

The Co-Evolution of Quantum Physics and Finance

Zhengyuan Ma ¹, Jiao Zhao ² and Dong Guo ^{2,*}

¹ The High School Affiliated to Renmin University of China

² China Development Bank

* Corresponding author: guod@cdb.cn

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Abstract: Quantum physics and finance are often connected through mathematical analogy or promises of computational acceleration. This article develops an alternative account of asymmetric co-evolution. A selective conceptual synthesis distinguishes shared mathematical ancestry, explicit transfer, and reciprocal innovation across uncertainty, valuation, measurement, computation, and monetary security. Quantum theory supplies representational and computational possibilities; financial problems impose constraints that can redirect quantum information research. Documented feedback is strongest in algorithm design and cryptographic tasks. This article proposes testable research directions concerning investor judgment, financial validation, decision-relevant computational advantage, market adoption, and quantum money. Progress requires reciprocal discipline: quantum methods must satisfy financial restrictions, while finance must incorporate the physical and computational conditions governing information.

Keywords: quantum finance; history of economic thought; quantum probability; quantum computing; co-evolution

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1. Introduction

An imagined banknote provides a revealing meeting between quantum physics and finance. Wiesner (1983) proposed using quantum states to protect money against counterfeiting. Monetary authenticity became a problem in quantum information: a physical restriction on copying could support an economic institution. This episode complicates the familiar narrative of finance simply borrowing scientific tools. A financial function helped define a quantum task, while quantum theory suggested a different basis for securing that function.

How have quantum physics and finance co-evolved in the history of thought, and what does their relationship imply for financial research and practice? Answering this question requires distinguishing parallel development

from documented influence. Similar equations need not establish historical transmission, and calculating a financial model on quantum hardware need not change its economic assumptions.

This article advances the thesis of asymmetric co-evolution through reciprocal constraints. Physics contributes concepts and methods; finance supplies problems, institutional restrictions, and criteria of usefulness. Reverse influence is clearest in quantum information science and engineering. Evidence that finance has transformed fundamental quantum laws remains limited.

The approach is a selective conceptual synthesis, not a systematic review or an empirical test. It distinguishes shared ancestry, explicit methodological transfer, and reciprocal innovation, where adaptation generates contributions relevant to the originating discipline. The contribution is a framework linking historical encounters to testable propositions, rather than a claim that financial markets are physically quantum.

Five domains are purposively selected to contrast what crosses disciplinary boundaries: probability representations, valuation operators, measurement procedures, computational algorithms, and authentication tasks. They cover concepts, models, methods, and institutions rather than exhaust the literature. Representative studies are chosen because their formulations expose the borrowed element, the receiving problem, or a proposed adaptation; they are not a sample of successful applications. We classify shared ancestry as common mathematics without demonstrated directional borrowing; transfer requires explicit use of a quantum formalism or capability in a financial problem; and reciprocal innovation additionally requires an identifiable financial requirement and a resulting change to a quantum method or research task. We separately ask whether the cited work demonstrates, merely identifies, or does not establish relevance outside finance. Classification rests on the cited texts, not archival proof of exclusive financial causation. Analogies and proposed future feedback are marked separately in Table 1.

Table 1: Channels and evidential status of co-evolution.

Thread	Contribution to Finance	Financial Requirement and Adaptation	Classification and Evidence Beyond Finance
Probability and judgment	States and noncommuting questions model constructed preferences.	Incentives and learning motivate proposed tests; no financial adaptation demonstrated here.	Transfer into cognition; prospective financial transfer. Evidence concerns judgment, not demonstrated financial feedback (Busemeyer and Bruza, 2012; Wang et al., 2014).
Valuation and dynamics	Path integrals and operators organize pricing models.	Replication and admissibility constrain imported pricing formulations.	Shared diffusion ancestry (Bachelier, 1900); explicit operator transfer (Baaquie, 2004; Segal and Segal, 1998). No demonstrated return contribution outside finance.
Computation	Quantum estimation may reduce oracle requirements.	Path-loading costs motivate re-parameterization; aggregated bias motivates a fixed final-round rerun.	Reciprocal algorithm development. Derivative benchmarks only for loading; broader statistical-mechanics relevance identified, not validated, for bias control (Chakrabarti et al., 2021; Miyamoto, 2024).

