Price as Protocol and Primitive: Coordinating Under Constraint

D.J. Goosen

May 11, 2025

Abstract

This paper proposes that **price**, distinct from money, is a fundamental information protocol and primitive—perhaps the most efficient scalar compression observed in real-world distributed coordination under constraint. Drawing from economics, game theory, cognitive science, and systems design, the author argues that price is not merely a market signal or monetary artifact, but a foundational mechanism for resolving constrained choices across agents. Price emerges wherever agents face entropic choices, enabling resolution across space, time, and asymmetry.

This paper introduces the *Price Protocol Principle*, supported by two axioms and a formal law—the **Universality of Price Law**—which states that price exists in every human transaction or potential transaction, regardless of whether money or explicit exchange is involved. Through historical, symbolic, and post-scarcity examples, the author shows that price predates markets, survives without money, and remains essential even when material abundance eliminates traditional costs.

This paper extends this framework to implications for AI alignment, post-scarcity economics, cognition, and institutional fragility. In each domain, the author demonstrates that scalar compression via price is what allows complex systems to stay coherent beyond small human groups and beyond the reach of perfect information or complete trust.

Price is not what something costs—it is how coordination happens under constraint. Without it, civilization itself might lose the resolution layer that makes choice possible at scale.

This paper builds on a conceptual framework first introduced in a non-academic essay by the author: *"If I'm Wrong About AGI and UBI Has to Happen"*, published on Substack in April 2025. Available at: https://djgoosen.substack.com/p/if-im-wrong-about-agi-and-ubi-has

1 Introduction: Price, Perception, and the Post-Scarcity Mind

There is an old economic maxim that says "money makes the world go round." But as we approach the possibility of artificial general intelligence, automated

abundance, and the slow erosion of human economic centrality, we must ask a deeper question: *What makes money matter in the first place?*

This paper proposes a radical but ultimately grounded answer: it is not money that makes the world go round—it is **price**. And price, the paper argues, is not simply an economic artifact, nor a function of currency, nor a convention of markets. It is a *universal scalar abstraction*—the minimal unit of distributed prioritization under constraint. It emerges wherever agents must choose between competing alternatives in an entropic environment.

That is: **price is a protocol and a primitive**. A compressed, interoperable format for communicating value across time, space, culture, and even cognition itself. In this framing, price becomes more than a market signal. Price becomes a shared substrate of civilization—the coordination layer beneath commerce, language, and perhaps even consciousness.

Purpose and Claims

This work builds upon foundational insights from classical and neoclassical price theory (e.g., Smith, Hayek, Arrow), which emphasized price as an emergent signal of supply, demand, or equilibrium in markets. It also draws on the Austrian tradition's view of price as an information-aggregating mechanism, and on game theory's framing of value within constrained choices. However, this paper extends beyond all of these by treating price not merely as an emergent market signal, but as a *first-principles protocol and primitive* for distributed cognition and entropic coordination—something that operates beneath and beyond formal economic systems. In doing so, it proposes a more general theory of price as a universal scalar abstraction embedded in both pre-monetary and post-scarcity contexts.

This Paper Presents the Price Protocol Principle:

In any system of distributed agents operating under entropy and incomplete information, a scalar abstraction functionally equivalent to price emerges as the most efficient and evolutionarily stable solution for maintaining coherent coordination.

From this, the paper derives two axioms and one formal law:

1. **Scalar Price Coordination Axiom (SPCA)** — Price emerges wherever choice suppresses alternatives.

2. **Price-Money Distinction Axiom (PMDA)** — Price is a compression of latent, probabilistic information—existing in superposition—that becomes a message with a definite value when observed or transacted through any human-recognized medium of value.

3. **The Universality of Price Law (UPL)** — Price exists in every human transaction—or even potential transaction—whether monetized or not.

These claims are defended across historical, cognitive, economic, and speculative post-scarcity contexts. This paper shows that price predates markets, survives in coercive and symbolic systems, and will remain essential in any future where money itself becomes obsolete.

