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Entrepreneurship and Conway's Game of Life: A Theoretical Approach from a Systemic Perspective

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Abstract

This study establishes a comprehensive structural isomorphism between Conway's Game of Life and the entrepreneurial process, analysing the latter as a complex adaptive system governed by non-linear dynamics rather than linear predictability. Through a rigorous qualitative approach based on a systematic literature review and abductive inference, the research identifies and correlates four fundamental dimensions: uncertainty, adaptability, growth, and sustainability. Transcending traditional metaphorical comparisons, this paper introduces a novel mathematical model that modifies Conway's deterministic logic by incorporating an «Agency» variable (A). This critical addition quantifies how an entrepreneur's internal capabilities can counterbalance environmental pressures (neighbourhood density) to determine survival thresholds, effectively transforming the simulation into a «Game of Life with Agency» where participants actively influence their viability potential (Ψ). The analysis explicitly correlates specific algorithmic configurations with real-world business phenomena: high-entropy initial states («The Soup») mirror early-stage market uncertainty where outcomes are probabilistic; «gliders» represent the necessity of strategic pivoting and continuous displacement for survival; and «oscillators» symbolise dynamic sustainability through rhythmic equilibrium rather than static permanence. Furthermore, the study validates the «Gosper Glider Gun» pattern as a model for scalable, generative growth. By bridging abstract systems theory with managerial practice, the research positions these simulations as «mental laboratories» for decision-making. The findings theoretically validate iterative methodologies like the Lean Startup and conclude that successful entrepreneurship operates on the «Edge of Chaos», providing a rigorous framework for navigating high stochastic uncertainty.

Keywords: entrepreneurship; Conway's game of life; complex adaptive systems; entrepreneurial agency; mathematical modelling; nonlinear dynamics

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1. Introduction

Research frequently aims to discover novel perspectives on established events, tools, or processes, seeking to illustrate their functions and interdisciplinary impacts more effectively. Entrepreneurship, as a business creation process, exemplifies this quest and has been extensively analysed from psychological, sociological, and cultural perspectives. These studies relate the phenomenon to behaviours, attitudes, and customs that have significantly broadened the collective understanding of its utility.

Making comparisons is a little easier when there is some parallelism between what is being studied and what is being compared, but this is not always the case. The idea of seeking relationships between events or activities that might not be directly related is not new.

Einstein, for example, managed to construct his general theory of relativity by imagining complex situations based on possible, though not every day, events; it is enough to recall the simile he used about a person in free fall to explain how the effects of gravity disappear from the observer's perspective, in this particular case, from the perspective of the person falling. Following that line of thinking, this study investigates the intricate correlation between Conway's Game of Life and the multifaceted landscape of entrepreneurship, articulating how principles derived from this mathematical model can illuminate the challenges faced by entrepreneurs.

Conway's Game of Life, although conceived as a mathematical simulation, offers valuable lessons for entrepreneurship by depicting how simple rules can generate complex and adaptive behaviours. In this system, small initial decisions can have unpredictable consequences, similar to the business environment where conditions change rapidly and outcomes emerge from dynamic interactions. Mitchell (2009) posits that complex systems, such as the one devised by Conway, reflect patterns of self-organisation also found in economic markets as well as in entrepreneurship. This idea is also visualised by Johnson (2001), who argued that successful entrepreneurs recognise that they cannot control all factors, but can design initial structures as minimum viable products that favour continuous adaptation.

Furthermore, Conway's Game of Life illustrates how business innovation and sustainability emerge not from a rigid design, but from the ability to respond creatively to environmental changes. As Blank (2013a) points out, modern entrepreneurship requires constant iteration and feedback-based learning, a process that can be visualised in the evolution of patterns within Conway's game. Furthermore, Holland (1995) highlights that complex adaptive agents survive by constantly exploring new combinations, something crucial in entrepreneurship, where opportunity exploration and tolerance of uncertainty determine success.

According to the authors of this study, Conway's Game of Life can be considered particularly suitable for obtaining useful insights for entrepreneurship because—as already pointed out—it combines structural simplicity with a great capacity to generate complex emergent behaviours, which faithfully reflects the nature of entrepreneurial ecosystems. Unlike other cellular automata, Conway's model operates with minimal but sufficient rules to produce patterns that simulate growth, stagnation or extinction, depending on the initial conditions. This property makes it a valuable tool for understanding how small initial strategic decisions in a venture can escalate in unpredictable but significant ways, thus simulating the non-linear dynamics of real-life business.

On the other hand, Conway's Game of Life allows us to observe how innovation, adaptation, and resilience can emerge from simple yet interconnected environments, aligning with key principles of contemporary entrepreneurial thinking. According to Blank (2013b), entrepreneurs must operate in uncertain contexts through continuous experimentation and agile learning, something that can be clearly modelled and visualised in the development of patterns within Conway's system. Other mathematical or computational models tend to be more rigid or require a greater number of parameters, losing the conceptual clarity that Conway's Game of Life offers. As Johnson (2001) argues, this clarity makes Conway an excellent mental laboratory for simulating how decentralised decisions can lead to creative and sustainable solutions, essential for survival and growth in entrepreneurship.

Importantly, Conway's Game of Life has been used in academic research to model survival phenomena in biological, social, and computational systems due to its ability to represent how complex patterns emerge from simple rules. For example, Adamatzky (2010) used Conway's cellular automaton to explore self-organisation and survival processes in biological systems, showing how certain configurations can persist or become extinct depending on the environment, thus simulating evolutionary processes. Similarly, Sayama (2015) explained that stable patterns or «organisms» within the game resemble living entities that survive because they achieve a dynamic equilibrium with their environment, which allows for the study of resilience in ecological or social contexts.

Similarly, Conway's Game of Life has been used in studies to simulate survival strategies in artificial intelligence and collective behaviour. In the research by Wuensche and Lesser (1992), this model was used to analyse how distributed entities learn to survive in a changing environment, demonstrating that rules that favour cooperation lead to greater stability. For his part, Langton (1990) argued that cellular automata, such as Conway's, allow for the study of the «Edge of Chaos», a critical state where systems are sufficiently orderly to maintain structure, but chaotic enough to adapt, an ideal condition for evolutionary survival. The aforementioned studies serve as background that supports the use of Conway's Game of Life as an abstract but powerful framework for analysing situations of adaptability and survival in complex scenarios or activities, such as, in this case, entrepreneurship.

The urgency of this theoretical integration is underscored by the current business landscape, characterised by global uncertainty, digital disruption, and extreme market volatility. Traditional linear and reductionist approaches, which treat entrepreneurial variables in isolation, are increasingly insufficient to explain the non-linear dynamics of modern ecosystems (Audretsch et al., 2024). Consequently, there is a pressing need for heuristic frameworks capable of modelling how micro-level interactions cascade into macro-level survival patterns without relying on prohibitive computational complexity.

