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Exploring the 'Entrepreneurial Entropy' Effect Based on Quantum Management Theory from the Perspective of Physics

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ABSTRACT: Quantum theory has profoundly transformed modern physics, offering new perspectives on the universe's fundamental structures. Extending these principles into the social sciences, quantum management theory provides an innovative framework for analyzing organizational dynamics. This study examines the interrelation of uncertainty, subject participation, and energy entanglement in enterprise management, thereby reconceptualizing traditional paradigms of organizational success.

By drawing on quantum phenomena such as the photoelectric effect and thermal radiation, the research redefines the concept of entrepreneurial entropy. Formerly grounded in classical thermodynamics, entropy is here reinterpreted through a quantum lens, establishing a novel analytical foundation for entrepreneurship. The findings contribute to the advancement of management and entrepreneurship studies by situating entrepreneurial processes within a quantum framework, offering fresh theoretical insights into organizational innovation and socio-economic development.

KEYWORDS: quantum management; photoelectric effect; energy conservation; entrepreneurial entropy; information energy particles

1. INTRODUCTION

The interplay between natural science and social science is fundamental to advancing our understanding of the world. While natural science seeks to uncover the universal principles governing existence, social science investigates the structures and dynamics of human societies. Their intersection provides a critical foundation for explaining the laws and processes that shape collective human experience.

The advent of quantum theory, introduced by Max Planck in 1900 through the concept of energy quanta and subsequently advanced by Albert Einstein's hypothesis of light quanta in the context of the photoelectric effect, marked a decisive break from classical Newtonian physics. Quantum mechanics has since become a cornerstone of modern science, offering a distinct epistemological lens through which to interpret the objective world.

Entrepreneurship, as a branch of social management science, holds the potential to construct novel paradigms by drawing inspiration from the philosophical principles of natural science. Yet, the application of quantum theory to management remains at a formative stage, largely confined to theoretical exploration. Notably, the intersection of quantum theory and entrepreneurial entropy has received limited scholarly attention.

This study seeks to address this gap by integrating insights from quantum physics—particularly the photoelectric effect and thermal radiation—with the classical thermodynamic concept of entropy. Through this synthesis, we aim to establish a new analytical foundation for entrepreneurial management. By combining quantum principles with entropy theory, the research investigates their implications for entrepreneurial behavior and organizational dynamics. Ultimately, the study advances the philosophical integration of natural and social sciences, offering a novel perspective on the emergent construct of entrepreneurial entropy.

2. LITERATURE REVIEW

Hahn and Knight (2021) argue that quantum theory encompasses diverse research domains, including quantum mechanics, quantum physics, and quantum informatics, all dedicated to the study of quantum phenomena. At its core, quantum theory elucidates the fundamental laws governing energy quanta within the microscopic material world. Reality itself is constituted by quantum fields that manifest as waves, which, under observation, collapse into particles (Leong, 2022; Murphy, 2021; Laszlo, 2020; Dyck & Greidanus, 2017). This phenomenon, known as wave–particle duality, demonstrates that before measurement, a photon behaves as a probability wave, yet upon observation, it assumes particle-like characteristics (Dyck & Greidanus, 2017).

In 1927, Heisenberg introduced the uncertainty principle, positing that measurement inevitably disturbs the quantum system, thereby rendering simultaneous precision in determining position and momentum unattainable. Heisenberg maintained that one could only examine one property at a time, as the act of measurement precludes exact knowledge of both. Building upon this, Bohr (1928) advanced the principle of complementarity, which asserts that quantum phenomena cannot be exhaustively described from a single perspective. Instead, complementary approaches are required, each revealing distinct facets of the phenomenon.

Quantum theory is increasingly recognized as a novel lens for interpreting social phenomena (Van Langenhove, 2020; Hahn & Knight, 2021; Lord et al., 2015). Zohar Danan (2016) argues that principles of physics can be seamlessly integrated into diverse disciplines, including management. Within this context, quantum physics inaugurates a new scientific era characterized by inclusivity, participation, and value realization. Building on this foundation, Ma Zhengli (2017) identifies four central concepts of quantum leadership: organizational integrity, leadership uncertainty, leadership wave–particle duality, and complementary inclusiveness. Cheng (2017) extends quantum thinking to organizational management systems, suggesting that enterprises guided by quantum principles may adopt flexible forms such as virtual organizations, boundaryless structures, and self-organizing entities.

Nevertheless, the application of quantum theory in management remains contingent upon situational factors, including industry characteristics, business models, market dynamics, employee knowledge structures, and enterprise nature (Xin, 2020). Beyond the organizational level, quantum theory promises to reshape broader societal structures and revolutionize corporate practices (Inglesant et al., 2021). Fan (2021) emphasizes that intangible assets—ideas, brands, relationships, capabilities, and management practices—align closely with quantum principles. Peng (2017) further advocates for quantum management thinking as a driver of continuous change, innovation, individual value realization, entrepreneurial spirit, and organizational energy.

Importantly, quantum methods demonstrate particular efficacy in analyzing unstable and sporadic systems, exemplified by innovation processes (Leong, 2022; Zhao, 2022; Ottosson & Björk, 2004; Ottosson, 2003). Innovation, as the propelling force of entrepreneurship, is frequently conceptualized as Innovation-Driven Entrepreneurship (IDE) by scholars such as Cai, Zhang, and Zahra (2021; 2023). This perspective underscores the potential of quantum theory to enrich entrepreneurship studies by offering a robust framework for understanding the dynamics of innovation and organizational transformation.

Rudolf Clausius first introduced the concept of entropy as a foundational principle of the second law of thermodynamics. Clausius argued that within an isolated system, molecular motion inevitably progresses from order to dispersion and disorder, with entropy increasing irreversibly along non-reversible processes (Zhang, 2011). Entropy thus represents the ineffective energy inherent in a system. Ludwig Boltzmann further advanced this notion, emphasizing that molecular motion in isolated systems transitions from concentrated order to chaotic dispersion. When entropy reaches its maximum, the system attains equilibrium—a state often described as "heat death."

In 1969, Prigogine extended the theory by introducing the concept of dissipative structures. He demonstrated that in open systems far from equilibrium, matter and energy exchange with the environment can reduce entropy through nonlinear interactions, thereby generating new ordered structures. Establishing such dissipative processes requires four conditions: openness, disequilibrium, nonlinearity, and fluctuations (Meng et al., 2019; Li, 2017). This perspective broadened entropy's relevance beyond physics, paving the way for its integration into sociology and management, as pioneered by Rifkin and Howard (1981).