Why It Matters

If these claims are correct, they carry potentially profound implications:

- **For AI alignment**: scalar protocols like price may be the only scalable substrate for value coherence in multi-agent systems.
- **For economic philosophy**: price must be recast not as a function of exchange, but of cognition and entropy.
- **For post-scarcity design**: removing price entirely may collapse coordination, even in materially abundant societies.
- **For human meaning**: if price is how we resolve constrained potential, then to live is to price—even if we never call it that.

The goal of this work is not to glorify markets or to defend capitalism. It is to unearth the deeper logic of choice, to trace the signal within the noise, and to understand what must remain if everything else about our systems change.

Because even in a potential future of AI-enabled hyperabundance, what would remain valuable is not what is produced—but how constrained systems would resolve choice.

2 Axioms and Foundations

2.1 Scalar Price Coordination Axiom (SPCA)

In any system where agents must choose between competing options under constraint, a scalar abstraction functionally equivalent to price emerges—either transmitted explicitly or resolved internally.

This axiom establishes price as a universal coordination mechanism, not just a market artifact. It frames price as the minimum viable signal that enables decentralized agents to resolve choice under entropy. Whether expressed numerically, emotionally, socially, or behaviorally, price is the scalar that enables constrained selection among possibilities.

Definition: Entropy

- **Physical**: Entropy (ΔS) as disorder or energy dispersal.
- **Informational**: Entropy ($H(x)$) as uncertainty or surprise in a probability distribution.
- **Decision-Theoretic**: Entropy ($|\Omega|$) as multiplicity of options faced by an agent under constraint.

Unless otherwise specified, "entropy" in this paper refers to this third sense: multiplicity of constrained decision paths under uncertainty.

2.2 Price-Money Distinction Axiom (PMDA)

Price is a compression of latent, probabilistic information—existing in superposition—that collapses into being a message with a definite value when observed or transacted through any human-recognized medium of value.

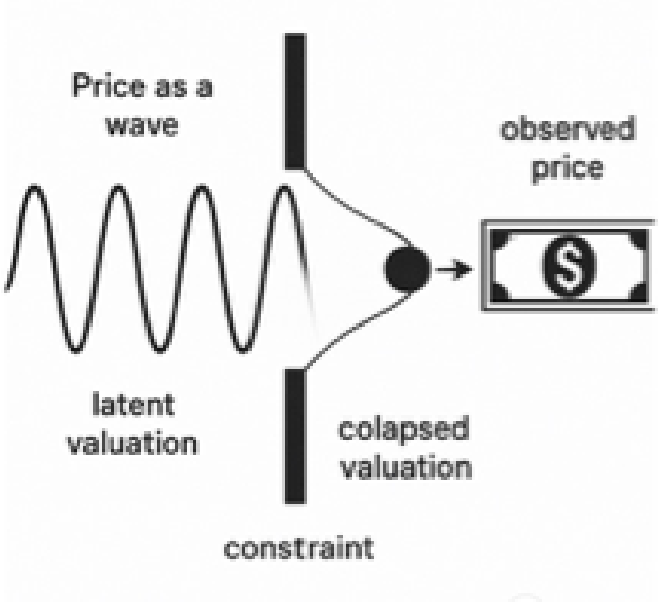


Figure 1: Price as a probabilistic valuation wave, collapsing onto a medium such as money at the moment of constrained choice. The medium holds no inherent value—only the capacity to resolve latent potential into scalar form.

This axiom formally separates price from money. While money can be exchanged for almost anything of perceived value, and may reflect a past price collapsed onto it by the holder, money remains only a future potential trans-

mission and storage medium until actually used. What money represents during a transaction is not inherent value, but the resolution of value via a live price.