However, despite the growing body of work linking complexity science to business, a specific deficiency persists in the current literature: there is a scarcity of parsimonious frameworks that can simulate these non-linear dynamics without relying on prohibitive computational density (Wurth et al., 2022). Existing models often describe ecosystem complexity but fail to provide accessible, rule-based tools for visualising how simple initial micro-foundations evolve into macro-level survival patterns (Zahra, 2021). This study addresses this gap by offering a novel application of Conway's algorithm, contributing a simplified yet rigorous heuristic. It bridges the divide between abstract systems theory and practical application, providing a unique method to model the emergence of stability and growth from chaotic environments.

All of the above leads to the following questions: What elements of Conway's Game of Life can be related to entrepreneurship? How might such a relationship, if any, help us better understand entrepreneurship? For all the above, studying Conway's Game of Life could provide a disruptive insight into understanding complex behaviours that arise from simple initial conditions, showing phenomena such as «oscillators» and «gliders» that exhibit both predictability and unpredictability, thus reflecting fundamental dynamics relevant to several fields—as already established—including entrepreneurship.

Entrepreneurship, understood as a process fundamentally based on the discovery and exploitation of opportunities in uncertain environments, seems closely aligned with some of the behaviours observed in Conway's Game of Life or with some of its characteristics. As is well known, when navigating the unpredictability of market dynamics, entrepreneurs face challenges that require adaptability, strategic decision-making, and knowledge of

resource management principles that resonate strongly with the evolutionary nature of cellular automata.

When scrutinising the intersection of these two systems, four key dimensions—uncertainty, adaptability, growth, and sustainability—emerge not merely as isolated concepts but as interdependent variables within a complex adaptive system (Cao & Shi, 2021). Rather than treating these dimensions as static definitions, this study posits them as dynamic forces where the Game of Life serves as a simulation of their interaction. These dimensions present alternative lenses through which business processes can be analysed, offering insights into how companies can thrive amid complexity and change, regardless of whether their initial premises are simple or complex. This research seeks to elucidate these parallels and establish a theoretical and mathematical framework that practitioners can leverage.

By exploring the analogies between Conway's Game of Life and entrepreneurial behaviours, this study explicitly affirms its significance across three critical domains. First, it contributes to entrepreneurial theory by offering a post-Newtonian framework that moves beyond linear causality to explain emergence and self-organisation. Second, it advances entrepreneurial learning by providing a visual and heuristic tool for understanding trial-and-error dynamics in high-uncertainty environments. Third, it enriches complex systems approaches by validating cellular automata not just as a biological curiosity, but as a rigorous method for modelling the social and economic interactions that define modern business ecosystems.

Subsequent sections will expand on the core concepts of Conway's Game of Life, their relevance to contemporary entrepreneurship, and methodological approaches for integrating these insights into viable business strategies. The research seeks to bridge the gap between theoretical models and practical applications in the complex field of business through Conway's proposition and its relationship to entrepreneurship.

In addition, a mathematical model is proposed to illustrate the relationship between the aforementioned game and entrepreneurship. Crucially, this framework introduces a fundamental variation to Conway's original deterministic logic: the inclusion of an 'agency' variable. This distinction acknowledges that, unlike passive biological cells, entrepreneurs possess the capacity to actively influence their adaptability, effectively transforming the theoretical approach into a non-deterministic Game of Life with Agency.

2. Literature Review

To provide a comprehensive theoretical foundation, this literature review is organised into three converging perspectives. First, entrepreneurship is examined as a complex adaptive system, emphasising the non-linear interactions inherent in entrepreneurial ecosystems (Theodoraki et al., 2022). Second, the relationship between games, simulations, and complexity is explored, moving beyond classical game theory to understand dynamic decision-making processes (Rehman & Elrehail, 2023). Finally, Conway's Game of Life is positioned as a specific heuristic model that bridges these domains, illustrating how simple rules generate complex emergent behaviours.

2.1. Entrepreneurship

Entrepreneurship is a multidimensional phenomenon that involves combining resources, taking risks, and seeking opportunities in an uncertain environment. According to Shane and Venkataraman (2000), entrepreneurship focuses on the discovery, evaluation, and exploitation of opportunities to create value. This process is not limited to the creation of new ventures but also includes innovation within existing organisations and the ability to adapt to environmental changes. For Schumpeter (1934), entrepreneurship is a force of

«creative destruction» that drives economic change through innovation. Entrepreneurs are agents of change who challenge the status quo and create new combinations of resources, which can lead to the creation of new markets and the transformation of existing industries.

In this sense, entrepreneurship is not only an economic activity but also a social and cultural process that influences the evolution of societies. Entrepreneurship can be studied from various perspectives that provide a broader understanding of the phenomenon. Its complexity could be analysed, for example, from an economic perspective, where it is considered a key driver of innovation and economic growth (Schumpeter, 1934). Alternatively, from a psychological perspective, one might focus on the characteristics of the entrepreneur, such as personality, resilience, and risk-taking (McClelland, 1965). Entrepreneurship could also be studied from a sociological perspective, based on the social and cultural factors that influence business decisions (Aldrich & Cliff, 2003); or from an educational perspective, which highlights the importance of training and learning in developing entrepreneurial skills (Gorman et al., 1997). Finally, entrepreneurship can be analysed from a technological perspective, exploring how technology and digitalisation facilitate and transform the entrepreneurial process (Acs & Audretsch, 2003).

2.1.1. Entrepreneurship as a Dynamic System

A dynamic system is characterised by the interaction of multiple components that converge on one another, generating non-linear and emergent behaviours. In the context of entrepreneurship, these components include the entrepreneur, the economic environment, social networks, institutions, and available resources (Shane & Venkataraman, 2000). Therefore, entrepreneurship could be understood as a dynamic system due to its complex nature, interdependent behaviour, and adaptive capacity, evolving in response to internal and external changes in the market being explored.

Fundamentally, entrepreneurship is not a static phenomenon, but a process that develops over time. Entrepreneurs interact with their environment, making decisions that affect the direction of their businesses and, in turn, are influenced by factors such as government policies, market trends, and competition (Aldrich & Ruef, 2006). This constant interaction generates a feedback loop that can amplify or reduce opportunities and challenges. Since entrepreneurship is an adaptive system, and entrepreneurs must adjust their strategies in response to unforeseen changes, it is a constantly changing system with varying levels of uncertainty.

The COVID-19 pandemic is a case in point; this event forced many companies to redefine themselves, adopting online models or diversifying their products. This adaptive capacity is a key characteristic of dynamic systems, which seek to maintain their equilibrium in the face of external disturbances (McKelvey, 2004). In agreement with York and Venkataraman (2010), innovation is also a crucial point for entrepreneurship as a dynamic system, especially when it must respond to the problems it faces, such as resource constraints, since it must reconfigure existing means to create value. York and Venkataraman (2010) emphasise the importance of continuous adaptation to the environment and a dynamic vision of business sustainability on the part of entrepreneurs.

