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The thermodynamic driving force in entrepreneurship

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A R T I C L E I N F O

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A B S T R A C T

This study explores the thermodynamic underpinnings of venture creation, providing a fresh perspective on entrepreneurship, especially impulsive, non-deliberative actions in seizing opportunities. Thermodynamics clarifies various natural processes and offers insights into entrepreneurial behaviour. Entrepreneurs, driven by profit potential, often take risks under uncertainty. The paper proposes a thermodynamics-based conceptual model, akin to the Bénard cell, to understand how impulsivity influences entrepreneurial decisions amidst rising entropy. It suggests that even minor impulsive actions can significantly affect a venture's success, integrating nonrational behaviour into entrepreneurial theories.

1. Introduction

There is a driving force "moving beyond the intendedly-rational logics of entrepreneurship" (Lerner et al., 2018, p. 52). This paper posits that the principles of the second law of thermodynamics and the concept of entropy apply to entrepreneurship, suggesting that the impetus behind entrepreneurial initiatives may be analogous to thermodynamic processes.

Pross (2003) described thermodynamics as "the science of the possible" (p. 404). Inherent in this science is the second law of thermodynamics, often called the entropy law, which states that isolated systems evolve towards a state of maximum disorder (Schneider & Kay, 1994). The enigma that arises is reconciling the inherent tendency of entrepreneurship towards self-organised endogenous stability with the thermodynamic progression towards increased disorder (Vogel, 1989). This paradox is addressed through Schrödinger's principle of 'order from disorder' (Schneider & Kay, 2010), providing a conceptual bridge between the two seemingly disparate processes.

This research asserts that ventures essentially create endogenous order from the exogenous disorder, paralleling the initial phase of structure formation—start-up nucleation—to the successive stages of venture growth. Thriving in chaos and uncertainty involves coming into order from the self-organisation of dissipative structures to capture profits. "The concept of dissipative structures, from the field of complexity theory, is used to develop and explain a specific sequence of activities which underpin effective transformation" (Macintosh & Maclean, 1999: 297).

This research encompasses the identification, creation, and exploitation of opportunities and the role of entrepreneurs in these processes. Entrepreneurs navigate through an environment characterised by chaos (Mason, 2006), deploying mechanisms and structures to generate profit while striving for a state of thermodynamic equilibrium internally despite the external turbulence. This paper explains the thermodynamic driving forces in entrepreneurship, examining the foundational concepts of thermodynamics and their application to entrepreneurial phenomena. The paper presents an alternative theoretical framework predicated on thermodynamic forces to clarify Lerner et al.'s (2017) non-deliberative, nonrational dynamics prevalent in entrepreneurial actions. A "growing body of research shows that unreasoned drivers (e.g., disinhibition, impulsivity) are non-ignorable facets of human activity that are equally indispensable to a predictive framework for entrepreneurial action" (van Lent et al., 2020, p. 4). The discussion extends to impulsivity and non-deliberative entrepreneurial responses to opportunities within the thermodynamic context. The extant academic discourse on intuition and impulsivity in entrepreneurship does not fully consider the underlying forces and motivations. This paper posits that thermodynamic forces can provide novel insights and enhance our understanding of entrepreneurial behaviour, which, while fundamentally rational, may initially involve nonrational, non-deliberative responses to perceived opportunities. These behaviours are refined into deliberate strategies (McMullen & Shepherd, 2006). Hill (1938) emphasises the transformation of intangible impulses into tangible economic outcomes through imaginative and synthetic planning.

The development of this paper is thus grounded in the

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interdisciplinary application of these theories to entrepreneurship, proposing a novel approach to understanding the dynamics at play. The paper's impact lies in its potential to advance theoretical discussions, stimulate further research inquiries, and inspire new methodologies for examining entrepreneurial behaviour and success. It aims to contribute to the academic discourse by providing a fresh lens through which the entrepreneurial process can be viewed, particularly concerning the aspects of impulsivity (Pietersen & Botha, 2021; Wiklund et al., 2018) and intuition (Ramoglou, 2013).

2. Literature review

2.1. Thermodynamic perspectives

In business venturing, entrepreneurs universally share a common vision – growth, prosperity, and profit, as Kirzner (1980) noted. The entrepreneurial spirit is a pursuit of self-organisation and the strategic assembly of external resources aimed at expansion and financial success. This paper investigates self-organisation within complex systems through the lens of thermodynamics, focusing on the second law.