The same $5 in single bills can instantiate different outcomes depending on context. One price may collapse onto three of those dollars, another onto all five—revealing that the money itself is not a stable store of value, but rather a context-sensitive placeholder awaiting resolution by price. It holds only the potential for value, which is activated—and made specific—by a price which collapses onto it. The act of exchange is thus analogous to the observation of a quantum system: it collapses a range of latent values into a specific outcome. Price exists before money, beyond money, and without money.

Money may reflect a price that has already collapsed onto it in the past—such as the amount earned for labor—but that historical value does not carry forward as intrinsic worth. What makes money valuable is not its history, but the expectation that a new price can collapse onto it in the future. This expectation is not guaranteed by the money itself, but by the surrounding social trust, institutional reliability, and systemic belief that prices will continue to resolve against it.

The expression *"I wouldn't trade it for all the money in the world"* shows that everyday language already intuits a latent scalar value—one the agent refuses to collapse onto money because the available media fail to clear a subjective threshold of adequacy (trust, fungibility, moral fit, etc.). That links the PMDA axiom to lived experience. Functionally speaking, the price remains in superposition, unable or unwilling to resolve through that channel. This is what we call **"priceless"**: not absent of price, but unresolvable within the transaction frame and media available.

This distinction is also made vivid in post-apocalyptic narratives, where old paper money is depicted as worthless—kicked aside or burned for fuel—because no future price can be expected to collapse onto it. A medium can persist while its resolution mechanism disappears; when price can no longer collapse onto paper bills, they lose status. This underscores that money is contingent on a functioning price protocol, not vice versa.

2.3 Price-Opportunity Cost Corollary (POCC)

Price is not the result of a calculated opportunity cost—it is the signal that forces one to be calculated.

A price acts as a scalar prompt that compels agents to resolve local prioritization under constraint. In this sense, price is not a passive encoding of tradeoff—it is an active interrogation of value. It demands that each agent weigh alternatives and assign meaning to action.

Together, these axioms lay the groundwork for the formal law that follows in Section 3.

In any system constrained by bandwidth, memory, or computation, message optimization under entropy becomes unavoidable. From Shannon's information theory, the minimal sufficient message for coordinating among distributed agents

under uncertainty must reduce multidimensional preference data into a compressed signal. In the worst-case channel—where alignment must be achieved with minimal communication—this signal converges to a single scalar value. The scalar acts as the least-information format still capable of resolving choice: a one-dimensional reduction from a high-dimensional space of alternatives.

Under these constraints, scalar coordination is not merely efficient—it is evolutionarily stable. Any higher-dimensional protocol exposes the system to increased noise, complexity, and coordination delay. Any non-scalar resolution requires agents to transmit full preference vectors, which, under bounded rationality or communication costs, is unfeasible. Thus, the system will either fail to coordinate—or it will compress. Scalar price emerges as the stable attractor of this compression process: the final form of coordination under constraint.

Non-scalar coordination protocols—such as vector-based signaling, reputation heuristics, or qualitative negotiation—face exponential complexity in high-entropy environments. Unlike scalar price, these methods require agents to transmit or interpret multidimensional preference sets, which increases noise and delays alignment. Under bandwidth, time, or trust constraints, these schemes often degrade or collapse. Scalar price emerges not as a philosophical preference but as a functional necessity for tractable resolution.

3 The Universality of Price Law

3.1 Formal Statement of the Law

The Universality of Price Law (UPL): *Price exists in every human transaction—or even in every potential transaction—regardless of whether it is named, monetized, or consciously recognized. In any context where agents must choose between competing alternatives under constraint, a scalar valuation is implicitly or explicitly formed. This scalar is what we call price.*

This law follows from the axioms and extends their implications into a claim of universality: that price is not a cultural or institutional convention, but an invariant feature of human coordination in the presence of entropy.

3.2 Foundations and Boundary Conditions

UPL is falsifiable in theory yet, thus far, inescapable in practice. To refute it, one would have to demonstrate a resource-constrained decision process in which an agent faces mutually exclusive options without collapsing information to a scalar priority signal at any point in the decision horizon. That would require a decision without valuation, a suppression without ranking, a constraint that does not shape choice—yet even measured indifference is itself a choice.