Entrepreneurship also exhibits emergent properties, outcomes that cannot be predicted simply by analysing its components separately. The success of an entrepreneurial ecosystem could be an example of this, as it depends not only on the quality of the entrepreneurs or the novelty of the initiative, but also on the collaboration between consumers, investors, and governments (Isenberg, 2010). Recent research reinforces this systemic view, arguing that entrepreneurial ecosystems follow a dynamic lifecycle where the interaction of these components dictates the transition from genesis to consolidation (Cantner et al., 2021).

These interactions generate complex patterns that can only be understood from a systems perspective. Arguably, since entrepreneurship involves the interaction of multiple elements that evolve and adapt over time—generating complex and emergent behaviours—it could be considered a dynamic system. This perspective would allow us to better understand the challenges and opportunities that entrepreneurs face in a constantly changing world, which sometimes resembles a game.

2.1.2. Entrepreneurship as a Game and Complexity Simulation

Entrepreneurship can also be studied from a game perspective, which could be considered a process where entrepreneurs make strategic decisions, manage uncertainty, and compete in a dynamic environment (Isabelle, 2020), in addition to competition, strategy, uncertainty, and the possibility of winning or losing. In a game, participants make decisions based on specific rules and objectives, and the outcome depends on the actions of all players. Similarly, in entrepreneurship, entrepreneurs compete in a market where the rules are defined by factors such as supply and demand, government regulations, and the actions of competitors.

According to Game Theory, participants in a game make strategic decisions based on the possible actions of other players. In the context of entrepreneurship, this translates into the need to anticipate competitors' actions, customer preferences, and market conditions. For example, an entrepreneur launching a new product must consider how competitors will react and whether consumers will be willing to adopt the innovation. This strategic interdependence is a key characteristic of both games and entrepreneurship.

However, there are four characteristics that entrepreneurship shares with a game: (a) competition, (b) strategy, (c) uncertainty, and (d) binary outcome, which are explained below:

- **Competition**: In entrepreneurship, as in a game, competition is a central factor. Entrepreneurs compete for resources, customers, and the market, and must develop strategies to differentiate themselves from their competitors. According to Porter (1980), competitive advantage is achieved through innovation, efficiency, and the ability to respond to market needs.
- **Strategy**: Entrepreneurship requires careful strategic planning, similar to that used in video games. Entrepreneurs must decide how to allocate resources, when to enter or exit a market, and how to position their products or services. These strategic decisions are crucial to long-term success.
- **Uncertainty**: In both games and entrepreneurship, uncertainty is an inherent characteristic. Entrepreneurs operate in an environment where market conditions can change rapidly, and decisions must be made with incomplete information. According to Knight (1921), uncertainty is distinguished from risk because it cannot be quantified, which adds an element of unpredictability to the entrepreneurial process.
- **Binary outcomes**: In many games, the outcomes are binary: win or lose. The same is true in entrepreneurship: while outcomes can be more nuanced, there is also a dichotomy between success and failure. A study by Shane (2008) shows that most startups fail within the first few years, highlighting the «all or nothing» nature of entrepreneurship.

Now, if one makes a linear comparison between entrepreneurship and Conway's Game of Life, uncertainty emerges as a common element, along with three additional dimensions: adaptability, growth, and sustainability. The following subsections examine these dimensions from the perspective of entrepreneurship before discussing their correlation with Conway's Game of Life.

2.2. Entrepreneurship and Uncertainty

Entrepreneurship is an activity intrinsically linked to uncertainty. From the conception of an idea to the consolidation of a business, entrepreneurs face an environment with multiple variables, which, in many cases, are unpredictable. Uncertainty, in this context, is not only a challenge but a determining factor that can make the difference between success and failure.

Uncertainty in entrepreneurship refers to the lack of certainty about the future outcomes of a business decision or action. According to Knight (1921), uncertainty is distinguished from risk, as the latter can be quantified and managed through probabilities, whereas uncertainty involves situations in which even the probabilities are unknown. In entrepreneurship, this distinction is crucial, as entrepreneurs operate in dynamic markets where economic conditions, consumer preferences, and competitor actions are difficult to predict.

For entrepreneurs, uncertainty can be a deciding factor. A study by Shane and Venkataraman (2000) highlights that the ability to identify and seize opportunities in uncertain environments is what distinguishes successful entrepreneurs from those who fail. However, this same uncertainty can lead to failure if the decisions made do not align with market conditions. The COVID-19 pandemic could be considered a good example to illustrate the above; during that period, a significant number of entrepreneurs faced unprecedented uncertainty, resulting in the closure of numerous businesses (Fairlie, 2020). Those who managed to quickly adapt to the new conditions survived, while others were unable to overcome the challenges. This depended more on random conditions than on specific strategies, as the response to the pandemic was not a standard process and each action taken, independently, generated different responses in the scenarios that experienced it.

As explained above, uncertainty in entrepreneurship can also be considered a random phenomenon; that is, the lack of patterns or predictability in events. In the business context, this manifests itself in the impossibility of accurately predicting the success or failure of an initiative. According to Taleb (2007), some events that significantly impact businesses are unpredictable and infrequent but have profound consequences. These «black swans», as the author calls them, are examples of how randomness can influence entrepreneurship.

Another example of randomness in entrepreneurship is the success of technology companies such as Facebook or Google. While these companies are now global giants, their beginnings were marked by high uncertainty and random factors, such as the timing of their product launches or their massive user adoption (Lerner & Gompers, 2001). In these cases, success was not only the result of meticulous planning but also of unforeseen fortuitous circumstances.

As explained in Conway's Game of Life, the way a game is played will determine the expansion, life, or death of cells, due to the random behaviour of their initial conditions. This can be inferred from what has been explained in this section regarding uncertainty and entrepreneurship, thus establishing a parallel between Conway's Game of Life and the launch of a company. It is also important to note that McMullen and Shepherd (2006) propose that entrepreneurship is essentially a response to uncertainty, and that the entrepreneur acts without fully understanding the outcomes, even if he or she knows the rules of the game. These authors introduce the idea that the entrepreneur must perceive and evaluate opportunities under conditions of incomplete information and emphasise that entrepreneurial action requires judgement about the value of an opportunity, which implies making adaptive decisions.

2.3. Entrepreneurship and Adaptability

Entrepreneurship is a dynamic activity that requires not only creativity and vision but also a constant ability to adapt to change. In an increasingly volatile business environment, adaptability has become a critical factor that can determine a company's survival or failure. Adaptability refers to the ability of an entrepreneur or company to adapt to changes in the environment, whether technological, economic, social, or competitive. Naturally, in a world where market conditions can change rapidly, a lack of adaptability can lead to failure.

According to Teece et al. (1997), in their theory of dynamic capabilities, companies that manage to adapt to changing environments are those that maintain a sustainable competitive advantage. This involves not only reacting to changes but also anticipating them and transforming the company's resources and capabilities to take advantage of new opportunities. A clear example of the importance of adaptability is the digital transformation that many companies have experienced in the last decade. Those that failed to adapt to new technologies, such as e-commerce or social media, became obsolete. In contrast, companies like Amazon and Netflix have demonstrated an exceptional ability to adapt to market demands, which has allowed them to dominate their respective sectors (Bharadwaj et al., 2013).