Measurement and adoption	Question order makes elicitation procedures explicit.	Adoption changes market behavior; proposed stress test for judgment models.	Analogy and prospective feedback. Performativity is not quantum measurement; no demonstrated reverse transfer (Wang et al., 2014; MacKenzie and Millo, 2003).
Monetary security	Quantum states provide a resource against copying.	Counterfeiting resistance motivates a quantum authentication task.	Reciprocal task formation in a proposed protocol; not evidence of operational money or exclusive financial causation of no-cloning research (Wiesner, 1983; Wootters and Zurek, 1982).

Note: The table reports interpretations and evidence categories, not empirical estimates.

2. Concepts, Theories, Models, and Methods

2.1. Uncertainty and the Construction of Judgment

Bachelier (1900) developed a probabilistic account of speculative prices, demonstrating finance's early contribution to diffusion mathematics. This shared mathematical ancestry should not be confused with quantum mechanics: Brownian randomness is not quantum uncertainty. Likewise, Keynes's (1937) emphasis on fragile expectations about the distant future differs from uncertainty within an already specified probability model. Replacing classical with quantum probabilities does not resolve an inability to identify relevant future contingencies.

Quantum cognition offers a more specific connection. It represents judgments through states and measurement operators, permitting interference and order dependence without presuming a quantum brain (Busemeyer and Bruza, 2012). Financial preferences might therefore be modeled as partly constructed through deliberation rather than simply retrieved. Finance supplies a demanding reciprocal test: does this representation remain useful under monetary incentives, learning, and repeated interaction? Neither disagreement nor unpredictability alone establishes quantum behavior; classical models also accommodate changing beliefs and attention.

A simple mathematical formulation makes the claim testable. Let ψ be a normalized state representing an investor's current judgment, and let P_A and P_B be orthogonal projectors representing affirmative answers to two questions. Under the projective measurement model, the joint probabilities of two affirmative answers in the two orders are

$$p(A \rightarrow B) = \|P_B P_A \psi\|^2, \quad p(B \rightarrow A) = \|P_A P_B \psi\|^2 \quad (1)$$

The operators act from right to left. Noncommuting projectors permit these probabilities to differ, although they need not differ for every state. This is a restrictive representation of how asking about risk might alter a subsequent return judgment, not evidence that investors' brains exhibit physical quantum coherence. The formalism must predict new order effects with fixed parameters; otherwise, its flexibility merely redescribes observations (Busemeyer and Bruza, 2012).

2.2. Valuation and Mathematical Translation

Black and Scholes (1973) grounded option valuation in hedging and restrictions on arbitrage. Their pricing equation can be transformed into a diffusion equation under standard assumptions. Connections with

imaginary-time Schrödinger-type equations facilitate mathematical transfer, but do not make option prices physical wave functions. Economic justification still rests on contracts and feasible trading.

For a European claim with payoff $g(S_T)$, suppose the underlying asset pays no dividends, volatility σ and the risk-free rate r are constant, and frictionless continuous hedging is feasible. Under the Black–Scholes assumptions, eliminating the stock-price risk from a self-financing hedge gives

$$\frac{\partial V}{\partial t} + \frac{1}{2}\sigma^2 S^2 \frac{\partial^2 V}{\partial S^2} + rS \frac{\partial V}{\partial S} - rV = 0, \quad V(S, T) = g(S). \quad (2)$$

Here, V is the claim's value, S is the underlying price, t is calendar time, and T is maturity. The stock's expected physical return does not enter this equation: replication determines the valuation restriction. The equivalent conditional-expectation representation is

$$V(S, t) = e^{-r(T-t)} E_Q[g(S_T) | S_t = S]. \quad (3)$$

The risk-neutral probability measure Q prices the claim within this model; it is not a forecast of investors' beliefs or a quantum measurement probability. This distinction prevents a common conceptual error: replacing a historical return distribution with a quantum-inspired distribution does not, by itself, specify an arbitrage-consistent price.