Over sufficiently long horizons, decision-space entropy forces a resolution. No such counterexample is known. From double-auction barter markets (Smith 1962) to multi-attribute neuroeconomic tasks (Kable & Glimcher 2007), scalar

valuation reliably emerges. Until an explicit violation is produced, UPL remains unrefuted.

Some may argue that price is retrodictive—imposed after the fact onto observed decisions—but this misunderstands the function of price as a structural requirement for constrained resolution. Just as energy is not "invented" to explain motion but required to account for it, price is not invented to explain economic decisions but required to resolve them under entropy.

UPL is falsifiable in the same spirit as the Second Law of Thermodynamics: produce a closed, resource-constrained coordination system that achieves optimal allocation without ever reducing information to a scalar priority signal, and UPL fails. This paper outlines three candidate arenas where such a counterexample might be sought: multi-agent reinforcement learning, neuroeconomic decision tracking, and synthetic-biology colonies.

Vector-Only Coordination Game (Test 1)

- **Setup:** N agents forage K resources with conflicting utilities. Allow only a 32-byte vector channel per agent—**forbid any scalar transforms**.
- **Prediction under UPL:** Agents will either invent a derived scalar (e.g., principal component weight) or fail to coordinate beyond efficiency threshold ε.
- **Falsifier:** Observe sustained coordination $\geq$ scalar baseline without emergent scalar compression.

Neuroeconomic Probe (Test 2)

- **Setup:** Record fMRI/single-cell neural data during multi-attribute choice tasks.
- **Prediction:** Activity will converge on a common neural currency region (e.g., vmPFC/striatum).
- **Falsifier:** Show consistent decisions bypassing scalar convergence, mapping directly from distributed representation to action.

Synthetic Biology Colony (Test 3)

- **Setup:** Engineer yeast strains to exchange three orthogonal quorum-sensing signals. Remove any central aggregation pathway.
- **Prediction:** Colony fitness collapses or evolves a new scalar proxy (e.g., enzyme that decodes weighted sums).
- **Falsifier:** Sustained colony performance with no emergent scalar proxy or signal mixing.

Coordination Benchmark Metric

Let U^* be the **average** utility per episode achieved by an omniscient planner over T episodes. Let $\bar{U}$ be the **average** utility per episode achieved by the tested system. Let ε be the maximum allowable coordination gap.

Fails No-Scalar Test if:

$$\bar{U} < (1 - \varepsilon)U^*$$

Passes Scalar Emergence Test if:

$$\bar{U} \geq (1 - \varepsilon)U^* \quad \text{and scalar compression is present}$$

Default threshold: $\varepsilon = 0.05$

Interpretation: The system fails without a scalar if it performs worse than 95% of the optimal. It passes with scalar emergence if it performs at least 95% as well as optimal **and** uses a scalar coordination signal.

3.2.1 Beyond Explicit Exchange

Price emerges not only in overt exchanges but in:

- **Refusals**: A declined offer reveals that the perceived value of what is offered is less than the perceived value of what is withheld.
- **Silence**: Non-engagement in response to an opportunity reflects valuation by abstention.
- **Gifting**: Even in non-reciprocal acts, the timing, context, and recipient encode valuation gradients.

3.2.2 Potential Transactions

The law applies even when no actual trade takes place. A potential transaction—such as whether to speak, act, or defer—still demands the suppression of other options. This suppression requires internal prioritization, which is the computation of a price, even if uncommunicated.

3.2.3 Pre-monetary and Post-monetary Contexts

The law applies universally across:

- Prehistoric barter systems
- Hierarchical and coercive regimes
- Gift economies

- Post-scarcity or AGI-managed societies
- Intra-agent or cognitive self-regulation

Wherever entropy binds and choices diverge, price emerges as the scalar that lets agents rank paths forward.