In this sense, adaptability is not just an option but a necessity to survive in an increasingly demanding, automated, virtual, and competitive business environment. Entrepreneurial adaptability can be compared to a «game» where the rules and players (entrepreneurs) may be the same but conditions are constantly changing, meaning that strategic decisions must make the difference between winning or losing (alive or dead).

However, the analogy extends beyond competition; it encompasses the realm of simulation and complexity. Recent scholarship highlights that game-theoretic approaches are evolving into simulation-based models that better capture the adaptive nature of entrepreneurial decisions in fluctuating markets (Rehman & Elrehail, 2023). In this view, the «game» is not merely a strategic contest but a complex environment where outcomes emerge from the interplay of multiple adaptive agents.

In this context, adaptability is a key skill that allows entrepreneurs to adjust their strategies to market conditions.

According to game theory, developed by von Neumann and Morgenstern (1944), participants in a game make decisions based on the possible actions of others, which generates an environment of strategic interdependence, as observed in the game developed by Conway, where the randomness of a cell's position affects the behaviour of others. In entrepreneurship, this interdependence manifests itself in the need to adapt to competitors' actions and customer expectations (Porter, 1980). This «win-lose» approach highlights the importance of adaptability as a key strategy in entrepreneurship. As York and Venkataraman (2010) point out, entrepreneurs must be innovative and adaptive in the face of constraints to achieve sustainability and growth.

2.4. Entrepreneurship and Growth

Business growth is one of the most critical variables for a company's survival and success. In a competitive and dynamic environment, emerging companies must expand and adapt quickly to remain relevant, while established companies must determine their ideal level of growth. A lack of growth can lead to obsolescence and the demise of a company but excessive or poorly managed growth can lead to financial and operational problems, compromising business stability. Therefore, whether to grow or not to grow can mean the difference between life and death for a company, defined as success or failure.

Business growth is also a dynamic process that requires identifying opportunities and efficiently managing resources. According to Eisenhardt and Martin (2000), companies must develop dynamic capabilities that allow them to adapt and evolve in changing

environments. Business growth is crucial because it allows companies to expand their customer base, access new market opportunities, and improve their profitability. According to Penrose (1959), companies seeking to expand generate competitive advantages through the efficient exploitation of their internal resources and the acquisition of new capabilities. In this sense, growth is not only a desirable goal but a necessity for long-term survival.

However, growth depends on the size of the chosen market niche or the limitations of the market itself. This could be understood as the possibility of growing beyond the limits of the market. An example of the importance of growth is the expansion of technology companies like Amazon and Tesla. Amazon began as an online bookstore but, thanks to an aggressive growth strategy, it became an e-commerce and cloud computing giant (Stone, 2013). Similarly, Tesla has grown thanks to innovation and investment in new technologies, which has allowed it to remain competitive in the automotive sector (Z. Zhou, 2024).

On the other hand, a lack of growth can have negative effects, such as a loss of relevance and declining revenue. Companies like Kodak and Nokia, once leaders in their sectors, failed to adapt to the pace of market growth and were overtaken by more innovative competitors (Christensen et al., 2015). It is not difficult to imagine that, under current conditions, all markets have limitations that prevent them from going beyond what is expected of them, as might be observed on a game board whose boundaries are defined by rules and certain conditions. In this sense, entrepreneurial growth can also be understood as a strategic game in which entrepreneurs must make calculated decisions to expand without compromising the stability of their business. Sarasvathy (2001) introduces the concept of effectuation, which describes how successful entrepreneurs make decisions based on available resources and adapt their strategies in the face of market uncertainty.

2.5. Entrepreneurship and Sustainability

Sustainability has become a crucial aspect of entrepreneurship, as it directly influences the viability and longevity of a business. In a context of limited resources and growing environmental challenges, companies that do not incorporate sustainable practices risk becoming obsolete or facing regulatory and reputational issues. Furthermore, sustainability is not only an ethical issue but also a key strategy for business resilience and long-term competitive advantage (Porter & Kramer, 2011).

The concept of sustainability in entrepreneurship refers to a company's ability to operate without compromising its resources in the future. According to Elkington (1999), business sustainability is based on the triple bottom line approach, which considers the balance between economic, social, and environmental performance.

Thus, a sustainable company seeks to maximise its profits and minimise negative impacts on society and the environment. Companies that adopt sustainable strategies can enhance their reputation, attract investors conscious of their social and environmental impact, and ensure their continued existence in increasingly regulated markets. One example is Patagonia, a company that has based its success on environmental responsibility and corporate transparency (Haanaes, 2016). On the other hand, companies that have ignored sustainability, such as those in the oil industry without ecological transition strategies, have faced greater financial and regulatory risks (Bocken et al., 2014).

If entrepreneurship is considered a strategic game, sustainability becomes a fundamental element for planning and decision-making. In this sense, sustainability must be considered a factor of concern, as ignoring it can mean missing out on opportunities for growth and development. From a playful perspective, entrepreneurship can be understood as a game in which entrepreneurs must balance different resources and strategies to stay in the market.

Companies that do not integrate sustainability into their business model may face difficulties due to consumer pressure, government regulations, and competitors who have adopted responsible approaches. For example, Tesla has successfully capitalised on sustainability as a key differentiator in the automotive industry, gaining competitive advantages through innovation in electric vehicles and renewable energy (Z. Zhou, 2024). However, sustainability not only entails risks but also opportunities. The transition to a green economy has opened new markets and incentivised investment in innovative and sustainable solutions. Startups that integrate sustainable principles into their business model can access preferential financing, benefit from tax incentives, and consolidate a lasting competitive advantage (Evans et al., 2017).

2.6. Four Interrelated Dimensions

Although the four concepts explained in Sections 2.2–2.5—uncertainty, adaptability, growth, and sustainability—can be analysed separately, in the context of entrepreneurship, they are deeply intertwined. The very nature of entrepreneurship involves operating under conditions of uncertainty, where the outcomes of actions are not fully known, nor is all the information necessary to make decisions available. This uncertainty forces the entrepreneur to act judiciously and take risks, which is a key starting point for any entrepreneurial process.

In the face of this uncertain environment, adaptability becomes a critical capability. Successful entrepreneurs are those who can adjust their strategies, resources, and business models to respond to sudden changes in the market, technology, or regulations. This adaptive capacity not only allows them to survive but also to identify new opportunities, even in volatile environments. Adaptability, in turn, is essential for achieving business growth, as it allows for scaling operations, entering new markets, or pivoting the business model based on new realities.

Growth, however, must be accompanied by practices that guarantee sustainability, understood not only in economic terms but also in social and environmental terms. In this sense, sustainability is not a final state but rather a dynamic capacity that depends on the ability of the enterprise to evolve and remain viable over time.

Together, these four elements form a cycle that functions as a feedback loop characteristic of complex adaptive systems (Roundy et al., 2018): uncertainty acts as the initial condition that necessitates adaptability; this adaptability facilitates growth, which in turn must be governed by sustainability principles to ensure the system does not collapse under its own expansion.

