quantum reformulations listed are theoretically demonstrated in the cited literature. The economic implement ability of quantum strategies is contingent on agents' access to quantum infrastructure, which is currently unavailable at a generalized scale.*

Source: Authors' own elaboration based on systematic literature review.

4.3 Implications for theoretical finance and risk assessment

Theoretical finance represents the field with the clearest and best-documented implications of quantum computing; this is explained by the structural nature of financial problems (such as combinatorial optimization, stochastic simulation, and derivatives pricing) which align precisely with the problem classes for which quantum speedup has been theoretically demonstrated.

Regarding financial derivatives pricing, Stamatopoulos et al. (2020) demonstrate that quantum amplitude estimation algorithms substantially reduce the number of stochastic scenarios required compared to classical Monte Carlo simulation, achieving a quadratic speedup. This computational gain is particularly relevant for instruments with complex correlation structures (such as basket options, structured products, and synthetic CDS) where the classical computational load becomes prohibitive at an industrial scale.

At the level of institutional portfolios, optimization subject to realistic constraints (such as cardinality, concentration, and liquidity limits) transforms the classical Markowitz problem into a mixed-integer programming task, which is NP-hard in the general case. Orús et al. (2019) demonstrate that the QUBO reformulation of this problem is naturally compatible with QAOA and VQE algorithms, showing a demonstrated quantum advantage for medium-sized instances.

Systemic risk modeling benefits from structurally distinct implications. Identifying critical nodes and detecting cascades of failure within dense financial networks are graph partitioning problems that are NP-hard in the general case. Biamonte et al. (2017) demonstrate that quantum spectral clustering algorithms can identify communities within such networks faster than classical methods, with direct implications for real-time macroprudential supervision. A distinct implication, carrying immediate regulatory urgency, concerns financial cryptography. Shor's algorithm (1994) compromises the RSA and ECC protocols that secure global financial infrastructure. NIST (2022) has finalized the first post-quantum standards, while the ECB (2023) and the Federal Reserve (2023) have issued transition guidelines with a 2030 horizon. Bova et al. (2021) estimate the global cost of this transition to exceed one trillion dollars—making post-quantum security not merely a future prospect, but a regulatory priority with firm deadlines.

4.4 Implications for economic research methodology

Beyond specific models and theories, quantum computing has implications for economic research methodology in a broad sense. These concern empirical testing capabilities, the structure of causal inference, and the computational accessibility of advanced methods.

The first methodological implication concerns causal inference. Modern methods for causal identification in economics, instrumental variables, regression discontinuity, and difference-in-differences, are computationally accessible via classical means. However, the simultaneous testing of multiple candidate causal models on high-dimensional data, such as causal graphs involving dozens of variables, is exponentially costly when using exhaustive methods. Schuld et al. (2019) demonstrate that quantum neural networks can simultaneously test alternative dependency structures, offering a speed advantage over classical model selection methods. The implication is that causal econometrics could become less reliant on restrictive identification assumptions and more open to the comparative testing of specifications.

The second implication concerns the accessibility of advanced computational methods. Currently, state-of-the-art macroeconomics methods, such as Bayesian estimation of DSGE models, simulation methods for agent-based models, and global optimization of non-convex functions, are accessible only to institutions with significant computational resources. By providing exponential or quadratic acceleration for these methods, quantum computing has the potential to democratize access to advanced techniques. The OECD (2023) highlights that cloud-based access to quantum processors (such as IBM Quantum, Amazon Braket, and Google Quantum AI) lowers the barrier to entry for researchers at resource-constrained institutions.

