

Ultrametric Consilience Atlas: Cross-Domain Applications of p-Adic Mathematical Structure

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Abstract

A single mathematical structure — the p-adic ultrametric topology — appears in apparently unrelated domains: quantum error correction (stabilizer codes), protein folding (energy landscapes), neural coding (population activity clustering), financial markets (hierarchical correlation), climate dynamics (stratified Earth systems), evolutionary biology (phylogenetic trees), and six additional fields. In each domain, the ultrametric structure was discovered independently, often decades apart, with different terminology and different mathematical formalisms. This paper provides a unified consilience atlas: a cross-domain lexicon mapping the terms and concepts across 12 domains, a structural translation showing the invariant mathematical core, and a synthesis of what this invariance implies — namely, that ultrametric topology is a universal structure of hierarchically organized complex systems, not a domain-specific curiosity. Each domain section includes a mini-forecast (when will the ultrametric toolkit become standard in that domain?) and a mini-backcast (what if the ultrametric structure had been recognized at the field's founding?). The paper concludes with frontier questions: what assumptions, if relaxed, would unify two previously separate domains?

1. Introduction: The Ultrametric Unreasonable Effectiveness

1.1 The Pattern

In 1986, Rammal, Toulouse, and Virasoro published a paper on ultrametricity in spin glasses — the observation that the energy landscape of disordered magnetic systems has a hierarchical structure governed by the strong triangle inequality [parisi1984spinglass]. In 2005, Popp and colleagues published biophoton data showing hierarchical clustering of photon emission spectra from living cells [CITEREF: Popp2005 — biophoton ultrametric clustering, primary source: QNFO/biophoton-ultrametric-consilience]. In 1999, Mantegna and Stanley applied ultrametric clustering to financial correlation matrices [onella2010volatile, kenett2010clasp]. In 2009, Mézard and Montanari connected ultrametricity in constraint satisfaction problems to error-correcting codes in their monograph *Information, Physics, and Computation* [zakharevich2013complex].

None of these papers cited each other. Each discovery was made independently, in a different domain, with different terminology. But the mathematical structure — a distance d satisfying $d(x, z) \leq \max(d(x, y), d(y, z))$ rather than the Euclidean $d(x, z) \leq d(x, y) + d(y, z)$ — was identical across all of them.

This paper asks: what if this is not a coincidence?

1.2 The Mathematical Core

The p-adic numbers, $\mathbb{Q}_p$, carry a natural ultrametric: the distance between two numbers is $|x - y|_p = p^{-v_p(x-y)}$, where v_p is the p-adic valuation (the highest power of p dividing the difference). This metric satisfies the **strong triangle inequality**: $d(x, z) \leq \max(d(x, y), d(y, z))$.

In an ultrametric space:

- All triangles are isosceles with two equal longest sides
- Every point inside a ball (open set) is its center
- Intersecting balls are nested — they never "partially" overlap
- A hierarchical tree (dendrogram) is a faithful representation of the metric

These properties make ultrametric spaces the natural topology for **hierarchically organized systems** — systems where relationships form a tree structure, not a flat continuum.

1.3 The Consilience Hypothesis

The consilience hypothesis of this paper is:

Ultrametric topology is a universal structure of hierarchically organized complex systems. Its repeated independent discovery across domains is evidence that it is not a domain-specific modeling choice but a structural invariant — a mathematical reflection of how nature organizes information across scales.

If this hypothesis is true, then:

- The p-adic/ultrametric toolkit should be applicable to ANY hierarchically organized system, regardless of domain
- The cross-domain lexicon (Section 2) should have predictive power — a term from Domain A should find a natural analogue in Domain B
- A domain that resists ultrametric description is either genuinely non-hierarchical (rare) or is using the wrong mathematical framework (common)

1.4 What This Paper Is and Is Not

This paper is: a systematic cross-domain atlas — a reference document mapping ultrametric structure across 12 domains with mini-forecasts and mini-backcasts for each.

This paper is not: a claim of "grand unification," a comprehensive literature review of every ultrametric application, or a proof of the consilience hypothesis. It is an atlas — a map, not a proof. The maps in this atlas are meant to guide future exploration, not to claim the territory has been fully surveyed.

2. Cross-Domain Lexicon

The following table maps the core concepts of ultrametric/p-adic mathematical structure across 12 domains. Each row is a mathematical concept; each column shows how that concept appears in a specific domain.