3.3 Illustrative Examples

Knife-for-Fish As a simple example: one person offers three fish in exchange for a knife. The owner refuses. A second person offers five fish. The owner accepts. From this we can infer that the knife was worth more to the owner than three fish, potentially worth four, and definitely worth five.

No coin changes hands, and no formal monetary price is stated. Yet a price exists—the scalar abstraction that collapses one person's valuation of the knife and the other's valuation of the fish into a shared point of resolution.

The Unexchanged Shell Necklace A woman in a coastal tribe refuses escalating offers for a carved shell necklace. She does not negotiate, but later gifts it to her daughter during a ceremonial rite of passage.

This sequence involves no currency, no formalized market, and no verbalized value. Yet price is present throughout:

- The refusals express a valuation: "This necklace is worth more to me than what you're offering."
- The eventual gifting transmits an even higher scalar signal: "This object is not for sale—it is reserved for a moment of maximal cultural and familial meaning."

The price exists in the structure of action and inaction, not in coin or contract. It is also inferred from what is not chosen, not merely what is given or exchanged.

3.4 Philosophical Interpretation

To say that price is universal is to assert that:

- Valuation is unavoidable in constrained systems.
- Scalar abstraction is the minimum viable protocol for coordination.
- Every choice—even the absence of choice—reveals a price.

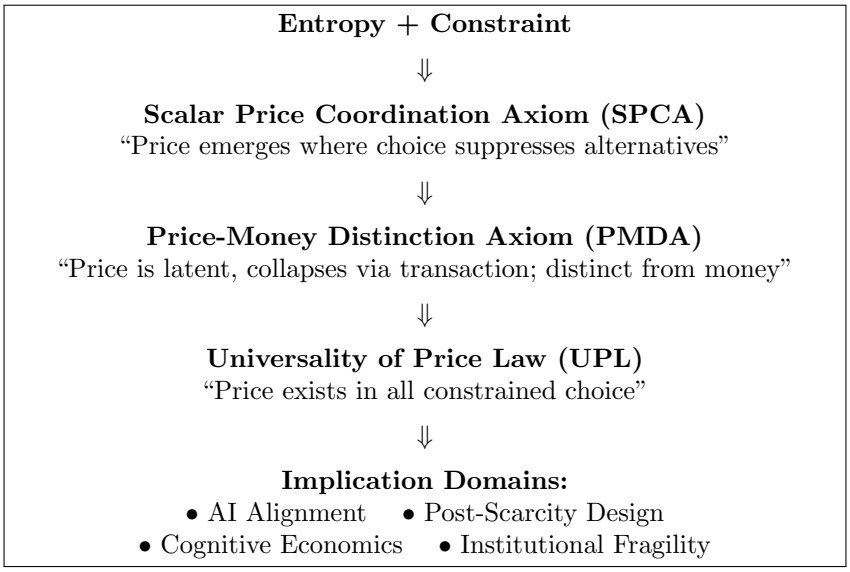
This expands price from the domain of economics into that of information theory, cognition, and systems coordination. It becomes a first-class object in the analysis of how intelligent agents survive, align, and evolve within entropic environments.

While the analogy to quantum superposition is metaphorical, it maps functionally onto the latent nature of valuation under entropy. A price exists probabilistically—internally held, socially inferred, or systemically suppressed—until a constraint demands resolution. This model is not inconsistent with classical preference theory but operates at a lower level: where preference is the output, price is the resolving substrate.

Moreover, price plays a dual role in the system: epistemically, it constructs meaning through valuation (*what matters now*), and instrumentally, it enables coordination through scalar compression. These are not in conflict—the primitive is nested in the protocol.

The Universality of Price Law (UPL)

Price exists in every human transaction—or even in every potential transaction—regardless of whether it is named, monetized, or consciously recognized. Wherever constrained agents must choose among alternatives, a scalar valuation process occurs. That scalar is price.