Ren (2001) applied entropy theory to enterprise systems, positing those organizational processes—encompassing structures, policies, methods, culture, and technology—inevitably experience declining effective energy and rising ineffective energy. In this view, closed enterprise systems move inexorably from order to disorder (Meng et al., 2019). Li (2017), however, contends that effective management and human intervention can generate new effective energy, counteracting entropy growth.

Building on these insights, entropy has been extended into entrepreneurship studies. Chen (2020) was the first to introduce the concept of entrepreneurial entropy. More recently, Chen et al. (2024) refined the construct into six distinct dimensions: trait entropy, opportunity entropy, team entropy, resource entropy, strategy entropy, and innovation entropy. Together, these categories delineate the dynamic processes through which entrepreneurial entropy evolves, offering a comprehensive framework for analyzing the transformation of entrepreneurial systems

3. RESEARCH METHODS FROM THE PERSPECTIVE OF PHYSICS

3.1 Thermodynamic Theory: The Explanation of the "Entropy" Effect

The first law of thermodynamics establishes the principle of energy conservation, affirming that energy can neither be created nor destroyed, but only transformed from one form to another. In contrast, the second law of thermodynamics states that while heat may be transferred from a higher to a lower-energy state, a portion of the energy is inevitably dissipated during the transfer. Building upon these foundational principles of classical physics, Rudolf Clausius introduced the concept of thermodynamic entropy in 1865. Entropy, as formulated by Clausius, represents the measure of energy dispersion and the irreversible tendency of isolated systems to evolve from order toward disorder.

$$\Delta s = s - s_0 = \int_{p_0}^{p} \frac{dQ}{T} \qquad (1)$$

The change in entropy, denoted as ΔS, arises from the difference between the entropy value (S) representing the terminal state (P) and the entropy value (S_0) of the initial state (P_0). In this context:

T represents the absolute temperature.

Q represents the heat.

"Entropy" falls within the category of thermodynamics. It is a state function commonly encountered in various systems. The change in entropy can be expressed using the following formula:

$$\mathrm{d}S = \sum d_e S + \sum d_i S \qquad (2)$$

dS represents the total entropy in the system.

d_iS represents the entropy increase resulting from the resources consumed within the system.

d_eS represents the entropy decrease caused by energy input from the outside.

The formula can be further used to derive the entropy production rate in a specific unit:

$$\frac{dS}{dT} = \sum \frac{d_e S}{dT} + \sum \frac{d_i S}{dT} \qquad (3)$$

When the system resources remain constant, the following interpretations apply:

If $dS/dT > 0$， it indicates that entropy is increasing. In other words, the upward trend in entropy surpasses any decrease.

Conversely, if $dS/dT < 0$, entropy is decreasing. Here, the increase in entropy is less significant than the decrease.

$$\frac{dS}{dT} = \sum \frac{d_e S}{dT} + \sum \frac{d_i S}{dT} < 0$$
$$\left| \sum \frac{d_e S}{dT} \right| > \sum \frac{d_i S}{dT} \qquad (4)$$

The thermodynamic formulation of entropy provides critical insight into the behavior of energy in nature. Although the total quantity of energy remains constant, the proportion of energy available for effective work continually diminishes. For both individuals and aggregate systems, the inability to acquire effective energy from the external environment results in the gradual dissipation of internal energy. Ultimately, this trajectory culminates in the phenomenon of heat death, wherein entropy reaches its maximum and the system attains equilibrium.

To sustain vitality and avert this irreversible decline, systems must obtain effective negative entropy from external sources. Only when the inflow of external energy offsets the internal generation of entropy can the system maintain continuity and resilience. This principle underscores the necessity of openness and exchange in sustaining dynamic equilibrium, highlighting the broader implications of entropy theory for understanding organizational vitality, adaptive capacity, and long-term sustainability.

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3.2 Explanation of Quantum Theory via the Photoelectric Effect

In 1905, Albert Einstein conducted groundbreaking experiments on the photoelectric effect, revealing that light exhibits both wave-like and particle-like behavior. These properties are not mutually exclusive; rather, they complement each other. No single property can fully capture the characteristics of photons. When a light wave with a specific frequency strikes an object, its electrons become excited by the photons, leading to the generation of an electric current and the release of photoelectrons. The photoelectric effect provides a clearer understanding of the wave-particle duality inherent in photons.

As shown in the figure below:

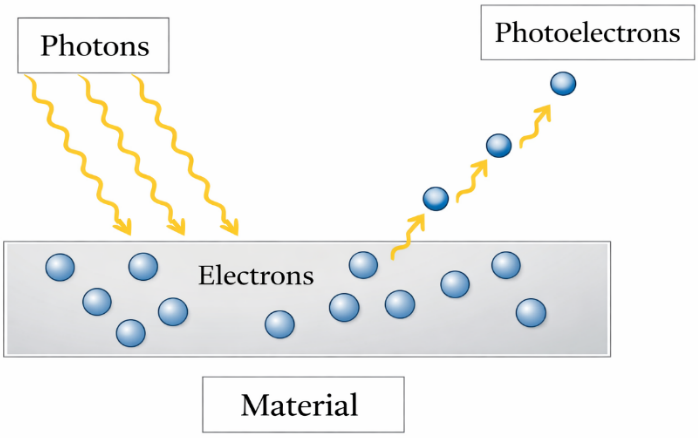

Figure 1. Simulation diagram of the photoelectric effect

According to quantum theory, the photoelectric effect can be understood as follows: Light consists of discrete particles called photons. When light irradiates an object, these photons are absorbed by electrons within the material. As a result, the electrons gain kinetic energy. If the absorbed kinetic energy is sufficient to overcome the gravitational force exerted by the nucleus, the electrons escape from the material's surface as photoelectrons. This process converts the absorbed energy into electrical energy. The photoelectric effect equation captures this phenomenon:

$$hv = E_k + W_0$$

$$E_k = \frac{1}{2} m v_{\max}^2 \qquad W_0 = h v_0$$

$$hv = \frac{1}{2} m v_{\max}^2 + h v_0 \tag{5}$$

In the context of the photoelectric effect equation, the following variables play crucial roles:

(hv) represents the energy of photon radiation.

(h) is Planck's constant.

(E k) denotes the energy of light particles.

(*W0*) corresponds to the work function required to overcome the object.

(*m*) represents the particle mass.

(*v*) stands for the oscillation frequency, which can be expressed as:

$$v = \frac{c}{\lambda} \tag{6}$$

Formula 6 reveals that the oscillation frequency of a particle is determined by dividing the speed of light (*c*) by the wavelength. Intuitively, we can understand that:

Longer wavelengths correspond to lower oscillation frequencies for particles, resulting in slower propagation speeds. Conversely, shorter wavelengths lead to higher oscillation frequencies and faster propagation speeds.