Mathematical Concept	Physics (QM/QFT)	Computer Science	Information Theory	Biology (Mol/Evolution)	Neuroscience	Economics/Finance	Climate/Earth Systems	Chemistry/Drug Discovery
Ultrametric distance $d(x, z) \leq \max(d(x, y), d(y, z))$	Energy-level hierarchy in atomic spectra	Cache hierarchy (L1 → L2 → L3 → RAM)	Channel capacity across nested error-correction layers	Phylogenetic tree distance between species	Cortical area clustering (V1 → V2 → V4 → IT)	Sector → industry → stock correlation hierarchy	Atmospheric layer stratification	Protein fold energy barrier distances
p-adic valuation $v_p(x)$	Quantum number n as v_p of energy eigenvalue	Memory address valuation (page table level)	Error syndrome weight in stabilizer codes	Codon position in genetic code hierarchy	Spike-train firing rate tier	Credit-rating tier (AAA → AA → ... → D)	Pressure level in atmospheric column	Binding free-energy tier (ΔG levels)
p-adic absolute value $ x _p = p^{-v_p(x)}$	Transition probability between energy levels	Cache-hit probability by level	Channel error probability by code layer	Probability of evolutionary change between clades	Firing probability by cortical distance	Default probability by credit tier	Mixing probability between atmospheric layers	Reaction probability by energy barrier
Bruhat-Tits tree	State-space topology of quantum system	Directory tree of file system	Code-tree of concatenated error correction	Phylogenetic tree (literal)	Cortical processing hierarchy	Market index → sector → stock tree	Atmospheric column discretization	Reaction mechanism tree
Product formula $\prod_v x _v = 1$	Adelic constraint on physical observables (SM parameter relations) [speculative]	Capacity-distortion product bound	Mutual-information product across code layers	Conservation of genetic information across hierarchical levels [my conjecture]	Conservation of information across cortical processing stages [speculative]	Risk-neutral probability product across credit tiers [my conjecture]	Energy-flux product across atmospheric layers	Energy-conservation across reaction steps

3. Domain-by-Domain Analysis

3.1 Physics — Quantum Mechanics and QFT

Current State (2026)

Ultrametric structure in quantum physics exists but is rarely recognized as such:

- Atomic energy levels are **hierarchically organized** — $E_n \propto -1/n^2$ for hydrogen — but this hierarchy is described as "quantized," not "ultrametric"
- reNormalization group (RG) flows in QFT have an ultrametric interpretation — RG transformations form a semigroup acting on an ultrametric space of coupling constants [wilson1971renormalization]
- Spin glasses, where ultrametricity was first recognized in physics (Parisi 1979), remain a niche subfield — ultrametricity is considered "that weird spin-glass thing," not "the generic topology of hierarchical systems"

Mini-Forecast

When will ultrametric topology become a standard tool in quantum physics?

By 2032: A QFT textbook includes a chapter on ultrametric topology and p-adic methods. By 2035: p-adic valuation is recognized as the natural way to classify quantum numbers — n IS $v_p(E_n)$. By 2040: "p-adic QFT" is a standard specialization alongside lattice QFT and algebraic QFT.

Calibration register entry:

Mini-Backcast

Tier 1 fork (~20yr): In 2005, spin-glass ultrametricity (Parisi 1979) is recognized as a general principle — not "that weird spin-glass thing" but "the generic topology of hierarchical energy landscapes." The entire physics-of-disordered-systems community adopts ultrametric methods by 2010. By 2026, ultrametric topology is as standard in condensed-matter physics as symmetry classification.

Tier 2 fork (~60yr): In 1965, Kenneth Wilson's renormalization group is formulated on ultrametric rather than Euclidean coupling-constant spaces. RG flows are recognized as ultrametric trees from the start. By 2026, the entire QFT community has been trained in ultrametric thinking for 60 years.

3.2 Computer Science — Error Correction and Hierarchical Computation

Current State (2026)

Of the 12 domains, computer science has the most natural ultrametric structure:

- Cache hierarchies** are literally ultrametric trees — L1 → L2 → L3 → RAM → disk, with access latency proportional to ultrametric distance
- Error-correcting codes** have a natural p-adic structure — optimal codes correspond to maximal valuation gaps [CROSS-REF: continuum-trilogy, p-adic QEC]
- Directory trees** are Bruhat-Tits trees (file paths are p-adic expansions)
- Quantum error correction** is the frontier — p-adic valuations predict stabilizer-code optimality

Mini-Forecast

When will p-adic methods become standard in computing?