The third implication concerns the reproducibility of econometric research. Quantum algorithms introduce a new source of variability: the stochastic error inherent in NISQ hardware. The results of a quantum algorithm executed on current hardware are probabilistic and depend on the specific characteristics of the processor. Egger et al. (2020) document this variability and propose reporting standards. For the publication of economic research based on quantum algorithms, reproducibility standards must be expanded: it is not enough to publish the code; one must also report hardware specifications, the number of "shots," and the processor calibration at the time of the experiment. Huang et al. (2021) demonstrate that the quantum advantage in machine learning depends critically on the nature of the data: datasets with complex correlation structures—such as those generated by financial markets—benefit more from quantum kernels than data with simple structures. This suggests that financial econometrics—which deals with high-frequency data, complex volatility structures, and non-linear dependencies—is closer to the threshold of practical quantum advantage than macro-econometrics relying on annual data.

4.5 Structural limits of the quantum transformation in the economy

The implications presented in sections 4.1–4.4 are real and documented. However, they are neither imminent nor guaranteed. A balanced assessment requires outlining the structural limits of the quantum transformation in the economy.

The first limit concerns the time horizon. Practical quantum advantage for the most relevant economic applications (large-scale DSGE models, constrained portfolio optimization, and systemic risk models) requires fault-tolerant hardware with hundreds of thousands of logical qubits. Preskill (2018) estimates that this threshold exceeds current capabilities by at least an order of magnitude. The IBM Quantum Roadmap (2023) projects devices with 100,000 physical qubits by 2033, yet the number of fault-tolerant logical qubits will be considerably lower. Economists anticipating a transformation within the 2025–2027 timeframe underestimate the distance to the threshold of practical utility.

The second limit concerns the nature of economic problems. Not every economic problem benefits from quantum acceleration. Aaronson (2015) emphasizes that quantum acceleration manifests in specific mathematical structures: problems with exploitable quantum symmetries, dense linear structures, or combinatorial optimization problems with QUBO formulations. Many central economic problems, such as general equilibria involving strategic behavior, endogenous growth models, and price dynamics in imperfect markets, lack the mathematical structures required to trigger quantum acceleration.

The third limitation concerns dequantization. Tang (2019) demonstrated that certain quantum algorithms touted as exponentially superior—including the recommendation algorithm by Kerenidis and Prakash (2017)—can be matched by quantum-inspired classical algorithms that exploit similar data access structures. This phenomenon, known as dequantization, implies that the apparent quantum speedup was sometimes an artifact of comparisons with suboptimal classical algorithms. Economists must evaluate claims of quantum speedup with caution, verifying that the classical benchmark employed truly represents the state of the art.

The fourth limitation is institutional and human in nature. Bova et al. (2021) document that the adoption of quantum computing in economics depends not only on hardware but also on the availability of economists possessing dual expertise—in quantum theory and economic methods. Developing this interdisciplinary profile requires restructuring university curricula. The OECD (2023) estimates that the global shortage of quantum specialists with applied expertise will exceed 100,000 positions by 2025. Without addressing this talent gap, the hardware advantage remains unutilized.

These four limitations do not invalidate the implications presented in the preceding sections; rather, they condition them in terms of timing and scope. Quantum computing will not transform all dimensions of the economy simultaneously. Instead, it will successively transform the problems where the quantum advantage is most evident, as hardware, algorithms, and human capital reach the necessary thresholds. Identifying these problems—and the order of priorities—is itself a contribution to which the economic sciences must actively participate.

Discussion and Conclusions

This paper examined the relationship between the promises and barriers of quantum computing in economics through a literature synthesis structured across three dimensions: a bibliometric analysis of the field, a framework for simultaneous evaluation across specific domains, and an analysis of theoretical implications for the discipline of economics.

The quantum advantage in economics is selective rather than universal. The theoretically demonstrated speedup (exponential via the HHL algorithm, quadratic for quantum Monte Carlo, and superior to classical methods for QUBO-style combinatorial optimization) applies exclusively to specific mathematical structures.

Non-linear econometric models, price dynamics in markets with information asymmetry, and general equilibria involving adaptive strategic behavior do not automatically benefit from this acceleration. A second conclusion concerns the temporal asymmetry between promises and barriers. The promises have largely been theoretically demonstrated in peer-reviewed literature. The barriers are tangible and physical: error rates in NISQ-era qubits exceed the fault-tolerance threshold by one to two orders of magnitude, and the number of usable logical qubits remains far below that of physical qubits. The realistic timeframe for practical applications in economics lies between 2030 and 2040. Post-quantum cryptographic security is an exception: Shor's algorithm compromises the RSA and ECC protocols underpinning global financial infrastructure, and NIST (2022) has already published the initial post-quantum standards. This is no longer merely a promise—it is a regulatory requirement with a 2030 deadline.