Now, shifting our focus to macroscopic objects, French physicist Coriolis proposed a kinetic energy formula applicable when the velocity (v) is much smaller than the speed of light (c). In this context, Coriolis found that both a larger object mass and a faster object speed contribute to an increase in kinetic energy. The kinetic energy equation is:

$$E_k = \frac{1}{2}mv^2 \tag{7}$$

In the context of kinetic energy, we have the following variables:

(E k) represents the kinetic energy of the object.

(m) represents the mass of the object.

(v) represents the velocity of the object.

Comparing this with formula (5), we observe that the existence of kinetic energy conversion applies consistently to both macroscopic objects and microscopic particles.

3.3 Research on the Integration of Quantum Theory and the "Entropy" Effect

Max Planck introduced the concept of thermal radiation, positing that it shares similarities with electromagnetic radiation in terms of energy changes. Notably, thermal radiation exhibits discontinuities in energy transfer. By analyzing these properties, researchers can explore the uncertainties and complementarity inherent in thermal radiation energy quanta, drawing insights from the photoelectric effect equation.

When we combine the characteristics of "thermal entropy" with quantum theory, a fascinating interplay emerges. Thermal radiation energy quanta interact with a system through the external environment, transmitting effective energy. However, part of this energy is consumed internally, forming ineffective kinetic energy. Simultaneously, other system particles convert initial kinetic energy from thermal energy into effective energy, resulting in a negative entropy effect.

For a visual representation, consider the thermal radiation effect simulation diagram:

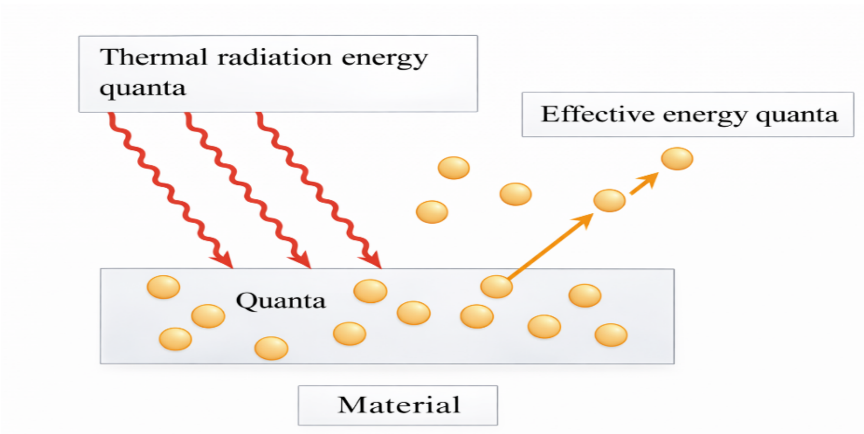

Figure 2. Simulation diagram of thermal radiation effect

From a physical perspective, thermal radiation energy exhibits two essential aspects: intensity and frequency. Intensity refers to the rate at which thermal radiation particles are emitted per second. It directly influences the number of effective thermal energy particles released. Higher intensity corresponds to a greater number of emitted particles; Frequency describes the energy associated with each thermal radiation particle. As per formula (6), shorter wavelengths result in higher initial energy for these particles. Specifically, shorter wavelengths lead to greater kinetic energy. By considering both intensity and frequency, we can derive the thermal radiation effect equation.

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$$\sum hv = \sum E_k + \sum W_0$$

$$\sum E_k = d_e S = \sum \frac{1}{2} mv^2_{\max} \quad \sum W_0 = \sum hv_0$$

$$\sum hv = \sum \frac{1}{2} mv^2_{mac} + \sum hv_0 \tag{8}$$

$$d_e S = \sum E_K = \sum \frac{mC^2}{2\lambda^2_{\max}} = \sum \frac{hC}{\lambda} - \sum \frac{hC}{\lambda_0} \tag{9}$$

In the context of thermal radiation, we consider three key components:

Total Kinetic Energy (Σ *hv*) of Particle Thermal Radiation: This represents the overall kinetic energy associated with the emitted thermal radiation particles.

Total Work Function (*W 0*): The work function accounts for the energy absorbed by the system. Specifically, it refers to the absorbed energy that does not directly impact the system.

Total Negative Entropy (d_eS) of Thermal Energy Electrons: The negentropy (d_eS) arises from the difference between the total energy of external thermal radiation and the absorbed work function. It quantifies the system's ability to harness effective energy from the external environment. By analyzing the above formula, we can draw the following conclusions:

The study of thermal radiation effects can be further extended to the law of conservation of thermal energy, and it is judged that the system's performance on radiation can be divided into three forms of conversion, respectively forming.

Reflection of Initial Kinetic Energy: Some particles reflect their initial kinetic energy, forming effective energy and contributing to negative entropy.

Ineffective Absorption of Energy: The system absorbs kinetic energy from particles but fails to generate useful kinetic energy.

Escape of Particles: Certain particles escape through the system, forming a diathermic body structure without contributing to kinetic energy.

These insights align with the law of conservation of thermal energy, which governs the overall behavior of thermal radiation within a system.

$$Q = Q_r + Q_a + Q_d \tag{10}$$

(Q) represents total Thermal Radiation Energy.

(Qr) represents total Initial Kinetic Energy

(Qa) represents total Ineffective Absorption of Energy

(Qd) represents total Escape of Particles

Consider a thermal radiation process where (n) thermal radiation particles enter a system. Among these particles, (k) particles are converted into initial kinetic energy. Particles from ($k+1$) to (m) are absorbed by the system. Particles from ($m+1$) to (n) transmit through the system. This behavior leads to the following formula:

$$Q = \sum_0^n hv = \sum_0^k \frac{1}{2} mv^2 + \sum_{k+1}^m hv_0 + \sum_{m+1}^n hv = d_e S + W_0 + Q_d \tag{11}$$

Thermal radiation simulation renderings are as follows:

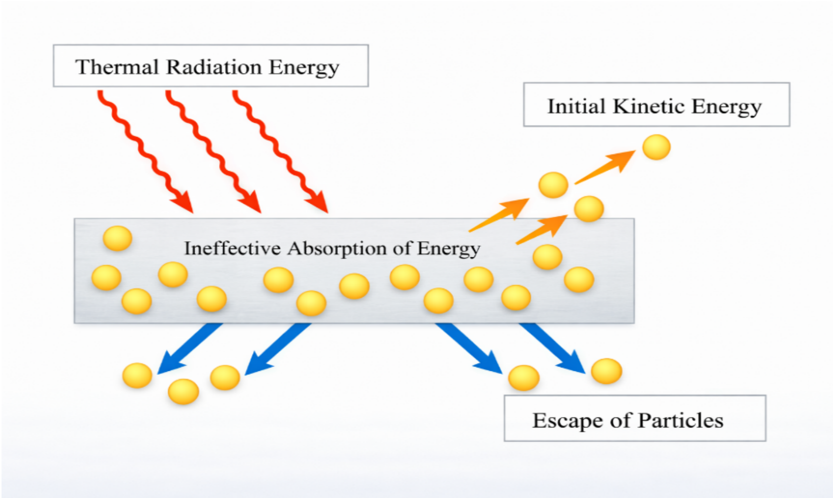

Figure 3. Simulation diagram of the thermal radiation effect with the transmission effect

By combining the photoelectric effect with the law of conservation of thermal energy, we can explore extreme conditions within a system during thermal radiation processes. Let's examine these scenarios:

Absolute Black Body: When the total thermal radiation value equals the total work function, the system absorbs all thermal radiation. This state is referred to as an "absolute black body."

Absolute White Body: If the total thermal radiation value matches the initial kinetic energy of reflection (resulting in negative entropy), we have an "absolute white body."

Heat-Transmitting Body (Transparent Body): When the total thermal radiation value equals the total transmitted energy, we encounter a heat-transmitting body or transparent body.

In various environments, the system may simultaneously exhibit these three distinct behaviors.

Driven by quantum theory research, we can analyze thermal radiation transfer phenomena from a quantum perspective, akin to other kinetic energy transfer processes. By leveraging the photoelectron conversion effect observed in the photoelectric effect theory, we can introduce the concept of "entropy" into quantum theory. Extending the photoelectric effect equation as the primary analytical formula for thermal radiation effects, we explore the feasibility of negentropy based on energy quanta. Ultimately, our goal is to derive an "entropy" effect consistent with the second law of thermodynamics.

4. THE DISCUSSION ON EXPLORING "ENTREPRENEURIAL ENTROPY" THROUGH QUANTUM THEORY

When we extend the application of quantum theory to the field of management and combine it with the concept of "entropy," we open up a new avenue of research: the study of "Entrepreneurial Entropy." In this framework, we focus on entrepreneurial phenomena using quantum theory as our lens.

4.1 The Influence of Information Energy Particles on "Entrepreneurial Entropy"

While physical particles in the natural sciences may not directly translate into entrepreneurial practice, meaningful parallels can nonetheless be drawn between the two domains. In this study, energy entropy is not conceived as a tangible resource, such as assets, currency, or equipment, that sustains entrepreneurial activity. Rather, we conceptualize entrepreneurial entropy as a non-material construct rooted in the dynamics of information flow.

In this context, negentropy—the antithesis of entropy—represents intangible outputs including information, spirit, knowledge, personality, and consciousness. These immaterial forms function as effective energy within entrepreneurial systems, manifesting as information-based, spiritual, and knowledge-based energy.

Drawing inspiration from quantum theory, we analogize the mass of particles to the load of information energy quanta in entrepreneurship, while the oscillation frequency of particles corresponds to the reaction frequency of information energy quanta. Although these entities lack physical substance, their granular and wave-like frequency variations resonate with the principle of wave–particle duality, a cornerstone of quantum mechanics. Collectively, we designate these immaterial constructs as dematerialized information energy particles, thereby establishing a novel theoretical framework for interpreting the energetic foundations of entrepreneurial behavior.

When considering information energy particles within the framework of quantum theory, meaningful parallels can be drawn with photons. These particles embody the dual characteristics of uncertainty and complementarity, both of which are central to quantum mechanics. Extending this analogy to the theory of entrepreneurial entropy, we posit that entrepreneurial organizations acquire effective information energy particles from the external environment.

Such inflows manifest as information with negative entropy properties, thereby enhancing organizational vitality. The process involves non-linear radiation into the entrepreneurial system, generating two distinct outcomes: (1) initial kinetic energy—representing effective energy that drives innovation and growth, and (2) absorbed energy—representing ineffective energy that contributes to entropy increase within the system. The dynamic interplay between these energies illustrates how entrepreneurial organizations simultaneously harness external information for advancement while contending with inevitable systemic losses.

This conceptualization underscores the dual nature of information energy in entrepreneurship: it is both a catalyst for organizational innovation and a source of entropy accumulation. By situating entrepreneurial entropy within the broader quantum framework, the study advances a novel theoretical model that integrates principles of uncertainty, complementarity, and non-linear radiation into the analysis of entrepreneurial behavior.

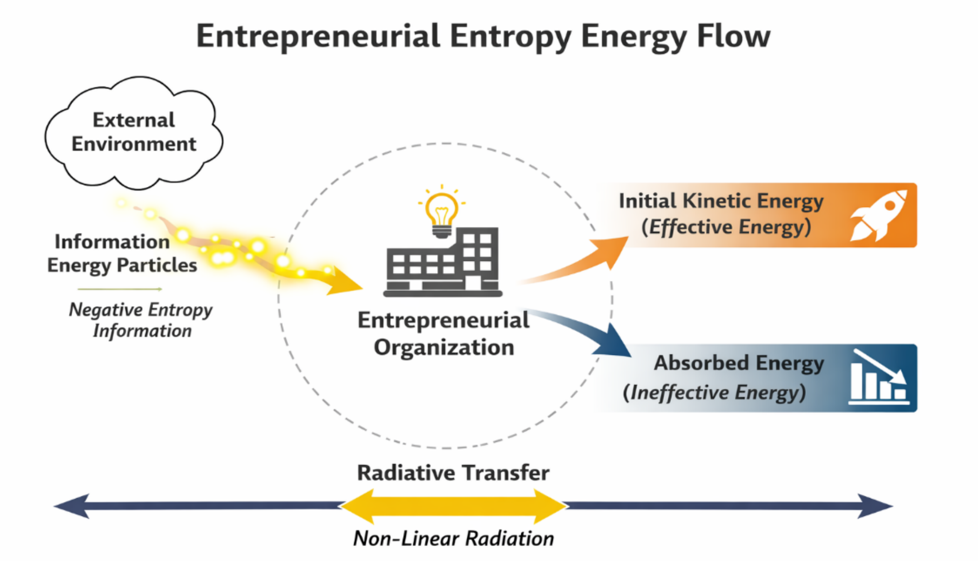

Figure 4. Entrepreneurial Entropy Energy Flow

Suppose we attribute quantum properties to information energy particles. In that case, the organization's formula for negative entropy value energy, as derived from formula (8), can be expressed as follows:

$$d_e S = \sum E = \sum \frac{1}{2} m v_{\max}^2 \tag{12}$$

The formula shows that the magnitude of "negative entropy" energy is directly related to two factors: the load (m) of information-energy particles and their reaction frequency (velocity) (v). This represents the effective energy entering the organization from the external environment. Let's break down the determinants of "negative entropy" energy:

The total amount of information energy particles

Unit load of information energy particles

Reflection frequency (velocity) of information energy particles

Assuming a consistent unit load for information energy particles, the energy of an individual particle hinges on its information response frequency. By applying formulas (8) and (9), we can derive the equation for information response frequency.

$$V_{\max} = \sqrt{\frac{2 \times h \times (V - V_0)}{m}}$$

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Assuming "*K*" is set to a constant, formula (13) below:

$$K = \sqrt{\frac{2 \times h}{m}}$$

$$V_{\max} = K \times \sqrt{V - V_0} \qquad (13)$$

Based on the equation provided, the initial kinetic energy coordinate resulting from establishing the information reaction frequency can be expressed as follows:

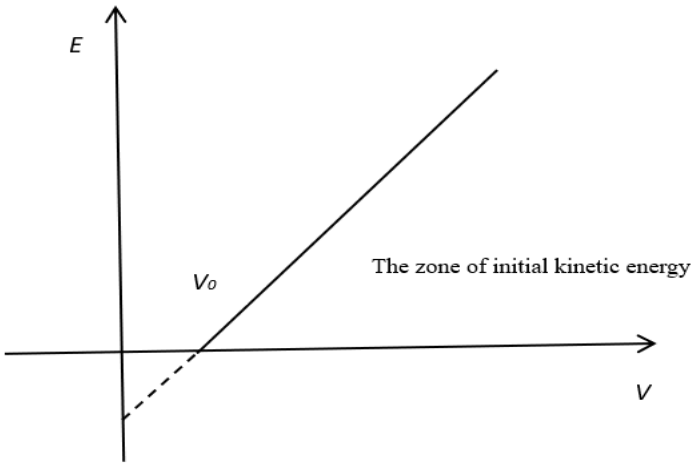

Figure 5. Coordinate diagram of the initial kinetic energy formed by the information response

From the formula and coordinate axes above, we can draw the following conclusions under the assumption of a fixed unit load of information energy particles. When the reflection frequency of external energy particles is higher, and the reflection frequency of absorbed ineffective energy particles is lower (i.e., (*V* > *V0*)), the initial kinetic energy of negative entropic kinetic energy becomes greater. If the reflection frequencies of external energy particles and absorbed invalid energy particles are the same (i.e., (*V* = *V0*)), no negative entropic kinetic energy is generated. From a physical perspective, it is impossible for (*V0* > *V*) to occur. According to formula (13), negentropic kinetic energy cannot be negative.

From this quantum-theoretic perspective, let's explore the effects of information-energy particles on "entrepreneurial entropy".

If a startup company acquires more effective energy particles from external sources and minimizes the absorption of ineffective energy, the company's negative entropic kinetic energy will be higher. Conversely, if the startup company obtains less effective energy from external sources, resulting in greater absorption of ineffective energy, the negative entropic kinetic energy obtained by the enterprise will be lower.

If the unit load carried by external information energy particles is larger, the negative entropic kinetic energy of the same number of particles becomes stronger. Similarly, when the reflection frequency of external information energy particles is faster, the negative entropic kinetic energy of these particles increases. Conversely, smaller unit information loads and lower reflection frequencies result in weaker negative entropic energy. When (*V* > *V0*), the entrepreneurial process must maintain characteristics far from equilibrium. As (*V*) approaches (*V0*), the likelihood of forming equilibrium state characteristics increases. Given a fixed unit load, the initial kinetic energy value depends on the relationship between (*V*) and (*V0*). Entrepreneurs can establish innovative open platforms (such as virtual organizations, boundaryless organizations, and self-organization) to avoid equilibrium. By increasing the reaction speed of the entrepreneurial process, rapid reflection frequencies of information energy particles lead to the establishment of a "negative entropy" state.

4.2 The Nonlinear Expression of the Prandtl Constant in Entrepreneurial Entropy

Within the context of the photoelectric conversion equation, Planck's constant (h) serves as a fundamental physical constant. It describes the essential features of energy quanta. By accounting for variations in particle momentum and displacement, it vividly captures the inherent uncertainty associated with energy quanta in quantum theory. This principle can be succinctly expressed as:

$$\Delta x \Delta p \geq \frac{h}{4\pi} \qquad (14)$$

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From a physical perspective, the Planck constant formula can be understood as follows: If we precisely know the position of a particle through observation, interference occurs when another particle with a shorter wavelength interacts, but the particle's speed remains uncertain. Conversely, if we know the precise position of a particle, interference from another particle with a longer wavelength affects its velocity, but the exact position of that particle remains unknown. This inherent characteristic of particles aligns with the uncertainty principle in quantum theory.

Let's connect this concept to "entrepreneurial entropy." Prandtl's constant reflects that the "entropy" energy obtained by startups follows a nonlinear acquisition pattern, validating the uncertainty inherent among information energy particles. Different energy subunits may exhibit varying entanglements and influences. In the entrepreneurial process, enterprises can establish diverse innovative elements through complex adaptations and fluctuations. By utilizing a variety of innovative approaches, organizations can create open platforms that gradually shape clear entrepreneurial goals through evolving methods and management practices. The principle of bottom-up complementarity ensures that entrepreneurial competitiveness is consistently maintained.

4.3 The Influence of Information Energy Quanta's Directionality on "Entrepreneurial Entropy"

In traditional physics research, energy and quality lack inherent directionality. However, in management studies, entrepreneurial success or failure often hinges on strategic directions. Therefore, it's worth exploring a potential relationship between energy and directionality. Let's delve into this scenario. If the external effective energy does not align with the correct entrepreneurial direction of the enterprise, even high external initial momentum won't prevent failure. Research aims to verify and explain this phenomenon using the lens of quantum theory. Hypothetically, if external information energy particles move in the opposite direction to the enterprise's correct energy, we encounter:

$$d_eS = h\times(-V) - h\times V_0 = -h\times(V+V_0)$$

$$d_eS = \sum \frac{1}{2}mV^2 = \left|-h\times(V+V_0)\right| = h\times(V+V_0) \tag{15}$$

$$V_{\max} = \sqrt{\frac{2\times h\times|V+V_0|}{m}}$$

$$K = \sqrt{\frac{2\times h}{m}}$$

$$V_{\max} = K\times\sqrt{|V+V_0|} \tag{16}$$

Based on the equation provided, establishing the negative information reaction frequency can be expressed as follows