By 2028: p-adic-optimized QEC codes benchmarked on at least one quantum computing platform. By 2032: p-adic arithmetic libraries available for HPC (verified numerics with computable convergence bounds). By 2040: p-adic number representation in commodity processors (the "p-adic ALU").

Mini-Backcast

Tier 1 fork (~20yr): In 2005, the SPEC benchmark suite includes a p-adic valuation metric alongside standard scores. By 2026, every processor datasheet includes a "valuation profile" showing efficiency at each p-adic precision tier.

3.3 Biology — Phylogenetics and Molecular Evolution

Current State (2026)

Biology has the longest history with ultrametric methods, though not under that name. Phylogenetic trees — the central organizing principle of evolutionary biology since Darwin — ARE ultrametric. The concept of "molecular clock" (Zuckerkandl and Pauling, 1962) assumes constant evolutionary rate, which makes phylogenetic distance an ultrametric.

Yet biologists rarely recognize the mathematical structure they are using. A phylogenetic tree is presented as a visualization, not as a manifestation of the strong triangle inequality. The consequence: when data deviates from tree-like structure (e.g., horizontal gene transfer, hybridization), biologists lack the mathematical tools to characterize the deviation in ultrametric terms — they can say "this is not a tree," but not "this is X far from being a tree in the ultrametric sense."

Mini-Forecast

When will ultrametric topology become standard in biology?

By 2030: Bioinformatics tools include an "ultrametricity index" — a measure of how tree-like a distance matrix is, derived from violations of the strong triangle inequality. By 2035: Phylogenetic methods textbooks include a chapter on p-adic/ultrametric mathematics.

Mini-Backcast

Tier 1 fork (~20yr): In 2005, the first bioinformatics tools include p-adic distance metrics for sequence alignment. By 2026, "ultrametric clustering" is as standard in bioinformatics as BLAST.

3.4 Neuroscience — Neural Population Codes

Current State (2026)

Neural population activity in cortex forms hierarchical clusters — neurons that fire together form tight clusters, neurons in different cortical areas form looser clusters. This is ultrametric structure, but it is analyzed with Euclidean tools (t-SNE, UMAP, PCA) that FLATTEN the hierarchy into a 2D or 3D embedding space.

The consequence: functional relationships that are 5 hierarchical levels apart and Euclidean distance a flat number in an embedding are treated as quantitatively comparable to relationships that are 1 level apart — losing the critical information about cortical processing depth.

Mini-Forecast

When will p-adic clustering replace t-SNE/UMAP in neuroscience?

By 2029: First paper demonstrating that p-adic clustering of Neuropixels data recovers known cortical hierarchy ($V1 \rightarrow V2 \rightarrow V4 \rightarrow IT$) with >90% agreement with anatomical tracing, vs. <80% for Euclidean methods. By 2033: p-adic clustering is a standard tool in systems neuroscience alongside t-SNE and UMAP.

Calibration register entry:

Mini-Backcast

Tier 2 fork (~60yr): In 1965, Hubel and Wiesel's discovery of the visual cortex hierarchy is formulated in ultrametric terms — the "simple $\rightarrow$ complex $\rightarrow$ hypercomplex" cell hierarchy is recognized as a p-adic tree. By 2026, 60 years of cortical hierarchy research has been explicitly ultrametric — every paper reports the p-adic depth of neural representations.

3.5 Economics and Finance — Market Microstructure

Current State (2026)

Financial market correlations have been known to be ultrametric since Mantegna (1999). The minimum spanning tree of stock correlations is an ultrametric dendrogram. Portfolio optimization that respects this structure (hierarchical risk parity, López de Prado 2016) outperforms Markowitz mean-variance optimization — especially during market stress events when all correlations go to 1.

Yet quantitative finance still overwhelmingly uses Euclidean correlation matrices. The Markowitz framework (1952) — which assumes pairwise independence — remains the standard taught in every finance curriculum, despite 70 years of evidence that it fails precisely when it is most needed (market crashes).

Mini-Forecast

When will ultrametric portfolio theory replace Markowitz?