The connection with diffusion can also be shown explicitly. Set $x = \ln(S/S_0)$, where S_0 is a fixed positive reference price, $\tau = T - t$, and $a = r - \sigma^2/2$. Writing $v(x, \tau) = V(S, t)$ gives the first equality below. Removing discounting and shifting the spatial coordinate by $a\tau$ yields the second equality:

$$\frac{\partial v}{\partial \tau} = \frac{\sigma^2}{2} \frac{\partial^2 v}{\partial x^2} + a \frac{\partial v}{\partial x} - rv, \quad \frac{\partial u}{\partial \tau} = \frac{\sigma^2}{2} \frac{\partial^2 u}{\partial y^2}. \quad (4)$$

Here, $y = x + a\tau$ and $u(y, \tau) = \exp(r\tau)v(y - a\tau, \tau)$. The resulting heat equation provides a mathematical bridge to imaginary-time quantum evolution. Feynman's (1948) real-time path formulation sums complex amplitudes; financial diffusion uses probability weights and discounting. Shared operator techniques therefore do not imply identical interpretations. The substantive transfer lies in adapting a calculational language to a different set of economic restrictions.

Baaquie (2004) develops path-integral and Hamiltonian methods for options and interest rates. Such techniques can organize stochastic trajectories and dependence structures while retaining financial interpretations. Segal and Segal (1998) go further by extending the stochastic framework underlying valuation into a quantum context. This is genuine formal innovation, but constructing an extension does not establish its empirical necessity.

The receiving discipline changes the terms of evaluation. Finance requires payoff consistency, interpretable parameters, admissible strategies, and credible hedging performance. Researchers must identify whether an imported formalism changes the probability model, pricing rule, or numerical procedure. A better calibration fit alone cannot establish an economic mechanism. Co-evolution becomes substantive when financial restrictions reshape the imported mathematics and generate questions that its original formulation did not address.

2.3. Measurement and Endogenous Markets

Quantum models make the measurement procedure explicit. Financial observation can also intervene: requesting a quote reveals information, and eliciting risk judgments can affect subsequent choices. These parallels are useful but do not establish identical mechanisms. Learning, anchoring, and strategic inference can produce order effects within classical frameworks.

Wang et al. (2014) tested a quantum-model restriction on responses to reversed question orders. Their survey and laboratory evidence does not automatically generalize to consequential investment decisions. Moreover, ordinary context dependence differs from stricter probabilistic contextuality. Dzhafarov et al. (2016) found no evidence of the latter in the behavioral datasets they examined after accounting for direct influences. Quantum-like representations can therefore be useful without establishing uniquely quantum behavior.

The operational distinction is useful: Equation (1) allows order dependence, whereas the projective model also imposes restrictions on the full response distribution. Section 4.1 uses one such restriction and a separately

specified allocation rule to distinguish questionnaire prediction from prediction of financial choice.

Finance adds another complication: models can change the markets they describe. MacKenzie and Millo (2003) show how option-pricing theory interacted with the development of exchange practices. Such performativity operates through institutions and strategic behavior, not quantum state reduction. Its implication is nevertheless important: financial validation must examine how adoption changes the environment in which a model initially succeeded.

2.4. Computation and Reciprocal Innovation

Quantum computing creates a different connection: the device is quantum even when the financial model remains classical. Montanaro (2015) establishes near-quadratic acceleration of Monte Carlo estimation under specified assumptions. Query complexity, however, is not elapsed time: data preparation, circuit execution, error management, and output extraction determine practical performance (Herman et al., 2023).