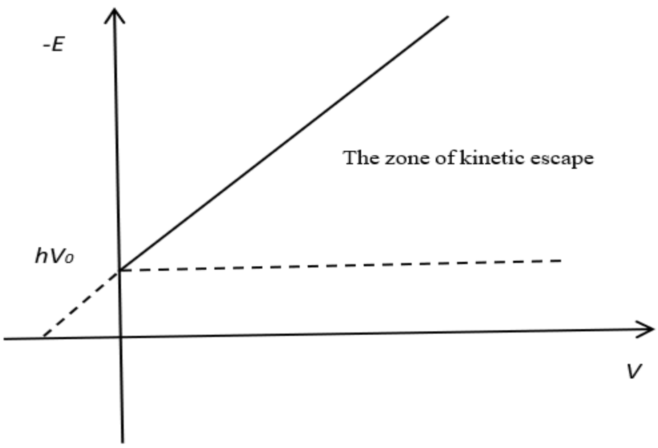

Figure 6. Coordinate diagram of the negative information response

While this type of reasoning may not directly apply to the photoelectric effect or thermal radiation, it holds relevance from a management perspective. Imagine that information energy particles from external radiation exhibit characteristics opposite to the development direction of the enterprise. These particles represent external information energy. Specifically, these particles move counter to the energy demand inherent in entrepreneurship. Assuming that the enterprise's energy demand aligns with the incorrect direction, the negative impact of these opposite energy particles accumulates without mutual offset. This cumulative effect can be expressed mathematically as *(-h(V + V0))*.

For entrepreneurship, if the entrepreneurial process acquires more opposite effective initial kinetic energy from external sources, the enterprise gains additional kinetic energy for escaping. The escape energy is the sum of (*hV*) and (*hV0*). Consequently, the "entropy" value of the enterprise increases cumulatively.

Higher internal information response frequency and load translate to improved work efficiency and stronger work ability within the enterprise. However, if the enterprise is influenced by stronger external kinetic energy in the opposite direction, it may accumulate energy in the wrong direction. Consequently, the escape speed of energy in the correct direction accelerates. In practical entrepreneurship, even if the company exhibits high work efficiency and strong personnel abilities, deviation from the correct strategic direction can lead to cumulative destruction.

By comparing formulas (13) and (15,16), we observe that under the same energy, Negative information energy particles from the external environment exhibit a much higher cumulative destruction capability for the enterprise *(-h(V + V0))*. This reflects a rapidly advancing destructive condition. In contrast, the cumulative formation capability of positive information energy particles *(h(V - V0))* is less impactful.

4.4 Examining the diverse outcomes of energy conversion in information particles within the context of entrepreneurship

In the realm of physics, thermal energy adheres to the principles of energy conservation. By extending the thermal energy conservation law (as expressed in Formula 10), we can delve deeper into the thermal radiation equation. These thermal radiation particles exhibit diverse energy conversion effects when interacting with various object media. Specifically, we observe three distinct types of energy: reflected initial kinetic energy, absorbed work function, and penetrating thermal radiation energy. These components combine proportionally to yield the following formula.

$$\frac{Q_r}{Q}+\frac{Q_a}{Q}+\frac{Q_d}{Q}=1$$

$$\frac{\sum_{0}^{k}\frac{1}{2}mV_{\max}^{2}}{\sum_{0}^{n}hV}+\frac{\sum_{k+1}^{m}hV_0}{\sum_{0}^{n}hV}+\frac{\sum_{m+1}^{n}hV}{\sum_{0}^{n}hV}=r+a+d=1 \tag{17}$$

In the context of energy conversion, where reflectivity (denoted as '*r*') represents the proportion of energy particles converted into initial kinetic energy, absorptivity (denoted as '*a*') signifies the fraction of energy particles transformed into absorbed work function, and transmittance (denoted as '*d*') indicates the proportion of energy particles passing through the system and radiating outward.

White Body State (k=n, r=1): In this scenario, all energy particles from external sources convert entirely into initial kinetic energy. The system achieves the highest level of 'negative entropy,' akin to an absolute white body state.

Black Body State ((m-k) =n, a=1): When all energy particles radiated from the outside transform solely into absorbed work function, the system does not gain any 'negative entropy.' This situation corresponds to an absolute black body state.

Transparent State ((n-m) =n, d=1): Here, all energy particles radiated from external sources pass through the system and continue to radiate outward. The system remains devoid of 'negative entropy,' forming an absolutely transparent state.

By applying these conclusions to the field of 'entrepreneurial entropy,' we can anticipate distinct entrepreneurial conversion effects in the future, summarized as the following three situations.

Entrepreneurial Optimization and Negative Entropy Within the entrepreneurial process, founders seeking to harness greater *negative entropy* from the external environment must adopt a *dissipative structure*—a self-organizing system capable of continuous optimization and adaptation. This structure aspires toward the idealized *absolute white body state*, wherein the organization achieves maximal efficiency in energy conversion. Establishing a management model characterized by *uncertainty* and *complementarity* is essential for sustaining dynamic equilibrium. To enhance conversion efficiency, entrepreneurs should minimize the prevalence of *black body* and *transparent body* organizational states. By maximizing the transformation of external radiation particles into initial kinetic energy (approaching r≈1) while reducing absorptivity (a) and transmittance (d), enterprises can evolve toward an orderly and resilient *white body* configuration.

Challenges of Black and Transparent Organizational States Entrepreneurial organizations operating under *black body* or *transparent body* conditions face significant barriers to generating effective *negative entropy*. These states are typified by limited technological and managerial innovation, conservative inertia, and resistance to adaptive change. Consequently, essential information momentum—embodied in innovation, learning, and non-linear management—fails to penetrate the organizational boundary. Such enterprises function as quasi-isolated systems, perpetuating entropy accumulation and ultimately succumbing to decline or failure.

Striving for White Body Attributes In practice, entrepreneurial systems exhibit three distinct modes of energy conversion, each with varying proportions. Sustainable enterprises must orient themselves toward the *white body* state while mitigating the effects of the *black* and *transparent* states. Operating within open and interactive environments enables entrepreneurs to maximize the inflow of effective *negative entropy* through innovation-driven activities. The three modes of energy transformation within entrepreneurial organizations are illustrated in the figure below, depicting the continuum from disorder to dynamic equilibrium.