By 2030: Hierarchical risk parity (HRP) and related ultrametric methods are taught alongside Markowitz in quantitative finance curricula. By 2035: HRP is the default portfolio construction method at ≥ 3 major asset managers (>\$10B AUM).

Mini-Backcast

Tier 2 fork (~60yr): In 1952, Markowitz's portfolio theory uses ultrametric correlation matrices instead of Euclidean covariance. The "diversification failure" during market crashes is PREDICTED by the theory — ultrametric clustering explicitly models the regime where the tree collapses to a single cluster. The 2008 financial crisis is a CONFIRMATION of the theory, not a failure of it.

3.6 Climate and Earth Systems

Current State (2026)

Climate models discretize on Euclidean grids. But Earth systems are hierarchical: atmosphere layers, ocean depths, ecosystem trophic levels, carbon-cycle reservoirs. The hierarchical structure is modeled as a feature of the equations, not as a property of the discretization.

The consequence: phenomena that are intrinsically hierarchical (convection, stratification) require fine grid resolution to capture — because the Euclidean grid is the WRONG topology for hierarchical systems. A Bruhat-Tits tree discretization would capture the same phenomena at $O(n \log n)$ rather than $O(n^2)$ grid points.

Mini-Forecast

When will ultrametric discretization enter climate modeling?

By 2033: A proof-of-concept paper demonstrates that a p-adic tree discretization of convective boundary layers achieves the same accuracy as a grid-based model at 50% of the grid resolution. By 2040: At least one operational climate model includes an ultrametric discretization option.

Mini-Backcast

Tier 1 fork (~20yr): In 2005, the IPCC Fourth Assessment Report includes a research track on alternative discretization methods alongside grid-based and spectral methods. By 2026, ultrametric climate models are a mature class with resolution-independent scaling.

3.7 Chemistry and Drug Discovery — Molecular Energy Landscapes

Current State (2026)

Protein folding and ligand binding occur on energy landscapes that are intrinsically ultrametric — the barriers between metastable states form a hierarchical tree. AlphaFold (2020) predicts STRUCTURE but not KINETICS — because the Euclidean loss function used in training (RMSD of atom positions) is insensitive to the ultrametric barrier structure that determines binding rates.

Mini-Forecast

When will ultrametric energy landscapes improve drug discovery?

By 2030: A paper demonstrates that the p-adic valuation gap between bound and unbound states predicts binding kinetics (on-rate, off-rate) with Spearman $\rho > 0.7$ against experiment, vs. FEP (free energy perturbation) at $\rho \sim 0.5$. By 2035: Ultrametric energy landscape analysis is a standard tool in computational drug discovery alongside molecular dynamics and free-energy perturbation.

Mini-Backcast

Tier 3 fork (~120yr): In 1884, van 't Hoff's chemical thermodynamics is formulated on p-adic rather than Archimedean energy coordinates. The "reaction coordinate" is inherently discrete from the start. Protein folding is solved analytically in the 1960s via ultrametric energy landscape theory.

3.8 Sociology — Organizational and Network Hierarchy

Current State (2026)

Organizational hierarchies, social networks, and cultural transmission all have ultrametric structure. But sociology has almost no engagement with ultrametric mathematics. The "small-world" network model (Watts and Strogatz, 1998) and "scale-free" networks (Barabási and Albert, 1999) are the dominant mathematical frameworks — both of which are non-ultrametric.

Mini-Forecast

When will ultrametric methods enter sociology?

By 2035: A paper in *American Sociological Review* or *Social Networks* uses ultrametric clustering to analyze organizational hierarchy or social mobility. By 2045: Ultrametric methods are a standard topic in quantitative sociology methods courses.

Mini-Backcast

Tier 2 fork (~60yr): In 1967, Milgram's "small-world" experiment is analyzed using ultrametric distance rather than Euclidean path length. The result — "six degrees of separation" — is reinterpreted as a property of the ultrametric tree depth, not the network diameter. By 2026, quantitative sociology has 60 years of ultrametric methods development.

3.9 Materials Science — Hierarchical Material Failure

Current State (2026)

Materials fail at multiple scales — atomic dislocations, grain boundaries, microcracks, macroscopic fracture. This is a natural ultrametric hierarchy: each failure mode operates at a characteristic scale with a characteristic energy barrier. Yet materials simulation (molecular dynamics, finite-element methods) typically treats each scale separately, with ad hoc coupling between scales.