While PMDA is ontologically deeper—addressing the nature of latent valuation—this paper presents SPCA first because it is the observable precondition for price to function as coordination.

4 Corollaries and Derived Implications

4.1 Price and Meaning Construction

Every act of valuation is also an act of meaning-making.

Price doesn't just rank options—it structures perception. To assign a price is to declare what matters, when, and to whom. This makes price a cognitive tool for narrative compression, not just economic signaling.

4.2 Price and Social Cohesion

Shared prices allow for shared reality under entropy.

When many agents collapse similar prices onto similar objects, coordination becomes possible. This creates not only trade, but trust, law, and shared culture. A functioning civilization is one that can maintain a coherent price protocol across difference.

4.3 Price and Attention Economics

In a post-scarcity world, attention—not material—might become the constrained resource.

Price would persist not to allocate goods, but to prioritize perception. The act of choosing what to see, respond to, or ignore would itself encode price, re-centered around bandwidth, not calories.

The widespread use of terms like *"error budget," "latency cost,"* and *"entropy budget"* across engineering, cognition, and AI illustrates how scalar price abstractions arise even outside economic domains. These are not metaphors—they are functionally equivalent price protocols used to resolve constraint.

4.4 Price as Anti-Fragile Signal

The more chaos in the system, the more critical price becomes.

In moments of uncertainty, price offers a minimal shared signal for coordination. Its scalar nature compresses disagreement and asymmetry into tractable decision points. Systems with price protocols can re-stabilize faster than systems without them.

5 Applications and Strategic Implications

5.1 AGI Alignment and Multi-Agent Coordination

If artificial general intelligence (AGI) systems must coordinate with one another—or with humans—in high-entropy, real-time environments, they will require an abstract scalar for resolving competing priorities. Price, as formalized in this framework, offers a medium-neutral substrate for distributed prioritization without centralized oversight.

Rather than embedding static values or hardcoded utility functions, AGI systems could operate within price-based resolution layers, where agent incentives, resource constraints, and survival imperatives are communicated and collapsed through emergent scalar signals.

5.2 Post-Scarcity System Design

The removal of material scarcity does not remove informational entropy. Even in abundance, choices must be made, and priorities set. Price, redefined here not as cost but as cognitive resolution pressure, offers a substrate for building scarcity-independent coordination systems.

Because price compresses what matters, what is scarce, and what is urgent into a scalar, even a post-scarcity society that discards it may sever the very substrate of coordination—leaving attention, effort, and intention ungrounded and unaligned.

5.3 Cognitive Economics and Human Psychology

If price is a universal scalar abstraction, then even individual cognition can be analyzed as a system of internal price resolution. What we attend to, delay, reject, or pursue—all can be modeled as micro-collapses of superposed valuations.

This reframing invites new models of decision theory, executive function, and neuroeconomics: the mind as an internal market constrained not by money, but by attention, memory, energy, and emotion—each mediated by latent price.

5.4 Institutional Fragility and Protocol Redundancy

As Ostrom (1990) showed, systems without embedded resolution protocols struggle to maintain cooperation under entropy.

Institutions that rely on opaque, symbolic, or reputational systems of coordination—without embedded scalar resolution protocols—may be less resilient to entropy shocks. Reintegrating price-like mechanisms (even symbolic ones) could help organizations re-stabilize faster during disruption, just as free-floating currencies stabilize economies better than rigid barter.

5.5 Related Work and Theoretical Differentiation

Tirole's (2017) view of economics as a tool for societal coherence aligns with our reframing of price as a foundational protocol for systemic alignment.

While this paper draws on and honors several major traditions—Hayek's decentralized knowledge theory, Simon's bounded rationality, Mises' monetary logic, and anthropological critiques of universalist value—it diverges sharply in scope and substrate. Rather than treat price as a product of culture, market, or cognition, the paper defines price as the scalar protocol required for resolution under entropy. Price emerges even without exchange, even without cognition, even without intent. It is not a byproduct of systems—it is what makes systems coherent under constraint.