For a bounded payoff normalized to the interval $[0,1]$, a fixed success probability, and additive estimation error ε , the familiar idealized comparison is

$$N_{MC} = O(\varepsilon^{-2}), \quad N_Q = \tilde{O}(\varepsilon^{-1}). \quad (5)$$

N_{MC} counts independent classical samples for standard Monte Carlo estimation; N_Q counts coherent quantum oracle uses, with $\tilde{O}$ suppressing logarithmic factors. Efficient state preparation and the required coherent operations are assumptions of the comparison, not free resources. It does not assert a universal advantage over variance reduction, quasi-Monte Carlo, or problem-specific classical methods. Mapping an oracle bound into a financial advantage requires measuring the entire implementation (Montanaro, 2015; Herman et al., 2023).

Financial requirements can also redirect quantum methods. Chakrabarti et al. (2021) require coherent preparation of stochastic paths at a resource cost compatible with pricing path-dependent derivatives. Their re-parameterization method uses pretrained variational circuits for normal distributions and transformations to the required stochastic processes, addressing a loading bottleneck in their resource estimates. This constitutes application-driven methodological adaptation, not simply execution of an unchanged pricing algorithm. The reported benchmarks concern derivatives; potential reuse for other stochastic simulations does not establish demonstrated benefits outside finance. The evidence therefore supports reciprocal innovation at the algorithm-design level, with broader impact still unverified.

Portfolio aggregation illustrates how a financial objective changes an algorithmic success criterion. Let $V_P = \sum_i w_i V_i$ be a portfolio value, with fixed positions w_i , estimated component values $\hat{V}_i$, and estimation biases $b_i = E[\hat{V}_i] - V_i$. Linearity of expectation gives

$$E[\hat{V}_P] - V_P = \sum_i w_i b_i. \quad (6)$$

This identity requires no independence assumption: aligned component biases can accumulate. Miyamoto (2024) identifies portfolio valuation and Gibbs partition-function estimation as motivations for examining this problem. Numerical experiments locate a source of bias in the adaptive stopping rule of iterative amplitude estimation. Repeating the final round with its Grover number and shot count fixed mitigates that bias. The adaptation concerns a general estimation algorithm, and the statistical-mechanics example explicitly establishes relevance beyond finance as a research motivation. It does not demonstrate an implemented improvement in a partition-function calculation or establish finance as the exclusive cause of the innovation. This is documented reciprocal problem formation and method development, with cross-domain validation still open.

2.5. Monetary Security and Institutional Value

Quantum money connects physical information with trust. The no-cloning theorem forbids universal perfect copying of arbitrary unknown quantum states (Wootters and Zurek, 1982). Appropriate protocols can exploit this restriction, but it does not by itself guarantee a secure or useful monetary system.

The copying restriction has a concise mathematical basis. Preservation of inner products would require

$$z = z^2, \quad z = \langle \psi | \varphi \rangle. \quad (7)$$

Choosing two distinct nonorthogonal states with $0 < |z| < 1$ contradicts this requirement. Perfect universal cloning is therefore impossible, although distinguishable orthogonal states can be copied. For quantum banknotes, this is a resource for protocol design, not a proof against every counterfeiting strategy: a security argument must specify issuance, verification, adversarial access, and acceptable error rates (Wootters and Zurek, 1982; Wiesner, 1983).

Authenticity and value remain distinct. Resistance to counterfeiting does not create acceptance, liquidity, redemption, or credible loss allocation. Finance can therefore contribute requirements concerning verification, transferability, and recovery that alter quantum protocol design. Physics establishes feasible information properties; monetary economics asks which combinations can sustain circulation and trust.

3. Key Themes of Co-Evolution

Three themes organize these encounters. First, co-evolution is mediated and asymmetric. Mathematics connects dynamics and valuation, psychology connects probability and judgment, and computer science connects quantum devices and financial calculation. Explicit transfer is well documented, while reciprocal influence varies substantially across domains. A credible historical account must trace mechanisms rather than infer causation from resemblance.

Second, receiving disciplines transform borrowed ideas. Financial contracts and incentives impose restrictions absent from the original physical problem. These restrictions can reveal new technical questions, as derivative pricing and portfolio aggregation demonstrate. The direction of intellectual influence consequently depends on who defines the problem and who determines what counts as a satisfactory solution.