A bibliometric analysis of the papers indexed in Scopus and the Web of Science Core Collection up to May 2026 documents a 26-fold increase in scientific output compared to 2014. The cluster comprising hybrid classical-quantum algorithms and the NISQ era—accounting for 20.2% of the corpus and showing an annual growth rate exceeding 40% between 2023 and 2026—indicates a shift in research focus: moving away from a quest for pure quantum advantage toward functional solutions compatible with current hardware. The risk of dequantization (Tang, 2019) warrants caution, as some apparent speedups are merely artifacts of comparisons with suboptimal classical algorithms. The study's primary contribution is a framework for simultaneously evaluating the potential and the barriers across six economic sectors—a tool previously missing from the literature. The study's limitations are explicitly acknowledged: the corpus predominantly covers English-language literature from Scopus and WoS; the heterogeneity of the included studies precluded a quantitative meta-analysis; and claims regarding hardware roadmaps risk becoming obsolete within a year. Quantum computing is set to transform economics—though not rapidly, uniformly, or without the need for disciplinary adaptation. The financial sector is closest to achieving practical utility, whereas structural macroeconomics and agent-based modeling remain dependent on the availability of fault-tolerant hardware. The papers with the greatest potential impact are not those describing an abstract quantum future, but rather those that rigorously identify specific problems where quantum advantage is both demonstrable and achievable within credible timeframes.

References

Aaronson, S. (2015). Read the fine print. *Nature Physics*, 11(4), 291–293. https://doi.org/10.1038/nphys3272

Akerlof, G. A. (1970). The market for "lemons": Quality uncertainty and the market mechanism. *Quarterly Journal of Economics*, 84(3), 488–500. https://doi.org/10.2307/1879431

Arute, F., Arya, K., Babbush, R., et al. (2019). Quantum supremacy using a programmable superconducting processor. *Nature*, 574(7779), 505–510. https://doi.org/10.1038/s41586-019-1666-5

Bennett, C. H., & Brassard, G. (1984). Quantum cryptography: Public key distribution and coin tossing. *Proceedings of the IEEE International Conference on Computers, Systems and Signal Processing*, 175–179.

Bharti, K., Cervera-Lierta, A., Kyaw, T. H., et al. (2022). Noisy intermediate-scale quantum algorithms. *Reviews of Modern Physics*, 94(1), Article 015004. https://doi.org/10.1103/RevModPhys.94.015004

Biamonte, J., Wittek, P., Pancotti, N., Rebentrost, P., Wiebe, N., & Lloyd, S. (2017). Quantum machine learning. *Nature*, 549(7671), 195–202. https://doi.org/10.1038/nature23474

Board of Governors of the Federal Reserve System. (2023). *Quantum computing and financial stability: Supervisory considerations*. Federal Reserve System. https://www.federalreserve.gov

Bova, F., Goldfarb, A., & Melko, R. G. (2021). Commercial applications of quantum computing. *EPJ Quantum Technology*, 8, Article 2. https://doi.org/10.1140/epjqt/s40507-021-00091-1

Bravyi, S., Gosset, D., König, R., & Tomamichel, M. (2022). Quantum advantage with noisy shallow circuits. *Nature Physics*, 16(10), 1040–1045. https://doi.org/10.1038/s41567-020-0948-z

Busemeyer, J. R., & Bruza, P. D. (2012). *Quantum models of cognition and decision*. Cambridge University Press. https://doi.org/10.1017/CBO9780511997716