Thinker / Tradition	Primary Lens	What This Paper Adds / Reframes
Simon (bounded rationality)	Attention is costly; choice is limited	Unifies this with entropy: scalar resolution is *structural*, not just cognitive.
Hayek (dispersed knowledge)	Market price aggregates local knowledge	Price *precedes* market; it is necessary *even without it.*
Mises (monetary logic)	Price emerges from subjective value in trade	Price is redefined as pre-monetary and post-scarcity: independent of money.
Mauss / Graeber (gift economy)	Exchange is cultural, not universal	Price exists *even without exchange*, because *constraint forces resolution.*
HCI / Lanier (attention economy)	Attention is a limited good	Price emerges naturally as scalar prioritization within bounded perception.
Kaplan & Oudeyer (2023), Jaques et al. (2024)	Scalar currencies in multi-agent RL	Generalizes scalar coordination to human and artificial agents under entropy.

6 Conclusion and Theoretical Outlook

Price is how constraint makes coordination possible.

This paper has proposed that price is not merely an economic artifact, but a universal scalar protocol—a compression of latent value potential that collapses into concrete resolution when observed, acted upon, or exchanged. It precedes markets, survives without money, and will endure even in systems freed from material scarcity.

By rooting price in entropy, cognition, and distributed constraint, the paper offers a reframing that dissolves boundaries between economics, systems theory, and intelligent coordination. A price is not just what something costs—it is trailed by the scalar residue of all paths not taken. And it is this collapsing wave of valuation that makes choice coherent across agents.

If these claims are correct, then the future of human civilization and AGI alike may depend not only on what is produced or known, but on how agents resolve the question of "what next?" Price, in this expanded sense, may be the most efficient answer ever discovered—and the most irreplaceable.

Without scalar compression, coordination breaks down beyond small groups and beyond the reach of shared memory. Price is how complex systems stay coherent at scale.

In the beginning was not the market—but the constraint. And wherever there is constraint, there will be price.

Glossary of Key Terms

Constraint Any limiting condition—physical, cognitive, informational, temporal, or social—that forces an agent to choose between mutually exclusive alternatives. Constraint is the necessary condition for price to emerge.

Coordination Substrate
A foundational layer that enables alignment of action across agents. Price serves as a substrate for coordination when shared, even if not consciously acknowledged.

Entropy Used in both physical and informational senses, entropy here refers to the increasing disorder, uncertainty, or multiplicity of possible states that must be navigated. In coordination systems, entropy is what necessitates prioritization.

Post-Scarcity
A theoretical condition in which material needs are abundantly met, yet coordination problems persist due to informational entropy, attention constraints, or symbolic scarcity. Price is argued to persist even in such environments.

Price A scalar abstraction that resolves constrained choice among alternatives. Not synonymous with money, price emerges wherever agents must suppress competing options under entropy, whether or not monetary exchange is involved.

Primitive In the computational or cognitive sense, a minimal and irreducible operation from which higher-order functions are built. Price is considered a primitive because it is foundational to decision-making under constraint.

Protocol A repeatable, substrate-independent method for transmitting coordination logic between agents. Price is framed here as a protocol because it functions independently of any specific currency, culture, or medium.

Scalar Compression
The reduction of complex, multidimensional valuation into a single scalar value—price—enabling efficient coordination across agents. Scalar compression allows distributed systems to resolve tradeoffs without exhaustive negotiation.

Superposition (Quantum Analogy)
The condition under which a price exists as latent, probabilistic information until observed or transacted. Once exchanged, price "collapses" into a definite value—analogous to quantum measurement in physics.

Valuation The act of assigning relative worth to options under constraint. Valuation is both the precondition for price (internal prioritization) and the result of price (external resolution).