2.7. Conway's Game of Life

2.7.1. Origin and Conceptualization

The Game of Life, developed by British mathematician John Horton Conway in the late 1960s, is a two-dimensional cellular automaton that simulates pattern evolution on a grid based on simple rules. It is a player-free game where an initial configuration evolves autonomously according to predefined rules. This game takes place on an infinite grid where each cell can be in one of two states: alive or dead. Cell evolution occurs in discrete time intervals called «generations», and, according to Gardner (1970), its behaviour is governed by four fundamental rules:

- **Survival**: A living cell with two or three living neighbours remains alive in the next generation.
- **Death by loneliness**: A living cell with fewer than two living neighbours dies in the next generation.
- **Death by overpopulation**: A living cell with more than three living neighbours dies in the next generation.

- **Birth**: A dead cell with exactly three living neighbours becomes a living cell in the next generation.

These rules generate complex, emergent patterns from simple initial configurations. Some well-known patterns include «oscillators», which maintain their position by repeating their shape in specific cycles; «gliders», coherent structures that physically move through the network across generations; and spacecraft, which move in a defined direction. According to Wolfram (2002), this behaviour reflects universal principles of dynamic systems.

The Conway's Game of Life has been widely studied in fields such as mathematics, computer science, and theoretical biology due to its ability to model self-organising processes and dynamic systems. Its impact on the theory of computation has been significant, as it is Turing-complete, meaning that it can simulate any computational algorithm given enough time and space.

Furthermore, modern computational studies have revisited these principles to develop «neural cellular automata», demonstrating that self-repairing and scalable systems can be engineered by training simple local rules to achieve global goals (Mordvintsev et al., 2020).

Since Conway's Game of Life is a dynamic system, the authors of this study propose that some characteristics can be found within it that relate it to entrepreneurship, which is also a dynamic system in itself.

2.7.2. The Four Main Features of Conway's Game of Life

Although seemingly simple, the Game of Life is an automaton that illustrates the four complex concepts—uncertainty, adaptability, growth, and sustainability—that have already been conceptualised in entrepreneurship and that go beyond binary outcomes and competitiveness, understood as characteristics or dimensions inherent to games. These characteristics are not only relevant in the context of the game but also have applications in fields such as biology, economics, and, of course, entrepreneurship.

- **Uncertainty in the Game of Life**: Uncertainty emerges as a systemic property despite the determinism of the basic rules, a phenomenon documented by Wolfram (2002) who demonstrated the extreme sensitivity to initial conditions in cellular automata. Although the rules of the game are deterministic—the state of a cell in the next generation depends only on the state of its neighbours in the current generation—the long-term evolution of the system is unpredictable. According to Gardner (1970), even simple initial configurations can give rise to complex and chaotic patterns that are difficult to anticipate. This unpredictability is analogous to the uncertainty faced by entrepreneurs in a dynamic business environment.
- **Adaptability in the Game of Life**: Adaptability is manifested in the ability of structures such as gliders to maintain their integrity through spatial displacement, a behaviour that Holland (1998) categorises as emergence in complex adaptive systems. Cells cannot «decide» their state, but the system as a whole exhibits adaptive behaviour. For example, certain configurations, such as «gliders», move around the network and can interact with other structures in ways that allow their survival and propagation. This phenomenon illustrates how adaptability arises from simple, localised rules.
- **Growth in the Game of Life**: Growth as a distinctive feature is verified by studying unbounded configurations such as the «Gosper Glider Gun», whose capacity for indefinite pattern generation shows self-organising properties. Some initial configurations may result in exponential growth, while others may quickly stagnate or disappear. For example, «devourer» structures are structures that can «consume» others, allowing for controlled and sustained growth. The game demonstrates that growth is neither linear nor predictable but rather depends on complex interactions between multiple factors.

- **Sustainability in the Game of Life**: Sustainability is demonstrated through the analysis of periodic and static structures that maintain their essential configuration over time, a phenomenon that Weick and Sutcliffe (2007) relate to principles of resilience in organisational systems. Some configurations, such as «still life» and «oscillators», can be maintained indefinitely without change, representing a sustainable equilibrium. However, other configurations can lead to extinction or uncontrolled growth that depletes available resources. According to Meadows et al. (1992), sustainability requires a dynamic balance between resource use and the regenerative capacity of the system, a principle reflected in the Game of Life.

2.7.3. Mathematical Model of the Game of Life

Drawing upon the work of Faux and Bassom (2023), who characterise Conway's Game of Life as a system where each cell is represented by a binary function, the governing mathematical formulas can be visualised as follows:

$$S\ (x,y,t) = \begin{cases} 1 & \text{If the cell is alive in } t \\ 0 & \text{If the cell is dead in } t \end{cases} \quad (1)$$

The change in state depends on the number of living neighbours:

$$N(x,y,t) = \sum_{i=-1}^{1} \sum_{j=-1}^{1} S\ (x+i,\ y+i.\ t) - S\ (x,y,t) \quad (2)$$

where $N(x, y, t)$ $N(x, y, t)$ $N(x, y, t)$ represents the sum of adjacent living cells. The rules determine the following state:

$$S(x,\ y,\ t+1) = \begin{cases} 1 & \text{If } N = 3 \textit{ or } (N = 2 \textit{ and } S(x,y,t) = 1) \\ 0 & \textit{Otherwise} \end{cases} \quad (3)$$

From the aforementioned formulas, depending on each particular case, dynamic patterns and structures emerge from the particular running phase of the game, which can be static, oscillatory, or in motion. Among these emergent configurations are the previously defined «gliders» and «oscillators», whose behaviours satisfy these state-transition rules. The evolution of the system is deterministic; for example, if you start with the same conditions, you will always receive the same result. However, due to the complexity of the interactions, its behaviour can be surprisingly chaotic and difficult to predict over the long term. This unpredictable, chaotic, or sometimes linear condition can be extrapolated to the reality faced by entrepreneurs when introducing their product or service into a market.

3. Rationale of the Study

The primary justification for this study lies in elucidating the relationship between stochastic market behaviour and entrepreneurial efforts to achieve success. Every entrepreneur must understand, recognise, and cope with market uncertainty and challenges, as well as the degree of competition their business will face.

While there is no guarantee that these factors will behave in the same or a similar way as expressed in Conway's Game of Life, the relationship between this game and the reality of entrepreneurship can serve as a guide for exploring strategy development and guiding decision-making.

4. Methodology

4.1. Aims

This study aims to: (i) Explore the fundamental characteristics of Conway's Game of Life and its relationship to entrepreneurship. (ii) Analyse how the rules of the Game of Life can be useful analogies for innovation and adaptation processes in entrepreneurship. (iii) Propose a mathematical model for entrepreneurship based on Conway's Game of Life.

In addition to the main objective of this study, the factors of entrepreneurship, the systemic and internal factors of the organisation, and the subsistent components are analysed here, depending on the scope of the entrepreneurship.