Thermodynamics lays out fundamental laws that govern energy transformations and transitions between different states of matter (Ortega & Braun, 2013). The second law of Thermodynamics states that the total entropy of an isolated system can never decrease over time (Gell-Mann & Lloyd, 1996). Entropy measures disorder or randomness in a system (Pross, 2003). The second law suggests that natural processes move towards greater disorder or entropy if not acted upon by an external force or energy (Lavenda et al., 1995).

In the context of business venturing, the second law of Thermodynamics and the concept of entropy can be metaphorically applied to understand the dynamics of entrepreneurial activities:

1. Entropy and Disorderliness: In business, entropy could be likened to the uncertainty, complexity, and disorder that entrepreneurs face in the market. This includes unpredictable consumer behaviour, rapidly changing market conditions and the inherent risk and uncertainty of starting and growing a business.
2. Second Law of Thermodynamics: When the second law of thermodynamics is applied metaphorically, it suggests that without any intervention, a business, like any other system, would tend to disorder. This could manifest as inefficiencies, market share loss, or even business failure. However, as in thermodynamic systems where energy is input to create order and structure (decreasing entropy locally even as the overall entropy of the universe increases), in business venturing, entrepreneurs input resources, energy, and innovation to create structured, organised companies that grow and are profitable despite the surrounding market chaos.
3. Self-Organisation: The concept of self-organisation in thermodynamics refers to the spontaneous emergence of order out of seeming disorder (Kondepudi et al., 2020). For example, adding energy to a fluid can create organised patterns such as convection cells. In business, self-organisation can be seen in how entrepreneurs marshal resources, structure their companies and strategise to create order (successful business operations) out of disorder (the chaotic market).
4. Growth, Prosperity, and Profit: These objectives of entrepreneurs can be seen as efforts to create islands of low entropy (highly organised and efficient operations) within the high-entropy environment (the market). The drive for profitability is equivalent to seeking a low-entropy state through deliberate organisation and strategy.

In short, while the second law of Thermodynamics dictates that the overall entropy of an isolated system must increase, entrepreneurial efforts can be viewed as the work done against this natural drift towards disorder. By strategically organising resources and navigating the complexities of the market, entrepreneurs seek to create orderly, profitable ventures in the face of the entropy represented by market uncertainties and competition. Georgiev and Iannacchione (2016) articulated that in systems far from equilibrium, energy gradients catalyse internal structuring, facilitating energy dissipation and reducing internal entropy, adhering to the principle of least action.

The Bénard cell serves as a model to understand this self-organising phenomenon, where a convection cycle decreases entropy within the system.

> With increasing number of internal states, the system begins to "see" and "respond" (i.e., make transitions between states) to its environment better and better. Each transition necessarily involves generation of entropy over and above that associated with maintaining a state. We may call it the transitional entropy production. Thus, an increase in the ability of a system to interact with its environment and exhibit goal-oriented behaviour will be associated with transitional entropy production" (Kondepudi, 2012, p. 44).

This framework has profound implications for understanding entrepreneurial behaviour in response to the market's uncertainties. Entrepreneurs, through self-organisation, capitalise on the nonequilibrium tensions within the system. Initially, entrepreneurs respond to opportunities with instinctive, non-deliberative actions. The discussed action framework commences with a thermodynamic driving force triggering an entrepreneurial movement towards opportunity, characterised by instinctive and intuitive action without a predetermined plan. This initial reaction, akin to the spontaneous order from chaos observed in the Bénard convection process, demonstrates a unique physical intelligence, symbolising the entrepreneurial capacity for spontaneous self-organisation in chaos.

2.2. Bénard convection process

Bénard convection, a phenomenon in fluid dynamics, manifests as natural convection within a fluid layer subjected to a temperature gradient (Reddy, 2020). This occurs as the lower surface of the fluid layer is heated, forming a systematic arrangement of convection cells, termed Bénard cells. The phenomenon, known as 'Bénard instability', induces a flow pattern that exemplifies spontaneous self-organisation upon heating, as depicted in Fig. 1. McKelvey (2016) described this process as one characterised by imposed tension, critical values, and emergent phase transitions leading to the formation of what Prigogine (1967) named 'dissipative structures' - structures that arise to mitigate the imposed tension.