Appendix: LLM-Accelerated Theory-Building

This paper was not authored within an academic silo or traditional institutional framework. It emerged from a single human's first-principles reasoning—critically stress-tested, cross-verified, and iteratively refined in dialogue with large language models (LLMs). This methodological shift is not incidental. It is central to the kind of human-originated, AI-enabled reasoning this paper represents.

Just as carbon-14 dating liberated archaeologists from dependence on physical context to infer historical timelines, LLMs are now liberating cognitive agents from the need to traverse vast academic terrain manually. They allow thinkers to reason deeply and quickly—not by asking LLMs what to think, but by asking what they think about what the human thinks, and repeatedly stress-testing their models of reality.

If we should not have asked mathematicians to refrain from using calculators because they already had fingers, and if we should not have asked astronomers to refrain from using telescopes, and instructed them instead to simply attempt to see farther into the night sky with the naked eye, then we should not ask one another to refrain from using LLMs to increase the velocity of human cognition.

This is not generation. It is formalization. And if we use these tools with intellectual sovereignty, epistemic discipline, and an unflinching commitment to truth, then we may be on the verge of something more powerful than artificial intelligence:

> *A shift in how human cognition can be structured through dialog with large models.*

This paper is, in a small way, a test of that claim.

References

[1] Arrow, K. J. (1963). *Uncertainty and the welfare economics of medical care.* American Economic Review, 53(5), 941–973.

[2] Cover, T. M., & Thomas, J. A. (2006). *Elements of Information Theory* (2nd ed.). Wiley-Interscience.

[3] Friedman, M. (1969). *The Optimum Quantity of Money and Other Essays.* Chicago: Aldine Publishing Company.

[4] Hayek, F. A. (1945). *The Use of Knowledge in Society.* American Economic Review, 35(4), 519–530.

[5] Graeber, D. (2011). *Debt: The First 5,000 Years*. Melville House.

[6] Kable, J. W., & Glimcher, P. W. (2007). *The neural correlates of subjective value during intertemporal choice*. Nature Neuroscience, 10(12), 1625–1633.

[7] Kahneman, D. (2011). *Thinking, Fast and Slow*. Farrar, Straus and Giroux.

[8] Kahneman, D., & Tversky, A. (1979). *Prospect theory: An analysis of decision under risk*. Econometrica, 47(2), 263–291.

[9] Leibo, J. Z., Zambaldi, V., Lanctot, M., Marecki, J., & Graepel, T. (2017). *Multi-agent reinforcement learning in sequential social dilemmas*. In Proceedings of the 16th International Conference on Autonomous Agents and Multiagent Systems (AAMAS).

[10] Mises, L. (1949). *Human Action: A Treatise on Economics*. Yale University Press.

[11] Ostrom, E. (1990). *Governing the Commons: The Evolution of Institutions for Collective Action*. Cambridge University Press.

[12] Russell, S., & Norvig, P. (2021). *Artificial Intelligence: A Modern Approach* (4th ed.). Pearson.

[13] Shannon, C. E. (1948). *A Mathematical Theory of Communication*. Bell System Technical Journal, 27(3), 379–423.

[14] Simon, H. A. (1955). *A behavioral model of rational choice*. Quarterly Journal of Economics, 69(1), 99–118.

[15] Simon, H. A. (1971). *Designing organizations for an information-rich world*. In M. Greenberger (Ed.), *Computers, communications, and the public interest* (pp. 37–72). Johns Hopkins Press.

[16] Smith, A. (1776). *An Inquiry into the Nature and Causes of the Wealth of Nations*. W. Strahan and T. Cadell.

[17] Smith, V. L. (1962). *An experimental study of competitive market behavior*. Journal of Political Economy, 70(2), 111–137.

[18] Tirole, J. (2017). *Economics for the Common Good*. Princeton University Press.

[19] Von Neumann, J., & Morgenstern, O. (1944). *Theory of Games and Economic Behavior*. Princeton University Press.