Information as the new currency of value

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What is the value of a lightning bolt? A strange question, perhaps. But as it arcs across the sky, that bolt is doing something remarkable: it's fixing nitrogen from the air, making it available to plants in a process that took nature billions of years to evolve. If we tried to replicate this service industrially, it would cost millions. Yet, in our economic systems, that lightning bolt is worth exactly zero dollars and zero cents.

Illustration: The Lightning paradox (imagine.art)

This paradox sits at the heart of our troubled relationship with nature. For centuries, we have tried to squeeze the infinite complexity of the natural world into the finite box of market prices. But as climate change accelerates and biodiversity collapses, it is becoming clear that our economic models are not just incomplete – they are actively dangerous.

A new paradigm is emerging in the interdisciplinary of biology, physics, information science, and quantum theory, offering fresh perspectives on how we might better understand and measure value. But to understand where these new ideas might lead us, we must first examine how our current concepts of value evolved. A recent study by Corsi and colleagues [1] traces this evolution by exploring a deceptively simple question: What makes something valuable?

From Nature's gift to market forces

The story begins with the Physiocrats, pre-classical economists of the 17th and 18th centuries in France. They saw nature as the ultimate source of wealth. For them, value sprouted from the Earth itself–every grain of wheat, every fruit-bearing tree was a testament to nature's generosity. In their view, all other human activities merely circulated existing wealth around rather than creating new wealth [1, 2].

However, as steam engines came to life and factories became more common during the late 18th and early 19th centuries, a new perspective emerged. Classical economists like Adam Smith, David Ricardo, Thomas Malthus, and Karl Marx shifted their focus from the soil to the workshop floor. Value, they argued, flowed not from nature's bounty but from human sweat and ingenuity [1, 3]. The worth of a chair was not in the tree it came from but in the careful hours spent crafting it.

This "labor theory of value" held strong until the late 19th century when the "Marginalist Revolution" challenged its dominance, giving birth to neoclassical economics [4]. This new approach, championed by economists like William Stanley Jevons and Alfred Marshall, introduced a radically different perspective: value was not objective at all, but deeply subjective, driven by market forces and human desires [1, 4]. This shift in economic thought is illustrated by the classic paradox of water and diamonds [5]. Water, essential for survival, is often priced far lower than diamonds, which are non-essential luxuries. The marginalist view explains this apparent contradiction by emphasizing the role of subjective value and market dynamics in determining prices. This perspective has had far-reaching

consequences, shaping economic policies and practices worldwide for over a century [6].

The environmental wake-up call

But as environmental crises intensify--from the destruction of rainforests to global warming, the limitation of this market-based understanding of value has become increasingly apparent. The rise of ecological challenges has forced economists and policymakers to face difficult questions: How do we price clear air? What is the market value for clean water?

Environmental economists have attempted to integrate ecological concerns into the neoclassical framework by putting a monetary value on environmental services [7, 8]. However, this approach has been criticized for trying to "put a price tag on nature" without fundamentally challenging the underlying economic paradigm [1, 9].

This is where our story takes interesting turns. More scientific disciplines began offering their own insights into the nature of value.

Interdisciplinary perspectives: when biology, physics, and economics collide

In the 1950s, economist Armen Albert Alchian made an interesting observation: economic systems behave remarkably like biological ones [1, 10]. Just as organisms evolve and adapt through natural selection, businesses need to change and innovate to remain competitive [1, 10]. This insight gave birth to the field of evolutionary economics, later developed by scholars like Giovanni Dosi and Richard R. Nelson, who showed how economic value emerges from the survival and adaptation of firms and institutions in complex, uncertain environments [11].

But evolution was not the only field making waves in economics. Nicholas Georgescu-Roegen, the father of bioeconomics, proposed something even more fundamental: economic processes follow the same thermodynamic laws that govern all life [1, 12, 13]. Just as living organisms cannot escape the inevitability of entropy, the economic system cannot sustain indefinite economic growth without accounting for energy degradation and resource depletion [12, 14]. This perspective suggested that traditional economics had been ignoring the most basic laws of physics, leading to unsustainable practices [1, 13].

Another significant contribution to understanding value through physical principle came from ecologist Howard T. Odum, who introduced the concept of "emergy" -- short for

energy memory -- starting in the 1980s [1, 15]. Emergy accounts for all energy inputs, from solar radiation to human labor, throughout a product's lifecycle. Odum was critical of neoclassical economic tools for assessing environmental value, considering them structurally inappropriate. Instead, he proposed a contribution-based notion of value, asserting that the worth of natural resources depends on the biophysical contributions to their generation rather than their relative scarcity [16, 17]. This perspective challenges conventional economic assessment by emphasizing the importance of energy and ecological contributions in determining value, advocating for a more holistic approach to environmental valuation.

Meanwhile, a new interdisciplinary approach, called econophysics, emerged in the 1990s and has been applying concepts from statistical physics to address economic problems, particularly those involving complex systems and stochastic processes [1, 18, 19]. While the formal field is relatively new, the relationship between physics and economics has deep historical roots, particularly in the development of mainstream economic methodology [20].