4.2. Study Design and Configuration

This study used a documentary review methodology, understood as a systematic process to identify, evaluate, and interpret existing research on a specific topic (Snyder, 2019). This approach made it possible to synthesise accumulated knowledge, identify theoretical patterns, and detect aspects that would support the analysis carried out (Torraco, 2016). In the case of the Game of Life, this methodology involved tracking primary and secondary sources with the aim of establishing a robust conceptual framework for the subject.

The review was implemented through a structured protocol that included:

- A search in academic databases (Web of Science, Scopus, JSTOR) was performed using a Boolean string combining keywords relevant to both fields: ("Conway's Game of Life" OR "Cellular Automata") AND ("Entrepreneurship" OR "Complex Adaptive Systems" OR "Business Dynamics"). The search covered the period from 1970 to 2024 to encompass both the foundational algorithmic literature and contemporary management applications.
- The selection of sources was governed by specific inclusion criteria: peer-reviewed articles, books, and conference proceedings in English and Spanish that explicitly linked computational modelling to social sciences, economics, or organisational ecology. Purely technical papers focusing solely on code optimisation without systemic or sociological implications were excluded. The final selection comprised the references cited in this document.
- A comparative analysis of findings (Kitchenham & Charters, 2007) was conducted to triangulate the biological rules with economic theories.

The main sources included foundational literature (Berlekamp et al., 1982), popular science articles (Gardner, 1970), and studies on complexity (Holland, 1998), complemented by observations from computer simulations to verify the patterns described.

The analysis combined qualitative and systematic techniques: first, thematic coding of recurring properties (uncertainty, adaptability, etc.) was performed following the framework of Braun and Clarke (2006). Specifically, an inductive three-stage coding process was adopted (Kraus et al., 2020). In the first stage (open coding), specific algorithmic behaviours in the Game of Life (e.g., "birth", "isolation", "glider movement") were identified. In the second stage (axial coding), these behaviours were interpreted and mapped to corresponding entrepreneurial phenomena (e.g., "market entry", "resource scarcity", "pivoting"). Finally, in the third stage (selective coding), these categories were aggregated into the four theoretical dimensions presented: uncertainty, adaptability, growth, and sustainability.

Then, constant comparative analysis (Glaser & Strauss, 1967) was applied to establish relationships between game dynamics and complex systems theories. By incorporating empirical observations cited in prior studies, it was possible to identify four fundamental characteristics of Conway's Game of Life: uncertainty, adaptability, growth, and sustainability. This approach leverages existing computational evidence to construct a robust theoretical framework, aligning with recent scholarship that bridges the gap between

abstract algorithmic models and practical entrepreneurial strategies to reduce the academic-practitioner divide (Shepherd & Gruber, 2021).

Furthermore, it is essential to distinguish between the methodological procedure and the subsequent theoretical reasoning. The identification and selection of literature followed the systematic protocols for rigour established by Snyder (2019) and Kitchenham and Charters (2007), ensuring that the data source was unbiased and comprehensive. In contrast, the construction of the parallel between the game and entrepreneurship relied on abductive inference. Following the logic of creative synthesis described by Torraco (2016), we reasoned not by direct deduction, but by identifying structural isomorphisms—functional similarities between the algorithmic rules of the cellular automata and the empirical behaviours observed in entrepreneurial ecosystems. This distinction clarifies that while the literature search was a structured verification process, the resulting analogy is a heuristic construct designed to offer new explanatory pathways, not a literal equation of human behaviour.

4.3. Limitations

While the inferential logic used establishes a strong functional validity between the two systems, this analogy has clear limits. Conway's Game of Life is a deterministic system where rules are immutable, whereas entrepreneurship involves human agency, emotional intelligence, and regulatory changes that can defy rigid algorithmic logic. Therefore, the proposed model should be viewed as a heuristic framework for strategic analysis rather than a predictive tool for individual human behaviour. The study is limited to examining the parallels based on four identified dimensions: uncertainty, adaptability, growth, and sustainability, acknowledging that social nuances exceed the binary states of a cellular automaton.

5. Discussion of the Results

5.1. Entrepreneurship and Its Relationship with Conway's Game of Life

Both systems operate within complex structures where small initial variations can generate unpredictable results, illustrating the «butterfly effect» central to chaos theory in business contexts (Debnath, 2022). Unlike the definitions provided in the literature review, uncertainty here is observed as an emergent property of the system's mechanics; in the game, the evolution of patterns depends on localised interactions between cells, making long-term configurations impossible to predict without step-by-step simulation.

While traditional management theories often depict the entrepreneur as a strategic operator controlling every move, complexity science suggests a role closer to that of an architect of initial conditions. In this view, the entrepreneur designs the «seed» pattern —configuring the business model, team, and value proposition—but once launched, the venture evolves through emergent interactions that are largely autonomous. Successful entrepreneurship is less about deterministic control and more about designing robust systems capable of navigating unpredictable market dynamics.

In this parallel, the entrepreneur is not an isolated cell, as a solitary cell tends to disappear quickly. Instead, the entrepreneur is represented by a group of cells that interact to form complex and sustainable patterns. Just as in Conway's Game of Life a group of cells can generate persistent configurations, in entrepreneurship, the entrepreneur relies on a relational environment to sustain their initiative. This emergent organisation resembles how certain patterns arise spontaneously from the localised interaction of a group of cells, without a centralised design.

Disruptive innovations or new industries are emergent behaviours that cannot be explained simply by analysing individuals in isolation. Furthermore, the Conway's Game

of Life illustrates how small variations in initial conditions can lead to radically different outcomes, a concept known as sensitive dependence on initial conditions. An entrepreneur must be able to adapt to a changing environment, similar to how game cells evolve according to the rules of the system. Basic principles, such as problem-solving or opportunity identification, can generate innovative and sustainable results when applied in a dynamic environment.

5.1.1. Entrepreneurship, Conway's Game of Life, and Uncertainty

Uncertainty is an intrinsic element; in the game, the evolution of patterns depends on localised interactions between cells, making long-term configurations impossible to predict without step-by-step simulation. In entrepreneurship, uncertainty arises from regulatory changes or market fluctuations, making accurate forecasts equally impossible. Both contexts require continuous adaptation: rules are fixed, but outcomes are not.

Innovative business models, such as «uberisation» or subscriptions, arise from principles like scalability or flexibility. Seemingly chaotic systems can spontaneously generate order if there are mechanisms for iteration and selection. Methodologies such as Lean Startup promote rapid experimentation to recognise and reduce uncertainty. Ultimately, failure is part of the process: most patterns in the game stabilise or disappear, just as most startups do not survive the early stages.

To illustrate this, Figure 1 presents a «Soup» configuration, a randomised initial state with high entropy. In this phase, it is visually impossible to determine which cells will stabilise and which will perish, perfectly mirroring the initial uncertainty of a startup ecosystem where the «winning» business model is not yet discernible (Ries, 2011).