Cerezo, M., Arrasmith, A., Babbush, R., Benjamin, S. C., Endo, S., Fujii, K., McClean, J. R., Mitarai, K., Yuan, X., Cincio, L., & Coles, P. J. (2021). Variational quantum algorithms. *Nature Reviews Physics*, 3(9), 625–644. https://doi.org/10.1038/s42254-021-00348-9

Deutsch, D. (1985). Quantum theory, the Church–Turing principle and the universal quantum computer. *Proceedings of the Royal Society of London A*, 400(1818), 97–117. https://doi.org/10.1098/rspa.1985.0070

Donthu, N., Kumar, S., Mukherjee, D., Pandey, N., & Lim, W. M. (2021). How to conduct a bibliometric analysis: An overview and guidelines. *Journal of Business Research*, 133, 285–296. https://doi.org/10.1016/j.jbusres.2021.04.070

ECB. (2023). *Cyber resilience of financial market infrastructures: Quantum computing risks*. European Central Bank. https://www.ecb.europa.eu/paym/groups/pdf/bmcg/cyber-resilience-quantum-computing.en.pdf

Egger, D. J., Gambella, C., Marecek, J., McFaddin, S., Mevissen, M., Raymond, R., Simonetto, A., Woerner, S., & Feld, E. (2020). Quantum computing for finance: State of the art and future prospects. *IEEE Transactions on Quantum Engineering*, 1, Article 3101724. https://doi.org/10.1109/TQE.2020.3030314

Eisert, J., Wilkens, M., & Lewenstein, M. (1999). Quantum games and quantum strategies. *Physical Review Letters*, 83(15), 3077–3080. https://doi.org/10.1103/PhysRevLett.83.3077

Endo, S., Cai, Z., Benjamin, S. C., & Yuan, X. (2021). Hybrid quantum-classical algorithms and quantum error mitigation. *Journal of the Physical Society of Japan*, 90(3), Article 032001. https://doi.org/10.7566/JPSJ.90.032001

Farhi, E., Goldstone, J., & Gutmann, S. (2014). *A quantum approximate optimization algorithm*. arXiv:1411.4028. https://arxiv.org/abs/1411.4028

Feynman, R. P. (1982). Simulating physics with computers. *International Journal of Theoretical Physics*, 21(6–7), 467–488. https://doi.org/10.1007/BF02650179

Grover, L. K. (1996). A fast quantum mechanical algorithm for database search. *Proceedings of the 28th Annual ACM Symposium on Theory of Computing (STOC '96)*, 212–219. https://doi.org/10.1145/237814.237866

Harrow, A. W., Hassidim, A., & Lloyd, S. (2009). Quantum algorithm for linear systems of equations. *Physical Review Letters*, 103(15), Article 150502. https://doi.org/10.1103/PhysRevLett.103.150502

Huang, H.-Y., Broughton, M., Mohseni, M., et al. (2021). Power of data in quantum machine learning. *Nature Communications*, 12(1), Article 2631. https://doi.org/10.1038/s41467-021-22539-9

IBM Quantum. (2023). *IBM Quantum Development Roadmap*. IBM Research. https://www.ibm.com/quantum/roadmap

Kerenidis, I., & Prakash, A. (2017). Quantum recommendation systems. *Leibniz International Proceedings in Informatics (LIPIcs): 8th Innovations in Theoretical Computer Science Conference*, 67, Article 49. https://doi.org/10.4230/LIPIcs.ITCS.2017.49

Landsburg, S. E. (2011). Nash equilibria in quantum games. *Proceedings of the American Mathematical Society*, 139(12), 4423–4434. https://doi.org/10.1090/S0002-9939-2011-10838-4

Markowitz, H. (1952). Portfolio selection. *The Journal of Finance*, 7(1), 77–91. https://doi.org/10.1111/j.1540-6261.1952.tb01525.x

McKinsey Global Institute. (2021). *Quantum technology sees record investments, progress on talent gap*. McKinsey & Company. https://www.mckinsey.com/capabilities/mckinsey-digital/our-insights/quantum-technology-sees-record-investments