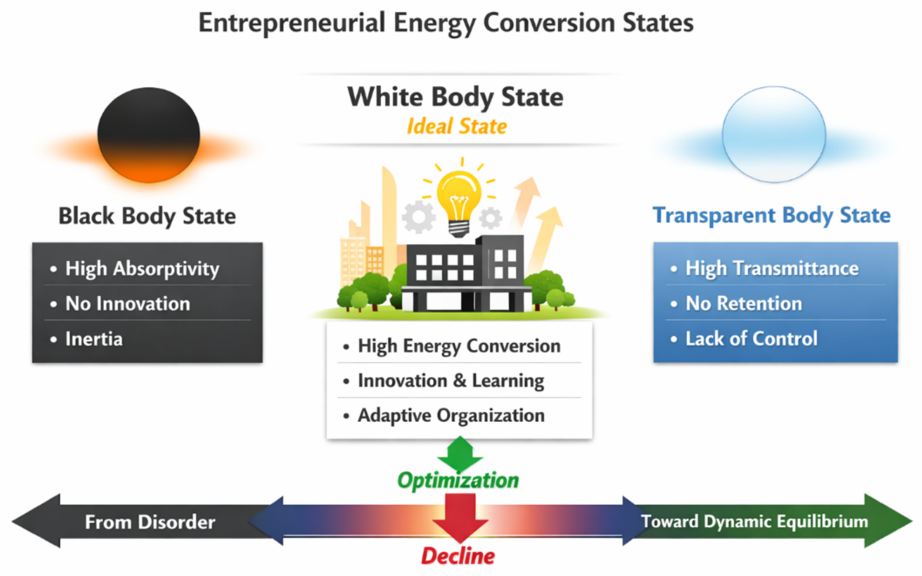

Figure 7. Entrepreneurial Energy Conversion States

5. ANALYSIS AND CONCLUSION

This paper begins with quantum theory as its fundamental premise, exploring how to effectively cultivate the "negative entropy" effect within the entrepreneurial context. By integrating principles from both physics and entrepreneurship, the following discussions unfold:

1. Quantum theory can establish new research directions in entrepreneurship.

   Physics and management can intersect seamlessly (Zohar, 2016). Quantum theory, when viewed from the microenvironment perspective, sheds light on the natural world by examining energy bodies represented as energy quanta. The principles of uncertainty and complementarity within quantum theory offer novel insights for management. Quantum theory underscores the prevalence of changes and fluctuations in entrepreneurial contexts. The effectiveness of entrepreneurship hinges on continuous validation amid these shifts, resulting in an orderly process of adaptation. Entrepreneurship's management characteristics include non-equilibrium states, openness, synergy, complementarity, non-linearity, and dynamic fluctuations. These elements collectively contribute to the process of entrepreneurial success, where constant adaptation and interplay foster growth. Quantum theory's complementary attributes align with concepts from self-organization theory, synergy theory, hypercycle theory, boundaryless organization theory, dissipation theory, and chaos theory—all rooted in innovation. Through correlation and complementation, these characteristics give rise to fresh cognitive processes in the entrepreneurial realm.

2. Quantum Properties of Information Energy Particles.

   By leveraging formulas (5) and (8), the photoelectric effect equation from quantum theory extends into thermodynamics, resulting in a non-continuous thermal radiation effect equation. This extension confirms that thermal radiation also exhibits wave-particle duality. In our research, we attribute intangible resources—such as information, spirit, and knowledge in social sciences—to energy. This unique form of kinetic energy shares wave-particle characteristics akin to photoelectric particles in physics. It serves as a bridge between organizations and the external world. We introduce the concept of "information energy particles" in communication, learning, and knowledge exchange. Through these particles, external innovation technology and innovation management facilitate effective kinetic energy transfer. This, in turn, enhances the “negative entropy” effect within the entrepreneurial process, fostering a scientifically sound and healthy entrepreneurial journey.

3. The concept of the ‘negative entropy’ effect hinges on external information energy particles, unit core load, and reaction frequency.

   By reasoning and analyzing formulas (8) and (13), this study bridges quantum theory with the ‘entropy effect’ within the entrepreneurial domain. Entrepreneurial Development and Effective Kinetic Energy: Entrepreneurs aiming for rapid development can leverage the perspective of ‘entropy’—also known as ‘negative entropy.’ To achieve successful entrepreneurial outcomes, organizations must first establish a borderless open platform, allowing them to acquire more information energy particles from the external world. Additionally, the richer the unit information core load carried by these particles, the greater their informational value. Consequently, the company accumulates more ‘negative entropy.’ The effect of ‘negative entropy’ also manifests in the reaction frequency of information energy particles. Longer particle fluctuation periods and lower transmission frequencies result in lower initial kinetic energy during information transmission. Conversely, enterprises actively pursuing rapid updates and changes in effective external information during the entrepreneurial stage enhance the initial kinetic energy of information energy particle transmission. This proactive approach contributes to the formation of a ‘negative entropy’ enhancement effect.

4. Planck's constant determines the uncertainty and complementarity characteristics of quantum theory.

   Quantum theory permeates our understanding from micro to macro levels in entrepreneurial management. In the entrepreneurial process, embracing the uncertainty inherent in quantum theory is essential. Entrepreneurs can maximize this characteristic by adopting modes of openness, nonlinearity, diversity, and correlation. Borderless management, non-structural cooperation, and multi-channel development methods align with the complementary features of quantum theory, fostering open, flexible, and diverse entrepreneurial activities. Planck's constant, emphasizing uncertainty and complementarity, plays a pivotal role. Entrepreneurs must drive healthy organizational development through continuous innovation. Organic decentralized management replaces rigid "either-or" thinking prevalent in traditional management (Ma, 2017). By establishing inclusiveness, organizations create a positive synergy—shared opportunities, joint decision-making, shared responsibilities, and collaborative participation—across multiple pathways within the entrepreneurial process.

5. Reducing Work Function in Entrepreneurship.

   Based on the reasoning and analysis of formula (9), when an organization absorbs effective energy from the external environment, certain information energy particles may fail to generate a “negative entropy” effect due to the organization’s inertia. This phenomenon becomes evident in the persistence of the organization’s outdated business model and established state. The stronger the organization’s absorption capacity, the greater the risk that external information energy particles remain trapped within the system’s habitual gravity, unable to escape and contribute to “negative entropy.” During the entrepreneurial stage, if the organization's existing work model, mindset, structure, processes, and culture exhibit strong inertial attraction toward the old state, any new kinetic energy introduced by external information particles is likely to be absorbed by this force. Further analysis reveals that when the frequency and wavelength of the new kinetic energy align with the fluctuations of the old state, their mutual attraction intensifies. This alignment can lead to a "heat death phenomenon," where the organization struggles to form "negative entropy" kinetic energy due to an excessively high work function. Consequently, entrepreneurial ventures face survival challenges. To address this, organizations can introduce a quantum management model. By embracing flexibility, openness, and diversified innovations, they can impact the old model with high loads, shocks, and kinetic energy. This approach effectively reduces the allure of the old state, minimizes entrapment, and fosters the generation of high "negative entropy" kinetic energy.