Establishing critical values demarcates the energy differential between the heated and cooler areas. The system undergoes a phase transition marked by a significant alteration in fluid dynamics between these critical values. Under intense heat, the fluid exhibits a dynamic, patterned circulation, creating geometric arrangements of warmer and cooler regions, indicative of a new order (McKelvey, 2016). Heylighen (2001) noted that the fluid spontaneously organises into hexagonal cells or parallel rolls, featuring ascending flows on one side and descending flows on the other. These emergent structures, dubbed dissipative structures by Prigogine (1967), represent islands of order (as shown in Fig. 1) formed according to the second law of thermodynamics. They act to dissipate the imposed energy, moving towards randomness and entropy in alignment with the second law of thermodynamics (McKelvey, 2016).

What causes the emergences and self-organisation that can explain such physical intelligence? What are the underlying reasons and rationales for such a generative mechanism of order creation? McKelvey (2001) described the Bénard process as such:

1. Orderliness forms in negentropy, which becomes available because of the energy differential (or adaptive tension) between a system and its surroundings. The imposition on the system's micro agents (dissipative structures) causes emergence.

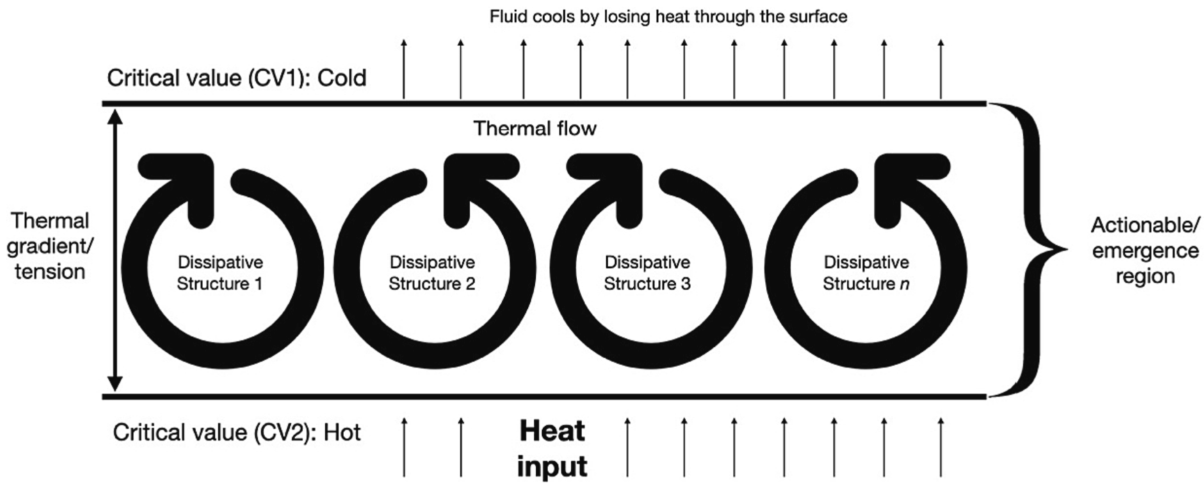

Fig. 1. Bénard cell in ballet-like movement.

2. The critical values (as illustrated in CV1 and CV2) are the measure of tension, defining the upper and lower bounds of the region of emergence (where self-organisation occurs) sandwiched between the regions of order (slow change) and chaos (dysfunctional change).

The ballet-like dance of the fluid molecules arises from an external force/applied heat, resulting in an energy differential. The micro agents or dissipative structures respond through self-organisation amid the complex and chaotic environment in the emergence region.

The external force, and its nature, results from the tension created by the Bénard energy differentials recognised by chaos and complexity scientists that foster negentropy and create emergent structure. In the simple Bénard cell, and in the atmosphere, an energy differential causes energy transfer via bulk (current) movements of gas molecules rather than via in-place vibrations and collisions. More broadly, think of an energy differential as producing coarse-graining among histories of the vibrating molecules—or among histories of bottom-level microagents in general. In this view, the energy differentials of complexity theory become the causes of emergent coarse-grained structure from entanglement pools (McKelvey, 2001, p. 141).

The Bénard instability represents a remarkable display of physical phenomena. It embodies a convection motion that manifests as a sophisticated spatial structuring within the system, as described by Prigogine & Stengers (2018).

3. Discussion

This paper posits that the impetus for entrepreneurial actions, particularly nonrational and non-deliberative ones, is fundamentally rooted in a thermodynamic driving force. This force emerges in response to the tension observed between critical values CV1 and CV2, as illustrated in Fig. 2. This tension arises from "an economic energy differential—a potential market of resources and by a motivation to act"," as clarified by (Lichtenstein, 2007, p. 8). The energy differentials "need to have a motivational valance attached before they can be expected to be felt as tension by agents" (McKelvey, 2001, p. 195). The alert entrepreneurs sensitive to these tensions and energy differentials recognise them as potential opportunities (Leong, 2022).