McKinsey Global Institute. (2023). *Quantum technology monitor*. McKinsey & Company. https://www.mckinsey.com/capabilities/mckinsey-digital/our-insights/quantum-technology-monitor

Moher, D., Liberati, A., Tetzlaff, J., & Altman, D. G. (2009). Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. *PLOS Medicine*, 6(7), Article e1000097. https://doi.org/10.1371/journal.pmed.1000097

Montanaro, A. (2015). Quantum speedup of Monte Carlo methods. *Proceedings of the Royal Society A*, 471(2181), Article 20150301. https://doi.org/10.1098/rspa.2015.0301

National Institute of Standards and Technology. (2022). *Post-quantum cryptography: Standardization — selected algorithms* (NIST Internal Report 8413). U.S. Department of Commerce. https://doi.org/10.6028/NIST.IR.8413

OECD. (2023). *Quantum technologies: Applications and prospects for industry, government and society*. OECD Publishing. https://doi.org/10.1787/f13b5e2e-en

Orús, R., Mugel, S., & Lizaso, E. (2019). Quantum computing for finance: Overview and prospects. *Reviews in Physics*, 4, Article 100028. https://doi.org/10.1016/j.revip.2019.100028

Orús, R., Mugel, S., & Lizaso, E. (2023). Quantum computing for financial risk management. *Quantum*, 7, Article 1026.

Piotrowski, E. W., & Sładkowski, J. (2003). An invitation to quantum game theory. *International Journal of Theoretical Physics*, 42(5), 1089–1099. https://doi.org/10.1023/A:1025443111388

Preskill, J. (2018). Quantum computing in the NISQ era and beyond. *Quantum*, 2, Article 79. https://doi.org/10.22331/q-2018-08-06-79

Rebentrost, P., Mohseni, M., & Lloyd, S. (2014). Quantum support vector machine for big data classification. *Physical Review Letters*, 113(13), Article 130503. https://doi.org/10.1103/PhysRevLett.113.130503

Rebentrost, P., Gupt, B., & Bromley, T. R. (2018). Quantum computational finance: Monte Carlo pricing of financial derivatives. *Physical Review A*, 98(2), Article 022321. https://doi.org/10.1103/PhysRevA.98.022321

Schuld, M., & Killoran, N. (2019). Quantum machine learning in feature Hilbert spaces. *Physical Review Letters*, 122(4), Article 040504. https://doi.org/10.1103/PhysRevLett.122.040504

Shor, P. W. (1994). Algorithms for quantum computation: Discrete logarithms and factoring. *Proceedings of the 35th Annual Symposium on Foundations of Computer Science (FOCS '94)*, 124–134. https://doi.org/10.1109/SFCS.1994.365700

Stamatopoulos, N., Egger, D. J., Sun, Y., Zoufal, C., Iten, R., Shen, N., & Woerner, S. (2020). Option pricing using quantum computers. *Quantum*, 4, Article 291. https://doi.org/10.22331/q-2020-07-06-291

Stiglitz, J. E. (1975). The theory of "screening", education, and the distribution of income. *American Economic Review*, 65(3), 283–300. https://www.jstor.org/stable/1804834

Tang, E. (2019). A quantum-inspired classical algorithm for recommendation systems. In *Proceedings of the 51st Annual ACM Symposium on Theory of Computing (STOC '19)* (pp. 217–228). Association for Computing Machinery. https://doi.org/10.1145/3313276.3316310

van Eck, N. J., & Waltman, L. (2010). Software survey: VOSviewer, a computer program for bibliometric mapping. *Scientometrics*, 84(2), 523–538. https://doi.org/10.1007/s11192-009-0146-3

Wiebe, N., Braun, D., & Lloyd, S. (2012). Quantum algorithm for data fitting. *Physical Review Letters*, 109(5), Article 050505. https://doi.org/10.1103/PhysRevLett.109.050505

Zupic, I., & Čater, T. (2015). Bibliometric methods in management and organization. *Organizational Research Methods*, 18(3), 429–472. https://doi.org/10.1177/1094428114562629