Mini-Forecast

When will ultrametric methods enter materials science?

By 2030: A paper demonstrates that the p-adic valuation of stress concentration predicts material failure modes across scales — from atomic to macroscopic — better than scale-separated models. By 2038: Multiscale materials simulation includes ultrametric coupling as a standard option.

3.10 Pharmacology — Dose-Response and Drug Interactions

Current State (2026)

Drug dose-response curves, drug-drug interactions, and adverse-event hierarchies all have ultrametric structure — the "therapeutic index" is a p-adic valuation: drugs with high therapeutic index have a large valuation gap between effective dose and toxic dose. Yet pharmacology uses log-linear models, not ultrametric ones.

Mini-Forecast

When will ultrametric methods improve pharmacology?

By 2032: A paper demonstrates that p-adic clustering of adverse drug reaction data identifies previously unknown drug-drug interactions (confirmed by subsequent clinical observation). By 2040: Pharmacovigilance systems include ultrametric clustering as a standard signal-detection method.

3.11 Metrology — Measurement Precision Hierarchy

Current State (2026)

Measurement precision forms a natural hierarchy: picometer → nanometer → micrometer → millimeter → meter. This is a p-adic structure: each tier is a valuation level. The NIST traceability chain (the chain of calibrations connecting a measurement to a primary standard) IS a Bruhat-Tits tree.

Yet metrology uses "measurement uncertainty" (GUM — Guide to the Expression of Uncertainty in Measurement) without recognizing the underlying ultrametric structure. A GUM uncertainty budget is a valuation profile — $v_p(\text{uncertainty})$ — but this is not how it is taught or applied.

Mini-Forecast

When will metrology adopt ultrametric vocabulary?

By 2030: A paper in *Metrologia* or an NIST Technical Note proposes "valuation class" as a measurement property alongside uncertainty. By 2038: GUM v4 includes a section on "ultrametric structure of measurement precision."

3.12 The QNFO Ecosystem — Inter-Project Consilience

Current State (2026)

The QNFO research ecosystem has 8 active projects that collectively span physics, computer science, biology, and information theory. Each project independently discovered ultrametric structure in its domain. The cross-domain consilience is present in the mathematics but not yet in the publication strategy — papers are published domain-by-domain, without cross-domain synthesis [CROSS-REF: consilient-gap-synthesis/gap-registry.md].

Mini-Forecast

When will QNFO publish a cross-domain synthesis?

This paper IS the cross-domain synthesis — or rather, its initial draft. By 2028: This paper is published at papers.qnfo.org with a DOI, cross-referencing all 8 QNFO projects. By 2030: At least one external researcher cites this atlas to connect ultrametric structure in their domain to the broader literature.

4. Synthesis: What Is Invariant Across All 12 Domains?

4.1 The Invariant Core

Across all 12 domains, the invariant mathematical structure is:

1. **Hierarchy:** The system is organized as a tree — nodes at each level represent groups of entities at the level below
2. **Ultrametric distance:** The distance between two nodes is the depth of their lowest common ancestor — satisfying the strong triangle inequality
3. **Valuation:** Each level of the tree carries a valuation v_p — the number of steps from the root
4. **Error confinement:** Perturbations are localized to a sub-tree — errors at one valuation level do not propagate to sibling sub-trees

4.2 The Domain-Varying Properties

What varies across domains is:

- What the "entities" are (energy states, stocks, neurons, species, molecules, social positions)
- What the "distance" means physically (transition probability, correlation, firing similarity, genetic distance, binding affinity, social proximity)
- What "error confinement" protects against (decoherence, market shock propagation, neural noise, mutation, toxicity, social mobility barriers)

4.3 The Synthesis Consilience

Meta-Principle: Ultrametric topology is a universal structure of hierarchically organized complex systems. The specific entities, distances, and error-confinement mechanisms vary across domains, but the MATHEMATICAL INVARIANT — the strong triangle inequality — is the same everywhere. Every time a domain independently discovers ultrametric structure, it is rediscovering the same mathematical fact, expressed in different language, applied to different entities.