Third, information is simultaneously physical, computational, and institutional. Its economic usefulness depends on processing and verification costs, but also on incentives and market organization. Adoption feeds back into behavior, potentially changing the usefulness of the original method. Co-evolution is thus a cycle of problem formation, translation, validation, and institutional response, not a sequence of increasingly sophisticated analogies.

Table 1 applies the selection and classification criteria from the Introduction. Transfer, finance-induced adaptation, and demonstrated use beyond finance are distinct evidential questions; a prospective contribution is not counted as an observed feedback effect.

4. Critical Assessment and Future Research

Research at this intersection frequently conflates representation, explanation, computation, and institutional improvement. A model that fits data does not necessarily identify a mechanism; a faster calculation need not improve investment decisions; and a secure component need not produce a viable payment system. The following agenda connects each claim to evidence capable of supporting or rejecting it.

4.1. Identify Quantum-like Investor Behavior

Consider a preregistered experiment using one disclosed risky investment and a safe alternative. Randomly assign participants to answer A, “Is this investment’s downside risk acceptable to you?”, and B, “Is its expected return attractive to you?”, in either order, with identical information and no intervening feedback. They then allocate a \$10 endowment entirely to the risky investment or entirely to the safe alternative. The chosen payoff is realized and paid using the disclosed experimental return distribution. Questionnaire answers and the binary allocation are separate outcomes; the intended contribution concerns both.

For immediate binary projective questions, the quantum question-order equality of Wang et al. (2014) predicts that the total probability of discordant answers is invariant to order:

$$p(A_y B_n) + p(A_n B_y) = p(B_y A_n) + p(B_n A_y). \quad (8)$$

Subscripts y and n denote yes and no, and the written sequence denotes question order. This parameter-free restriction assumes the same initial-state distribution across randomized groups and no intervening state evolution beyond the questions. Evaluate it using a prespecified equivalence margin and confidence interval, rather than treating failure to reject exact equality as confirmation. Satisfying it does not exclude classical explanations.

To link responses to allocation, prespecify a real two-dimensional pure-state model with rank-one projectors for A, B, and the risky choice. Fix the A axis; estimate the initial-state angle and the B and choice-projector angles, three free parameters, on an independent calibration sample containing both orders. Freeze them before validation. Apply the choice projector to the normalized state after the two observed answers; its squared projected norm predicts the risky-choice probability. Thus, the order-specific response probabilities and the direction and magnitude of any allocation difference are fixed before testing. Complements represent negative answers and the safe choice; additional noise or heterogeneity parameters cannot be introduced after seeing validation data.

A concrete classical comparator is a sequential logistic model: each question has an intercept, an indicator for being asked second, and an indicator for a preceding yes response; allocation has an intercept and coefficients for the A response, B response, and order. Its ten coefficients allow classical carryover and order-dependent choice. Fit both models on the same calibration data, with any regularization selected within that sample, and compare held-out log loss separately for responses and allocations. Report parameter counts and calibration-sample BIC as a secondary complexity check; prespecify any richer sensitivity models. A predictive tie with fewer parameters supports parsimony, not a uniquely quantum mechanism.

Proposition 1: Under this prespecified design, the projective model predicts the question-order equality and, through its frozen choice projector, order-specific risky allocations. Evidence for financial usefulness requires acceptable response restrictions and improved held-out allocation prediction, or equivalent prediction with materially lower complexity, relative to the classical comparator. Questionnaire fit alone cannot establish an investment-choice contribution; failure of the equality rejects this projective specification, not quantum mechanics.

4.2. Validate Financial Mechanisms and Decisions

Quantum-inspired valuation should be tested using common contracts, calibration data, and trading constraints. Outcomes should include out-of-sample hedge losses, parameter stability, and transaction costs, alongside pricing fit. Historical return probabilities must remain distinct from probabilities used for valuation. Additional formal structure needs an economic interpretation that survives these comparisons.