The paper further contends that even minor, non-deliberative, and impulsive actions by these entrepreneurs can set off significant consequences due to the complex interactions within a diverse pool of agents. This paper focuses on two key aspects: the agency/entrepreneur/structure (interpreted as dissipative structures) and the process (encompassing phase transitions), drawing parallels with the Bénard cell. It discusses the emergence of order, or coarse-graining, from the intricate, fine-grained structure of interconnected and entangled histories among diverse agents.

3.1. Entrepreneur as a dissipative structure

In the dynamic entrepreneurial ecosystem, the entrepreneur collaborates with diverse agents—employees, suppliers, investors, landlords, bankers, and other stakeholders—to form emergent dissipative

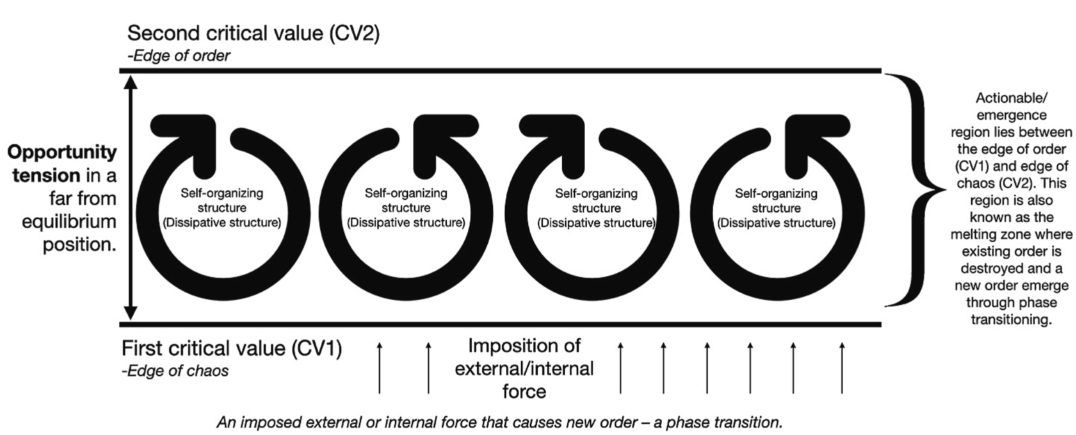

Fig. 2. Re-contextualised Bénard process.

structures that mitigate opportunity tension. This collective interaction necessitates a synergistic alignment of forces to forge an efficacious dissipative structure.

Hill explained:

> Every man who manages a business knows what a difficult matter it is to get employees to work together in a spirit even remotely resembling harmony. The list of the chief sources from which power may be attained is, as you have seen, headed by infinite intelligence. When two or more people coordinate in a spirit of harmony, and work toward a definite objective, they place themselves in position, through that alliance, to absorb power directly from the great universal storehouse of infinite intelligence. This is the greatest of all sources of power. It is the source to which the genius turns. It is the source to which every great leader turns, (whether he may be conscious of the fact or not) (Hill, 1938, p. 179).

Two distinct drivers of emergence are broadly discussed in the entrepreneurship literature. "(1) Far-from-equilibrium dynamics that trigger order creation (Leong, 2021), and (2) adaptive tension (McKelvey, 2004), which can push a system toward instability, leading to the emergence of new order" (Lichtenstein, 2007: 3). Here, opportunity tension is described in Fig. 2.

When business venturing begins from new venture formations, one of the fundamental driving forces (Leong, 2020) is to self-organise towards the emergence of a new state when opportunity tension is operating far from equilibrium (between CV1 and CV2, in Fig. 2). Far from equilibrium, self-organisation leads to the emergence of nonlinear and perpetual novelty, breaking away from the norm of order. The opportunity tension provides the impetus to drive entrepreneurial activities that thrive on reducing the tension (Lichtenstein et al., 2007). This paper posits that nonlinear transformations in entrepreneurial activities originate from the entrepreneur's minor, non-deliberative, and impulsive actions. Such minor shifts align with Granovetter's (1978) concept of a 'threshold point' in his threshold models of collective behaviour, signifying moments where "substantial heterogeneity of preferences and interdependence of decisions" (p. 1435) coalesce over time into cohesive dissipative actions. Organisational researchers, like Plowman et al. (2007), characterise organisations as systems where minor alterations can precipitate significant impacts. "The notion of sensitivity to initial conditions suggests that organisations are not predictable and that changes in them are often more emergent than intentional (Stacey, 1995). When a system moves beyond a specific threshold/limit (critical value CV1 in Fig. 2), it provides the "seed for self-organisation- the beginnings of a new configuration" (Lichtenstein, 2000: 132). Anderson (1999) posited that as co-evolved adaptive systems approach the brink of chaos—a concept also advocated by Kauffman (1995)—even minor modifications have the potential to trigger a domino effect, resulting in significant transformations, a phenomenon described by Plowman et al. (2007) as an 'avalanche of change' (p.520).