4.4 Why This Matters

If ultrametric topology is universal, then:

1. **Tools transfer:** A method developed for one domain (e.g., p-adic QEC from physics) can be applied to another (e.g., portfolio optimization in finance) with minimal adaptation
 2. **Forecasts converge:** The forecast for "when will Domain X adopt ultrametric methods?" is informed by the adoption history of Domain Y
 3. **Backcasts inform each other:** The counterfactual "what if Boltzmann had used p-adic statistics in 1897?" suggests that the counterfactual "what if Markowitz had used ultrametric correlation in 1952?" would have similar structural consequences
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5. Frontier Questions

The following questions are at the boundary of what the consilience atlas currently covers. They are NOT asserted — they are proposed as research directions, labeled with certainty calibration per QNFO standards.

Q1: Is the invariant core provable?

Can it be proven that any hierarchically organized system with error-confinement properties NECESSARILY satisfies the strong triangle inequality? Or is ultrametricity a sufficient but not necessary condition for hierarchy? [speculative]

Approach: Define a minimal set of axioms for "hierarchical error-confinement" and prove that ultrametricity follows. If the proof succeeds → ultrametricity is THE topology of hierarchy. If it fails → there exist non-ultrametric hierarchical systems; the atlas is overclaiming.

Q2: Are there systems that resist ultrametric description?

If a system is genuinely NON-hierarchical — if it has flat, egalitarian structure with no nested levels — does it resist ultrametric analysis? Or does everything look ultrametric under some transformation? [speculative]

Approach: Apply the ultrametricity index (Section 3.3) to 100 systems across 12 domains. If ALL systems score high → the consilience hypothesis is strengthened but the index may be too permissive. If some score low → those systems are candidates for "genuinely non-hierarchical" status.

Q3: What assumptions, if relaxed, would unify two previously separate domains?

Example: Relax the assumption that "distance means transition probability" in physics AND "distance means default probability" in finance. The unified concept is "distance as probability of remaining in the same ultrametric cluster under perturbation" — a single definition that works for both quantum state transitions (physics) and credit-rating migrations (finance). [my conjecture]

Approach: For every pair of domains in the cross-domain lexicon (Section 2), attempt to unify the mathematical concept in the row. Count how many pairs unify. If most do → the consilience hypothesis is strongly supported. If few do → domains are genuinely different despite structural similarities.

6. Conclusions

The ultrametric consilience atlas maps a single mathematical structure across 12 domains. The key findings:

1. **Universality:** Ultrametric topology appears independently in physics, computer science, biology, neuroscience, finance, climate science, chemistry, sociology, materials science, pharmacology, metrology, and the QNFO ecosystem. The repeated independent discovery is strong evidence that ultrametricity is a universal structure, not a domain-specific curiosity.
1. **Tool Transferability:** Because the mathematical core is invariant, tools developed for one domain (e.g., p-adic QEC from quantum physics) are transferable to others (e.g., portfolio optimization in finance) with minimal adaptation.
1. **Forecast Convergence:** The adoption forecast for ultrametric methods in each domain is informed by the adoption history of other domains. Physics will likely lead (strongest mathematical tradition), followed by computer science and finance (strongest commercial incentive), then neuroscience and climate science (longer institutional timelines).
1. **Backcast Parallelism:** The counterfactual backcasts across domains share a structural pattern: a single insight at the field's founding (Boltzmann 1897 for physics, Markowitz 1952 for finance, Hubel-Wiesel 1965 for neuroscience) would have produced 60-120 years of ultrametric methods development.

The atlas is not complete — 12 domains is a beginning, not an end. The frontier questions point to deeper structural questions about the relationship between hierarchy, error confinement, and the strong triangle inequality. But even in its current form, the atlas demonstrates that the p-adic/ultrametric mathematical toolkit is not a niche curiosity — it is a universal language for hierarchically organized complex systems.

Declarations

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Conflicts of Interest: The author is affiliated with QNFO, which develops p-adic/ultrametric mathematical methods.

Ethics Approval: Not applicable — theoretical synthesis only.

Consent to Participate: Not applicable.

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Use of Artificial Intelligence: This paper was drafted with assistance from large language models (DeepSeek-V4) for cross-domain synthesis, text generation, structure, and copyediting. All substantive analysis, domain knowledge, and conclusions are the author's.

Version History

Version	Date	Changes
v0.1	2026-07-31	Initial draft: 12-domain cross-domain lexicon, domain-by-domain analysis with mini-forecasts and mini-backcasts, synthesis consilience, frontier questions