Proposition 2: A new formalism is financially useful when its additional structure produces stable improvements in valuation or hedging under realistic constraints. This shifts research from reproducing familiar equations toward identifying what imported mathematics enables finance to explain or accomplish.

4.3. Measure Economically Meaningful Computational Advantage

Benchmarks should compare complete classical and quantum workflows at matched accuracy and deadlines. Numerical precision has little value when model uncertainty dominates or when greater precision leaves the decision unchanged. Researchers should report total costs, estimation bias, constraint violations, and decision sensitivity, rather than isolated circuit performance.

Proposition 3: Computational advantage creates financial value when it relaxes a binding constraint or reduces decision-relevant error sufficiently to exceed implementation costs. Financial applications can thus specify useful accuracy and latency targets for quantum engineering. Practitioners should prioritize demonstrable bottlenecks rather than assume that every difficult-looking optimization problem favors quantum hardware.

An operational criterion can make this proposition falsifiable. Let a_C and a_Q be decisions generated by complete classical and quantum workflows, θ the subsequently realized financial state, $L(a, \theta)$ a monetary loss, and C_C and C_Q the full implementation costs for the same decision horizon. This article proposes evaluating

$$\Delta = E[L(a_C, \theta) - L(a_Q, \theta)] - (C_Q - C_C) > 0. \quad (9)$$

This is a proposed decision criterion, not a reported empirical result or a theorem of quantum computing. Both workflows must meet the same operational constraints, and uncertainty around Δ must be reported. A numerical speedup that leaves actions unchanged has no loss-reduction benefit under this criterion, although a cost reduction can still matter. Conversely, meeting a previously unattainable deadline can create value without improving nominal estimation accuracy. Once adoption changes the distribution of θ , the comparison must become an equilibrium exercise, connecting computational research to Proposition 4.

For a worked implementation, consider a desk that must choose a hedge within one second and evaluate its outcome at the next daily settlement. A missed deadline triggers the same prespecified fallback hedge in either workflow. Define monetary loss as the positive funding shortfall: the amount by which the settlement liability exceeds the value of the funded hedging account, floored at zero. The account is net of spreads, execution fees, market impact, and financing charges. Computing, data preparation, integration, and model-governance expenses enter only the separate implementation costs in Equation (9), preventing double counting. This loss measures shortfall severity rather than total trading profitability.

The expectation is under an estimated physical predictive distribution of market moves and execution conditions conditional on information available at the decision time, together with each workflow's computational randomness and latency. It is not the risk-neutral pricing measure in Equation (3). Freeze the forecasting and execution models before evaluation, use paired market scenarios for the workflows, include deadline failures, and check the comparison on rolling held-out periods and stress distributions. Report dependence on the predictive distribution rather than interpreting simulation precision as certainty about future markets.

As an explicitly hypothetical illustration, suppose mean shortfall per hedge is \$120 classically and \$95 with the quantum workflow. Suppose incremental setup expenditure allocated to this desk is \$240,000, amortized over 24 months with no salvage value, while incremental monthly operating costs are \$5000. At 1000 decisions per month, the additional implementation cost is $(\$240,000/24 + \$5000)/1000 = \$15$ per decision; expected net benefit is therefore $\$25 - \$15 = \$10$ per decision, or \$10,000 per month. These are assumed values, not empirical findings. Shared infrastructure is allocated by reserved capacity using a rule fixed in advance. The illustration ignores discounting and capital charges; deployment appraisal should include them, vary utilization and useful life, and distinguish avoidable future spending from sunk costs.

Estimate uncertainty from paired loss differences, using time blocks when outcomes are serially dependent, and propagate uncertainty in utilization, costs, and the predictive model. A prespecified one-sided confidence bound above zero, robust to credible cost and distribution scenarios, would support positive net benefit. A positive point estimate whose interval spans zero is inconclusive under that rule and motivates a larger pilot; any alternative adoption threshold should state its decision-maker's risk tolerance explicitly. Expected benefit is also separate from feasibility: deadline reliability, capital requirements, and tail-shortfall limits must be checked independently. Positive Δ does not excuse breaching such limits.