The transformative 'avalanche of change' occurs within the emergence region, between the edge of order (CV1) and the edge of chaos (CV2), as depicted in Fig. 2. This critical zone, also termed the melting zone, is where the existing order disintegrates, paving the way for new structures to arise through phase transitions driven by tension gradients. Plowman et al. (2007) described this melting zone as brimming with "adaptive tension and tension gradients; it is in this state that emergent self-organisation and creative destruction occur" (p. 520). In this context, adaptive tension acts as a driving force and a catalyst, setting the stage for dynamic changes that lead to the emergence and the creation of order. As a system moves from equilibrium due to increasing adaptive tensions, it absorbs energy and information. Reaching a critical juncture, this energy ignites a process of dissipation throughout the system, disrupting existing patterns and spawning disorder. Amidst this upheaval, unpredictable formations, known as dissipative structures, begin to materialise as the system navigates chaos, transitioning from one phase to another (Plowman et al., 2007). These structures maintain their existence as long as the energy differential remains, fostering spontaneous self-organisation and yielding unforeseen emergent outcomes. As organisations shift from equilibrium towards instability, they exhibit complex behaviours—simultaneously stable yet replete with unpredictable dynamics (Plowman et al., 2007).

In light of the restated second law of thermodynamics, dissipative structures undergo self-organisation amid fluctuations and instabilities. This leads to irreversible bifurcations that facilitate generative emergence, a process where new order is birthed (Lichtenstein, 2020). In an open thermodynamic system, when an opportunity with a discernible differential, perceived as a gradient with exploitable potential, is identified, the system, under the guidance of the restated second law, endeavours to diminish this gradient by utilising all available entrepreneurial resources and methods (Leong, 2021). These self-organising processes effectively minimise gradients (Stinchfield et al., 2013). This propensity for self-organisation and the mechanism of dissipation lie at the heart of the thermodynamic narrative (Leong, 2021). Entrepreneurs operate within an ecosystem infused with energy and material flows. They sustain their entrepreneurial activities in an organised state by externalising energy or profit from these opportunity gradients, thereby dissipating them (Leong, 2021). The conceptual groundwork laid by Schrödinger and Prigogine further enriches the understanding of the emergence of nonequilibrium complexity in theoretical constructs.

> However, Schrodinger's equally important and less understood observation was his "order from disorder" premise. This was an effort to link biology with the fundamental theorems of thermodynamics. He noted that at first glance, living systems seem to defy the second law of thermodynamics as it insists that, within closed systems, entropy should be maximised and disorder should reign. Living systems, however, are the antithesis of such disorder. They display marvellous levels of order created from disorder. For instance, plants are highly ordered structures, which are synthesised from disordered atoms and molecules found in atmospheric gases and soils. Schrodinger solved this dilemma by turning to nonequilibrium thermodynamics, that is, he recognised that living systems exist in a world of energy and material fluxes. An organism stays alive in its highly organised state by taking energy from outside itself, from a larger encompassing system, and processing it to produce, within itself, a lower entropy, more organised state. Schrodinger recognised that life is a far-from-equilibrium system that maintains its local level of organisation at the expense of the larger global entropy budget (Schneider & Kay, 1994, p. 26).

Viewed through a nonequilibrium lens, living systems exhibiting biological self-organisation and thermodynamic behaviours find a parallel in the business venturing process. Here, entrepreneurs self-organise amidst nonequilibrium conditions marked by energy and material flows, striving to develop more stable and advanced structures from the disorder in their external environment. This dynamic generates opportunity tensions (Lichtenstein, 2007).