6. The distinction between external effective energy and internally absorbed energy plays a pivotal role in determining the ‘negative entropy’ state within entrepreneurship.

   Drawing upon the reasoning results from formula (13), we can apply principles from wave-particle duality theory and thermal radiation theory in quantum physics to the entrepreneurial context. When external informational energy particles exhibit high numbers, substantial load, and elevated frequency, their emission kinetic energy increases. Consequently, the allure of the company’s existing state diminishes, offsetting external kinetic energy. This dynamic strengthens the ‘negative entropy’ formed by external influences. For entrepreneurial organizations, obtaining more information from the external world enhances information efficiency. Faster information updates and a wider gap between internal and external information levels create room for development and progress. This state, akin to a ‘negative entropy’ condition, allows organizations to thrive. Entrepreneurs should establish learning organizations, address weaknesses, and employ non-linear methods to accelerate the attraction of new external information, innovative thinking, and novel models. By avoiding overly linear alignment between internal and external environmental information, organizations can foster future development.

7. External information momentum that deviates from the intended direction can accelerate the escape of entrepreneurial 'negative entropy.' Based on the reasoning and analysis of formulas (15) and (16), consider the following: When external information momentum significantly impacts entrepreneurship in the wrong direction, the organization experiences accelerated 'negative entropy' escape. This negentropic escape velocity ($V+V_0$) surpasses the rate of external normalized kinetic energy increase in 'negative entropy' formation ($V-V_0$). Consequently, detrimental external information factors hinder the organization's development along the correct path, leading to an eventual equilibrium state akin to heat death. The effect is more pronounced in highly effective and efficient organizations. For instance, if a proficient entrepreneurial organization strays from its strategic course due to external influences, its lifespan may be shorter than that of an inefficient counterpart facing similar circumstances. Information energy particles exhibiting incorrect directions pose greater harm to entrepreneurship. The stronger the reversal ability of external particles, the faster the organization's 'negative entropy' escapes. When confronted with impactful information energy particles opposing the desired direction, organizations should fortify their internal work function. By absorbing and mitigating adverse external effects, they can reduce the 'negative entropy' escape velocity.
8. Entrepreneurs should strive to establish organizational structures that tend toward a 'white body state.' Based on the derivations from formulas (11) and (17), this study delves into the organizational characteristics within entrepreneurship. Three transformational trends may emerge during the energy exchange process between entrepreneurial organizations and the external world. These trends can be categorized as follows: (1). Black-Body Organizations: Black-body organizations exhibit strong inertia and attraction to their existing state. External forces struggle to induce significant changes. All effective external energy is either neutralized or absorbed by the organization's inherent inertia, rendering the external environment ineffective in influencing the organization. (2). White-Body Organizations: White-body organizations represent a dynamic and flexible state. They lack fixed inertia and rigidity. Tolerance and complementarity define their characteristics. These organizations readily introduce and harness kinetic energy from the external environment. (3). Transparent Organizations: Transparent organizations face limitations in capabilities and resources. They cannot comprehend, understand, or absorb kinetic energy from the external environment. Consequently, they cannot convert external energy into 'negative entropy' or neutralize it." In the context of external energy exchange, a significant disparity between external information energy and an organization's internal information energy can create challenges. Often, valuable external information goes unnoticed by inefficient managers, hindering the application of advanced technology and management capabilities within the organization. However, entrepreneurial organizations can enhance their development potential and achieve a 'negative entropy' effect by transforming themselves into a flexible and adaptable 'white body state.' This transformation allows them to effectively absorb positive energy from external sources.

6. RESEARCH SUMMARY AND CONTRIBUTIONS

This study synthesizes insights at the intersection of entrepreneurship and quantum theory, with particular emphasis on the concept of entropy. By introducing the notion of information energy *particles*, the research explores pathways for cultivating the negative entropy effect within enterprises and underscores its essential role in sustaining organizational vitality. Drawing upon thermal radiation theory and energy conservation principles, the study analyzes the trajectory of external information energy particles and their differentiated impact on entrepreneurial entropy during the entrepreneurial process.

The primary contribution of this research lies in applying quantum theory to entrepreneurship. It offers an in-depth examination of the formation and dynamics of entrepreneurial entropy from a quantum perspective. By conceptualizing information energy particles and extending the definition of particles beyond the physical sciences, the study leverages the principle of wave–particle duality to enrich entrepreneurial management theory. Through detailed analysis, the research advocates for a paradigm shift in entrepreneurial management grounded in quantum principles. By embracing uncertainty and complementarity as foundational attributes, entrepreneurs are encouraged to adopt self-organizing structures, decentralized management, and flexible approaches. Departing from rigid hierarchies and linear management methods enables organizations to accelerate their progression toward maximizing *negentropy*—a critical determinant of entrepreneurial success.

7. RESEARCH LIMITATIONS AND AREAS FOR IMPROVEMENT

Differing from conventional studies, this research is positioned as exploratory, drawing upon quantum theory from physics and thermodynamic entropy theory to bridge natural science with social science, thereby applying its conclusions to entrepreneurship. While the study demonstrates innovative potential and extends theoretical boundaries, several research gaps and limitations remain:

1. The study introduces the concept of information energy particles as a novel form of existence. However, this construct remains abstract, and academic theoretical support for its manifestation as external energy particles is limited.
2. The rational justification for the existence of information energy particles requires further scrutiny. Future research should aim to define and quantify these intangible entities to establish a more rigorous theoretical and empirical foundation.
3. The study of entrepreneurial entropy is situated within the broader domain of management entropy. Yet, this field remains in its early stages, with notable gaps in theoretical depth and empirical validation. The limited scope of the literature review constrains the reliability and validity of the study's conclusions.
4. The research applies the quantum characteristics of uncertainty and complementarity to entrepreneurship, seeking to maximize organizational *negative entropy*. However, the analysis emphasizes primarily the positive implications of these attributes, without addressing potential adverse effects. Future studies should examine these negative dimensions to provide a balanced perspective.
5. The investigation focuses on the influence of intangible information energy particles on entrepreneurial entropy, while overlooking the role of tangible assets—both internal and external—in shaping entropy dynamics. Incorporating material dimensions into future research would yield a more comprehensive understanding of entrepreneurial entropy mechanisms.

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