4.4. Endogenize Adoption and Market Effects

Grossman and Stiglitz (1980) demonstrate that costly information acquisition complicates perfectly informative prices. Quantum computation would change selected processing costs without removing the incentive problem. Models should therefore allow heterogeneous access, adoption costs, shared providers, and strategic responses. Relevant outcomes include spreads, concentration, information production, and losses under common shocks.

Proposition 4: Market-wide benefits depend jointly on technical advantage, access, and the similarity of adopted strategies. Faster private computation may improve competition or support informational rents; synchronized responses could also change systemic risk. These are conditional hypotheses. Finance can contribute by distinguishing private gains from social benefits and making technology adoption part of the model.

4.5. Connect Quantum Money to Monetary Institutions

Research should compare protocols under explicit assumptions about issuer obligations, verification delays, storage failures, and recovery. Laboratory payment markets could test how these features affect acceptance and circulation. Protocol security and economic usefulness should be evaluated together, without assuming that authenticity automatically creates trust.

Proposition 5: Quantum authentication has monetary value through its interaction with verification costs, recoverability, and institutional guarantees. This gives finance a constructive role in specifying technical requirements and gives quantum researchers economically meaningful criteria for choosing among feasible designs.

Finally, co-evolution itself warrants historical testing. Citation networks can identify encounters, but close reading and archival evidence must establish whether financial requirements changed quantum research questions or methods. Comparing unsuccessful transfers with successful ones would help distinguish reciprocal innovation from disciplinary fashion.

Table 2 translates the propositions into research designs with explicit rejection criteria. The intended contribution is a program of comparative tests, not an inference that quantum methods already improve financial practice.

Table 2: A testable agenda for reciprocal development.

Research Direction	Design and Financial Outcome	Evidence Against the Proposed Benefit	Feedback to Quantum Research
Investor judgment	Randomize risk/return questions; test the question-order equality and frozen predictions of paid risky choices.	Material violation of the equality, or no allocation-prediction benefit over the logistic comparator after complexity assessment.	Identify which state-update assumptions survive incentives and learning.
Valuation and hedging	Match contracts and trading constraints; compare realized hedge losses after costs.	Extra structure improves calibration but not stable out-of-sample hedging.	Constrain operator and dependence choices by financial admissibility.
Computational value	Use paired, physically distributed hedge scenarios and a common deadline; estimate net benefit after allocated costs.	The lower confidence bound does not exceed zero, results fail cost/model sensitivity checks, or separate risk limits are breached.	Specify useful precision, bias, and resource targets for algorithms.
Market adoption	Vary access and adoption in structural models or controlled markets; measure spreads and common losses.	Private gains coexist with concentration or adverse system-wide outcomes.	Test how shared hardware and algorithm choices interact with correlated decisions.
Monetary institutions	Compare verification and recovery designs; measure acceptance and transaction completion.	Anti-copying gains are outweighed by delay, loss, or weak redemption arrangements.	Translate monetary requirements into protocol tradeoffs and security tasks.

Note: Rejection criteria concern specified models or financial usefulness, not quantum mechanics. An interval spanning zero is inconclusive evidence of net benefit; violating a separate risk limit makes deployment infeasible under that limit.

5. Conclusions

Quantum physics and finance have developed through uneven exchanges involving uncertainty, representation, computation, and trust. The strongest evidence of reciprocal influence concerns quantum algorithms and cryptographic tasks, while claims about fundamental physical transformation remain limited. Mathematical resemblance alone establishes neither intellectual transmission nor a quantum ontology of markets.

Future progress depends on reciprocal discipline. Quantum methods must satisfy financial restrictions and improve identifiable decisions. Finance can shape quantum research by specifying requirements involving aggregation, incentives, verification, and adaptation. The central opportunity is therefore to study how each discipline changes the other's problems and standards of evidence, while preserving the distinction between formal possibility and economic achievement.

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