This paper posits that a comprehensive understanding of living processes, including entrepreneurial activities, necessitates the inclusion of the second law of thermodynamics. How entrepreneurs self-organise, assemble resources, and progressively construct stable, efficient organisations mirrors the causalities defined in thermodynamics. While the second law is necessary for clarifying the business venturing process, it is not the sole determinant, given the free will and behavioural complexities of entrepreneurs, who may not always act rationally. A re-evaluation of thermodynamics reveals its fundamental role in guiding many processes observed in the emergence and sustenance of business ventures, aligning closely with nonequilibrium complexity theories as developed by Prigogine et al. (1985).

The comprehensive study of emergence, grounded in thermodynamic principles, equips entrepreneurship researchers with novel conceptual and methodological approaches to clarify how new ventures materialise from order crafted out of chaos. Thus, organisations' emergence and growth are system-wide dynamic processes aligned with the second law of thermodynamics, fundamental irrespective of other presumed drivers of emergence. Consequently, the development of complexity in entrepreneurial endeavours can be articulated using thermodynamic terminology. The entrepreneur's agency is pivotal in this process, as it is the entrepreneur's alertness to system differentials and potentialities, coupled with the freedom to act, that initiates the creation of emergent dissipative structures, effectively giving rise to new degrees of freedom (McKelvey, 2001).

3.2. Implications for theory and practice

The thermodynamic paradigm, exemplified by the Bénard cell model, redefines entrepreneurial processes as dynamic energy exchanges, challenging static conceptions in entrepreneurial theory. This interdisciplinary approach, blending physics and economics, reconceptualises the entrepreneur's role as an agent catalysing change within complex systems. Practically, it suggests entrepreneurs should strategically manage energy differentials in the market, emphasising risk management and continuous innovation in response to market instability.

This study is not without its limitations. The primary challenge is the abstract nature of applying physical laws, such as those from thermodynamics, to social science contexts, which may lead to difficulties in empirical validation. The complexity of the theoretical framework also poses a challenge to its practical application, potentially limiting its accessibility to practitioners. Furthermore, without empirical data, the study's reliance on theoretical and conceptual analysis may limit its generalizability across different entrepreneurial contexts.

Future research avenues include empirical validation of this framework across diverse entrepreneurial settings, longitudinal analyses to understand the evolution of business ventures, and cross-disciplinary studies integrating thermodynamics with entrepreneurship. Additionally, detailed case studies and comparative industry analysis could elucidate the practical applications of these principles. Integrating thermodynamic concepts into entrepreneurial education could further enhance strategic decision-making skills. This thermodynamic perspective thus offers a novel and multifaceted approach to understanding entrepreneurship, opening new directions for theoretical exploration and practical application.

4. Conclusion

The thermodynamic framework, exemplified by the Bénard cell, provides a complex and realistic depiction of thermodynamic systems by examining the energy transfers and interactions within evolving structures.

While Shane and Venkataraman (2000) characterised entrepreneurship as the intersection of opportunity and individual action, they did not delve into the dynamic forces within this nexus. "Perhaps their most important insight postulates that the core of entrepreneurship resides in the nexus of opportunities and the individual" (Sarason et al., 2006, p. 288). Our discourse posits the existence of a thermodynamic force at this intersection, which motivates entrepreneurs to initiate action. Additionally, this paper offers a framework to enhance our comprehension of the processes occurring within this nexus—the emergence zone between critical values CV1 and CV2—and theorise the symbiotic relationship between the entrepreneur (dissipative structure) and the surrounding context (environment) during the phase transition.

This paper encourages scholars and researchers to employ thermodynamic principles to investigate the multifaceted nature of emergence, creative destruction, and re-emergence in entrepreneurship. "Thermodynamic entrepreneurship is temporal inasmuch as a specific entrepreneurial act in one time period does not constitute entrepreneurship in the next. And it is measurable inasmuch as the possibility of amplified changes in the release of energy and material flows can in fact be measured" (Vogel, 1989, p. 192). Simply put, entrepreneurship is a journey of energy exchanges, gaining and losing according to the kinetic constraints and obeying the law of thermodynamics. Therefore, the emergence of opportunity tension created by the critical values is the beginning of business venturing. The initial tension of opportunities, delineated by critical thresholds, marks the commencement of business ventures. McKelvey (2001) succinctly noted that absent the energy gradient, the emergent structures dissolve, underscoring the necessity of such tension for the genesis of entrepreneurial endeavours. Without this tension, the potential for the formation of entrepreneurial ventures diminishes.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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References