However, modern econophysics takes a different approach from neoclassical economics. While both use physics principles, econophysics challenges many fundamental assumptions of mainstream economics. Corsi et al. (2014) identify three key differences, including methods (econophysicsts emphasize statistical mechanics rather than mechanical models), research goals (econophysicists reject the atomistic view of individuals and instead focus on statistical regularities and emerging properties of complex economic systems), and epistemological foundations (econophysicists take an empirically-driven approach based on real data, rather than starting from theoretical assumptions about rational choice) [1, 21].

The new econophysics approach offers a complementary perspective to traditional economic theories, suggesting that market behavior may be influenced by principles like those observed in physical systems, in addition to human psychology and decision-making processes [1, 22]. For instance, econophysicists have drawn analogies between information propagation in financial markets and energy dispersion in physical systems. While these processes are not identical, they may share some mathematical similarities that can provide insights into market dynamics [23]. This approach has led to new methods for analyzing complex financial systems, including advanced time-series analysis and network modeling of market structures [24, 25].

Learning from quantum physics: a new theory of value

Recently, a groundbreaking new theory has been weaving these threads together. Drawing on quantum and information theories, Vuong and Nguyen [26, 27] suggest that economists need to move beyond the anthropocentric mindset and adopt a way of thinking that aligns with the reality provided by quantum physics. They start with a crucial observation: our greatest rationality is bounded by our senses, perceptions, lack of information (or knowledge), and various psychological biases that distort reality. Even when economic thinking is backed up by the most "impressive-looking mathematics," it can hardly make sense because those mathematical formulas are based on economists' assumptions, not the truth [26].

In quantum reality, everything is information, including the quanta (or atoms) that construct reality [28]. Each quantum carries its own information or possible alternatives, even if it does not have a mental state [26, 28]. Then, a physical system constituted by a set of quanta will have a set of information. As the world is a network of interactions between physical systems, it is also a network of reciprocal information between those systems [29]. This network reflects two key features of reality: all variable aspects of an object exist only in relation to other objects, and the future is not determined unequivocally by the past but only probabilistically [29,30].

This understanding leads to a crucial insight into living organisms: they exhibit properties that have enabled their survival, growth, and reproduction. The key to existing effectively in a changing environment is better managing correlations with the external world or information; this involves gathering, storing, transmitting, and processing information [26]. Similarly, humans, as living organisms, need to interact with the surrounding environment constantly.

Building on this idea, the authors propose a fundamental shift in how we conceive value itself, expressed in a new formula [26]:

$$NV = NMV + NEV$$

Where NV represents the new notion of value, NMV is the normal net monetary value, and NEV is the net environmental value. This is not merely an accounting adjustment–it represents a practical reimagining of value that puts environmental impact on equal footing with monetary gains.

Building an eco-surplus culture

To implement this new conception of value, Vuong and Nguyen suggest we need "eco-surplus culture"?defined as a set of pro-environmental attitudes, values, beliefs, and behaviors shared by a group of people in society to reduce negative anthropogenic impacts on the environment as well as conserve and restore nature [31-32]. The authors emphasize that the role of this culture is to shape the beliefs and value systems of people [33].

The transition to this culture requires several imperative approaches. Central to this effort is communicating the risks of climate change and demonstrating how restoration and conservation can safeguard humans from incoming crises. However, significant obstacles exist in the form of climate change denialism and apathy, which are rooted in a lack of information, outdated knowledge, conservative thinking, resistance to new information, and fear of economic and political repercussions [34,35]. To address these challenges, the authors call for more active participation of scientists, along with science communicators and media, to improve the clarity and credibility of information [26,36].

Beyond communication strategies, the authors stress the vital importance of restoring connections between humans, especially urban inhabitants, and nature [37]. This can be achieved through increasing urban green areas and biodiversity levels and utilizing modern technologies, including AI, to disseminate environmental information effectively [38]. They also emphasize the value of promoting role models for sustainable lifestyles [26]. Importantly, they argue that during this transitional process, society should avoid confrontational mindsets against businesses. Instead, they advocate for unity and cooperation between society and businesses, grounded in eco-surplus values that prioritize environmental sustainability for the well-being of the socio-cultural and economic systems [26].

While this cultural transformation presents significant challenges, the authors argue it is essential to implement the new value paradigm. Only through such a fundamental shift in cultural values and behaviors can we create economic systems that truly protect both human prosperity and planetary health [26,39].

Conclusion: evolving economics to save our planet

From the Physiocrats who saw value in nature's bounty, through labor theorists and market economists, to today's quantum-inspired perspectives, our understanding of value has continuously evolved. The interdisciplinary insights from physics, ecological science, information, and quantum theory now offer us a viable and practical path to transition to a

sustainable relationship with Earth–one that recognizes both monetary and environmental values as equal components of worth.

This won't be easy?400 years of growth-focused economic thinking is deeply ingrained in our socio-cultural systems. However, as we face destructive environmental crises, the need for new ways of understanding and measuring value becomes more urgent. The lightning bolt that began our story stands as both a warning and inspiration?a reminder of the profound value that exists beyond our current economic metrics and a symbol of the natural wisdom we must learn to recognize and preserve if we are to create an economic system that can sustain both human and planet health.

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