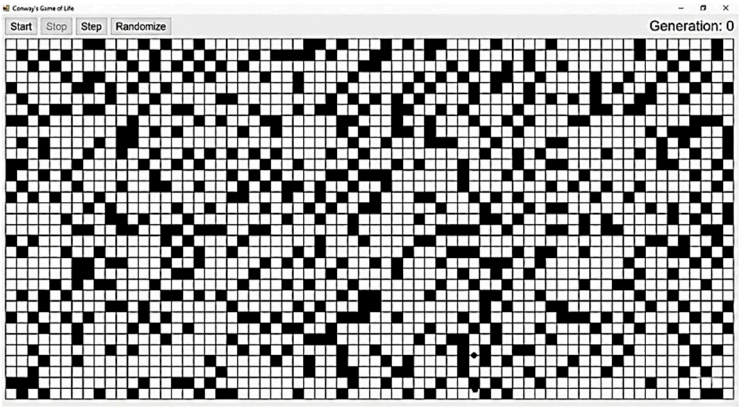


Figure 1. High entropy initial state (The Soup) representing market uncertainty. Source: Elaborated for this study.

5.1.2. Entrepreneurship, Conway's Game of Life and Adaptability

Regarding adaptability, the parallel extends beyond simple survival; it reflects a continuous calibration of internal resources against external volatility (Liguori & Pittz, 2020). Cells adjust to their immediate environment, surviving only if they meet specific interaction conditions.

Adaptability in both systems arises from simple rules that generate complex behaviours. Similarly, entrepreneurs modify strategies based on feedback from customers and competitors. This shows how seemingly rigid systems can evolve through flexible, decentralised mechanisms.

This dynamic is visually captured in Figure 2, which depicts a «glider». Unlike static blocks, this pattern persists solely through continuous displacement. This serves as a powerful visual metaphor for the pivot: the entity survives not by remaining in a fixed state, but by constantly regenerating itself in new coordinates to avoid stagnation.

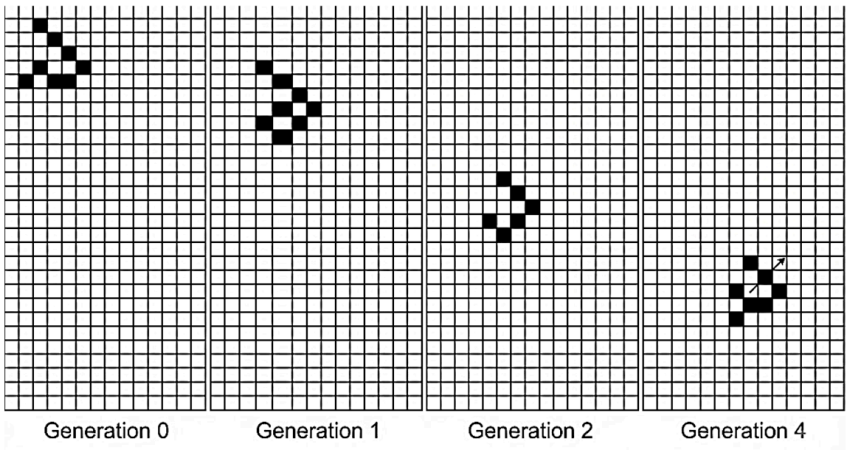


Figure 2. The «glider» pattern representing adaptability and pivoting. Source: Elaborated for this study.

Sustainable patterns, such as «gliders», persist because they adapt to the system's rules. In entrepreneurship, successful business models result from iterations that discard the unviable. Adaptability is not an intrinsic quality but a response to unstable environments. Therefore, navigating chaos through iterative learning is essential for survival.

5.1.3. Entrepreneurship, Conway's Game of Life and Growth

Growth follows non-linear patterns where small local interactions generate unpredictable global outcomes, consistent with recent findings on high-growth firms in uncertain ecosystems (Kuckertz et al., 2020).

Figure 3 illustrates this through the «Gosper Glider Gun», a remarkable configuration that acts as a finite engine capable of producing an infinite stream of gliders. This visualises the «holy grail» of entrepreneurial growth: a scalable system that generates continuous value (output) without depleting its core structural resources.

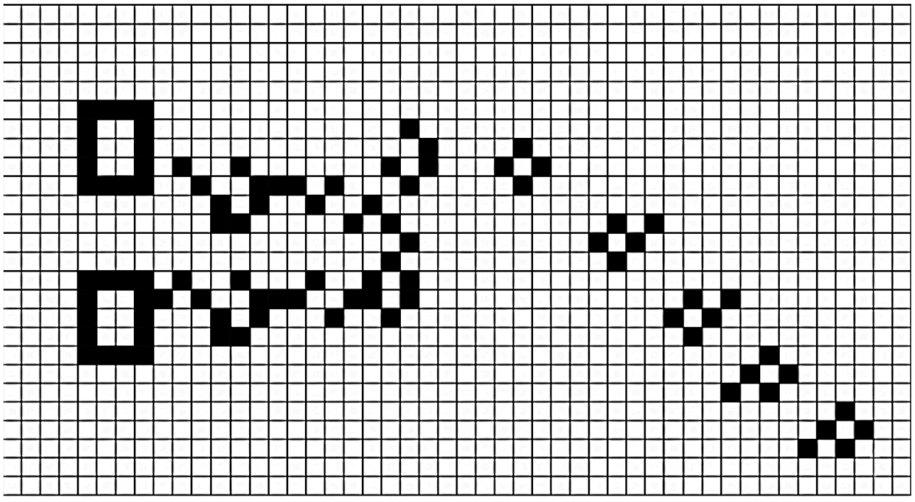


Figure 3. The «Gosper Glider Gun» representing scalable growth. Source: Elaborated for this study.

Successful growth requires patterns capable of reproducing themselves while maintaining their essential integrity, such as franchises or digital platforms.

However, growth faces limitations. In the game, expansive configurations eventually collide with neighbours that may slow their development. In business, scaling encounters barriers like market saturation or regulatory constraints. Optimal growth requires a balance

between stability and change; successful companies maintain a solid core while innovating on their peripheries.

5.1.4. Entrepreneurship, Conway's Game of Life and Sustainability

Sustainability emerges from the ability to maintain stable patterns without exhausting resources. «Oscillator» configurations persist indefinitely by finding equilibrium among their components, similar to sustainable ventures that achieve a balanced flow between revenues, costs, and growth.

As shown in Figure 4, «oscillators» (such as the Blinker or Toad) exemplify this capacity for structural maintenance through periodic repetition. This represents the sustainability of established firms that have mastered the rhythm of their operations, achieving a dynamic equilibrium that resists external volatility.