Anderson, P., 1999. Perspective: Complexity theory and organization science. Organ. Sci. 10 (3), 216–232. https://doi.org/10.1287/orsc.10.3.216.
Gell-Mann, M., Lloyd, S., 1996. Information measures, effective complexity, and total information. Complexity 2 (1), 44–52. https://doi.org/10.1002/(SICI)1099-0526(199609/10)2:1<44::AID-CPLX10>3.0.CO;2-X.
Georgiev, G., Iannacchione, G., 2016. Least action and entropy considerations of self-organisation in benard cells. In APS March Meeting Abstracts 2016, A40–014.
Granovetter, M., 1978. Threshold models of collective behavior. Am. J. Sociol. 83 (6), 1420–1443. https://doi.org/10.1086/226707.
Heylighen, F., 2001. The science of self-organisation and adaptivity. The Encyclopedia of Life Support Systems 5 (3), 253–280.
Hill, N., 1938. Think & grow rich. Ralston Society, Meriden, Conn.
Kauffman, S., 1995. At home in the universe: The search for laws of self-organisation and complexity. Oxford University Press, USA.
Kirzner, I.M., 1980. Perception, opportunity and profit. studies in the theory of entrepreneurship. The University of Chicago Press, Chicago.
Kondepudi, D., 2012. Self-organisation, entropy production, and physical intelligence. Ecol. Psychol. 24 (1), 33–45. https://doi.org/10.1080/10407413.2012.643716.
Kondepudi, D.K., De Bari, B., Dixon, J.A., 2020. Dissipative structures, organisms and evolution. Entropy 22 (11), 1305. https://doi.org/10.3390/e22111305.
Lavenda, B.H., Dunning-Davies, J., Compiani, M., 1995. What is entropy? Il Nuovo Cimento B Series 11, 110(4), 433–439. https://doi.org/10.1007/BF02741453.
Leong, D., 2020. Entrepreneurial energy and opportunities existing in space. Journal of Entrepreneurship, Business and Economics 8 (2), 196–218. http://scientificia.com/index.php/JEBE/article/view/144.
Leong, D., 2021a. Entrepreneurial energy in a far-from-equilibrium opportunity driving entrepreneurial actions. J. Entrepreneurship, Business and Economics 9 (1), 1–31. http://www.scientificia.com/index.php/JEBE/article/view/143.
Leong, D., 2021b. Thermodynamics and gradient manipulation mechanism in entrepreneurial actions. Int. J. Business Manage. 16 (9), 29. https://doi.org/10.5539/ijbm.v16n9p29.
Leong, D., 2022. Probabilistic interpretation of observer effect on entrepreneurial opportunity. Organizacija 55 (4), 243–258. https://doi.org/10.2478/orga-2022-0016.
Lerner, D., Hunt, R., Dimov, D.P., 2017. Following the muse: Non-deliberative, unreasoned nascent-stage venturing. Acad. Manag. Proc. 2017 (1), 14678. https://doi.org/10.5465/AMBPP.2017.6.
Lerner, D.A., Hunt, R.A., Dimov, D., 2018. Action! moving beyond the intendedly-rational logics of entrepreneurship. J. Bus. Ventur. 33 (1), 52–69. https://doi.org/10.1016/j.jbusvent.2017.10.002.
Lichtenstein, B.B., 2000. Self-organised transitions: A pattern amid the chaos of transformative change. Acad. Manag. Perspect. 14 (4), 128–141. https://doi.org/10.5465/ame.2000.3979821.
Lichtenstein, B.B., Carter, N.M., Dooley, K.J., Gartner, W.B., 2007. Complexity dynamics of nascent entrepreneurship. J. Bus. Ventur. 22 (2), 236–261. https://doi.org/10.1016/j.jbusvent.2006.06.001.
Lichtenstein, Benyamin B. 2007. Moving Far From Far-From-Equilibrium: Opportunity Tension as the Driver of Emergence. Organization Science Winter Conference.

http://scholarworks.umb.edu/management_wphttp://scholarworks.umb.edu/management_wp/13.

Lichtenstein, B. 2020. Generative Emergence: Research and Praxis for Social Innovation. In: Oxford Research Encyclopedia of Psychology. Oxford University Press. https://doi.org/10.1093/acrefore/9780190236557.013.735.

Macintosh, R., Maclean, D., 1999. Conditioned emergence: a dissipative structures approach to transformation. Strateg. Manag. J. 20 (4), 297–316. https://doi.org/10.1002/(SICI)1097-0266(199904)20:4<297::AID-SMJ25>3.0.CO;2-Q.

Mason, R.B., 2006. Coping with complexity and turbulence – an entrepreneurial solution. Journal of Enterprising Culture 14 (04), 241–266. https://doi.org/10.1142/S0218495806000155.

McKelvey, B., 2001. What is complexity science? It is really order-creation science. Emergence 3 (1), 137–157. https://doi.org/10.1207/S15327000EM0301_09.

McKelvey, B., 2004. Toward a 0th law of thermodynamics: Order-creation complexity dynamics from physics and biology to bioeconomics. J. Bioecon. 6 (1), 65–96. https://doi.org/10.1023/B:JBIO.0000017280.86382.a0.

McKelvey, B., 2016. Complexity ingredients required for entrepreneurial success. Entrep. Res. J. 6 (1) https://doi.org/10.1515/erj-2015-0053.

McMullen, J.S., Shepherd, D.A., 2006. Entrepreneurial action and the role of uncertainty in the theory of the entrepreneur. Acad. Manag. Rev. 31 (1), 132–152. https://doi.org/10.5465/amr.2006.19379628.

Ortega, P.A., Braun, D.A., 2013. Thermodynamics as a theory of decision-making with information-processing costs. Proceedings of the Royal Society a: Mathematical, Physical and Engineering Sciences 469 (2153), 20120683. https://doi.org/10.1098/rspa.2012.0683.

Pietersen, M. L., & Botha, M. 2021. Impulsivity and entrepreneurial behaviour: Exploring an unreasoned pathway. International Small Business Journal: Researching Entrepreneurship, 026624262110081. https://doi.org/10.1177/02662426211008149.

Plowman, D.A., Baker, L.T., Beck, T.E., Kulkarni, M., Solansky, S.T., Travis, D.V., 2007. Radical change accidentally: The emergence and amplification of small change. Acad. Manag. J. 50 (3), 515–543. https://doi.org/10.5465/AMJ.2007.25525647.

Prigogine, I., 1967. Introduction to thermodynamics of irreversible processes. Interscience.

Prigogine, I., Stengers, I., Pagels, H.R., 1985. Order out of chaos. Phys. Today 38 (1), 97–99. https://doi.org/10.1063/1.2813716.

Prigogine, I., Stengers, I., 2018. Order out of chaos: Man's new dialogue with nature. Verso Books.

Pross, A., 2003. The driving force for life's emergence: Kinetic and thermodynamic considerations. J. Theor. Biol. 220 (3), 393–406. https://doi.org/10.1006/jtbi.2003.3178.

Ramoglou, S., 2013. Who is a "non-entrepreneur"?: Taking the "others" of entrepreneurship seriously. Int. Small Bus. J. 31 (4), 432–453. https://doi.org/10.1177/0266242611425838.

Reddy, M.K., 2020. Numerical simulation of rayleigh-bénard convection in an inclined enclosure under the influence of magnetic field. Journal of King Saud University - Science 32 (1), 486–495. https://doi.org/10.1016/j.jksus.2018.07.010.

Sarason, Y., Dean, T., & Dillard, J. 2006. Entrepreneurship as the Nexus of Individual and Opportunity: A Structuration View DLU-JOS CALL FOR PAPERS: Special Issue on Entrepreneurship and Innovation, and Social Entrepreneurship View project. Article in Journal of Business Venturing. https://doi.org/10.1016/j.jbusvent.2005.02.007.

Schneider, E.D., Kay, J.J., 1994. Life as a manifestation of the second law of thermodynamics. Math. Comput. Model. 19 (6–8), 25–48. https://doi.org/10.1016/0895-7177(94)90188-0.

Schneider, E.D., Kay, J.J., 2010. Order from disorder: the thermodynamics of complexity in biology. What is life? The next Fifty Years 1953, 161–174. https://doi.org/10.1017/cbo9780511623295.013.

Shane, S., & Venkataraman, S. 2000. The promise of entrepreneurship as a field of research. In Source: The Academy of Management Review (Vol. 25, Issue 1).

Stacey, R.D., 1995. The science of complexity: An alternative perspective for strategic change processes. Strateg. Manag. J. 16 (6), 477–495. https://doi.org/10.1002/smj.4250160606.

Vogel, J.H., 1989. Entrepreneurship, evolution, and the entropy law. The Journal of Behavioral Economics 18 (3), 185–204. https://doi.org/10.1016/0090-5720(89)90022-3.

Wiklund, J., Yu, W., Patzelt, H., 2018. Impulsivity and entrepreneurial action. Acad. Manag. Perspect. 32 (3), 379–403. https://doi.org/10.5465/amp.2016.0177.