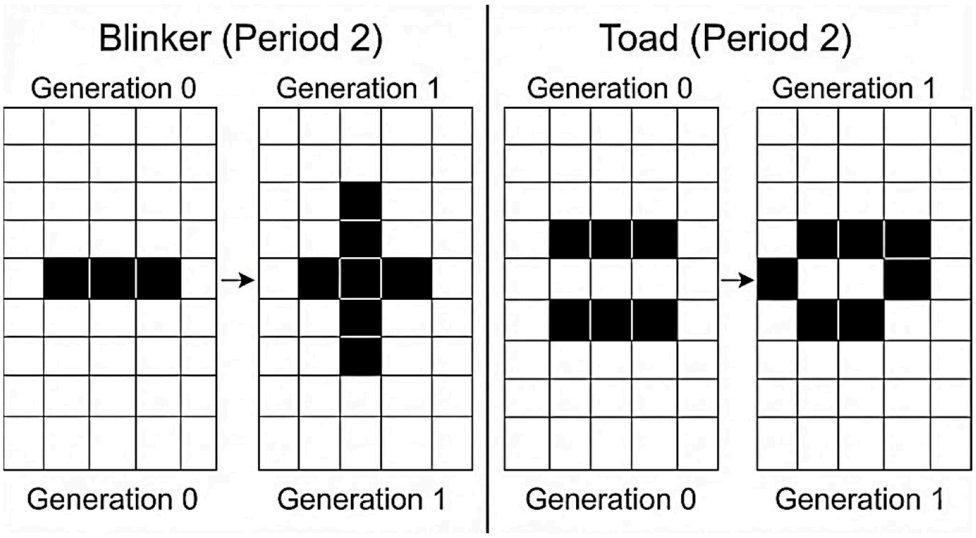


Figure 4. «Oscillator» patterns representing «Dynamic Sustainability». Source: Elaborated for this study.

True sustainability is a dynamic state of self-regulation.

Sustainable business models are harmoniously integrated into their economic and social ecosystems. Often, the most durable configurations are the simplest, suggesting that excessive complexity can compromise long-term sustainability. Truly sustainable organisations are those that can reinvent themselves while maintaining their fundamental purpose (see Table 1).

Table 1. Parallels between Entrepreneurship and Conway's Game of Life.

Dimension	Entrepreneurship	Conway's Game of Life	Parallels
Uncertainty	Entrepreneurs face a changing environment with no guarantee of success. Decisions must be made with incomplete information and constant risks.	Each new generation of cells can have unpredictable behaviour, depending on simple initial conditions	Both contexts are based on known rules or conditions, but the results can be unexpected and highly sensitive to small changes.
Adaptability	A successful startup must adjust its business model, strategies, or products to suit the environment and market needs.	Cells «survive» only if they adapt to their immediate environment; their survival depends on local dynamics.	The survival of both the enterprise and the cells in the game depends on their ability to adapt to their changing environment.

Table 1. *Cont.*

Dimension	Entrepreneurship	Conway's Game of Life	Parallels
Growth	It involves expansion, whether by increasing customers, revenue, or territory; growth can be rapid or gradual, depending on strategic decisions.	Cells can multiply rapidly, forming complex structures, but this growth depends on their initial configuration.	In both cases, growth arises as a result of favourable conditions and good strategic decisions (or initial patterns).
Sustainability	A business must be sustained over time, managing resources and avoiding errors that make it unviable.	Some configurations manage to remain stable or repetitive over time, avoiding extinction.	Sustainability depends on internal balance: in entrepreneurship, on resources and decisions; in games, on stable or cyclical patterns.

Source: Elaborated for this study.

5.2. Additional Parallels

5.2.1. Systemic Properties and Entrepreneurship and Their Relationship with Conway's Game of Life

Entrepreneurship does not emerge out of nowhere but is profoundly influenced by the systemic properties of the environment in which it develops. These properties, which include factors such as collaboration networks, infrastructure, public policies, and culture, form an ecosystem that facilitates or constrains entrepreneurial activity. This environmental dependency has been described in the recent literature as «ecosystem governance», where the alignment of bottom-up initiatives with top-down support determines the resilience of the system (Stam & van de Ven, 2021).

A healthy entrepreneurial ecosystem is characterised by the dynamic interaction of multiple actors, such as governments, universities, investors, and entrepreneurs, who generate synergies that drive innovation and economic growth. Systemic properties, such as connectivity and diversity, are critical to fostering entrepreneurship. For example, collaborative networks allow entrepreneurs to access resources, knowledge, and markets, which reduces uncertainty and increases the likelihood of success. Moreover, the diversity of actors in an ecosystem promotes innovation by facilitating the combination of different ideas and perspectives.

Public policies also play a crucial role in creating favourable conditions for entrepreneurship. For example, financing programmes, tax incentives, and flexible regulations can stimulate new business creation. However, for these policies to be effective, they must be aligned with the specific needs of the local ecosystem. It can, therefore, be stated that systemic properties are a determining factor for the success of entrepreneurship. A well-structured ecosystem, with strong networks, a diversity of actors, and appropriate policies, can drive innovation and economic growth. Conversely, the lack of these properties can limit a region's entrepreneurial potential.

Directly, the systemic properties of entrepreneurship are related to Conway's Game of Life in two aspects:

- **Emergence**: According to Holland (1998), complex systems generate global properties from local interactions. In entrepreneurship, this is reflected in how disruptive innovation can emerge from the iteration of minimum viable prototypes.
- **Adaptability**: Gompers and Lerner (2004) highlight that successful entrepreneurs are those who adapt quickly to change, similar to how patterns in the Game of Life evolve to survive in a dynamic environment.

From the perspective of Administrative Sciences, this analogy underscores the critical role of policy and institutional contexts in shaping the evolutionary dynamics of the ecosystem. Just as the specific birth and death rules in Conway's algorithm dictate the emergence

of global patterns, the regulatory frameworks and governance structures established by public administration determine the metabolic rate of the entrepreneurial environment.

In this sense, policymakers function as the architects of the system's initial parameters, defining the boundary conditions that either inhibit or stimulate activity. Recent scholarship in administrative theory suggests that effective ecosystem governance requires a shift from direct interventionism to the design of «enabling rules» that foster self-organisation, thereby reducing friction for high-growth ventures while ensuring systemic stability (J. Zhou & Cen, 2024). Consequently, the alignment between micro-level entrepreneurial actions and macro-level institutional logic becomes a determining factor for regional economic development.

5.2.2. Local Decisions and Global Success

As established, in Conway's Game of Life, the state of each cell —alive or dead— depends solely on the rules applied to its immediate environment; that is, its nearest neighbours. These local decisions, although simple, can result in unpredictable global behaviours, such as the formation of stable, oscillating, or mobile patterns. Similarly, in entrepreneurship, local decisions, such as choosing a market niche, hiring talent, or implementing a marketing strategy, may initially seem limited in scope. However, these decisions have the potential to generate significant global impacts, especially when aligned with market needs or emerging trends.

In the Conway's Game of Life, global success is not the result of a centralised design but rather of the decentralised interaction of multiple cells following local rules. For example, patterns such as the «planner» emerge from the interaction of individual cells without a predetermined plan. In entrepreneurship, the global success of a firm or business ecosystem can also emerge from local decisions. For instance, disruptive innovation often begins with small, local decisions, such as experimentation with new technologies or business models, which then scale and transform entire industries. Moreover, a firm's global success can depend on the synergy between multiple local decisions, such as collaboration among teams, partners, or communities.

In both the Conway's Game of Life and entrepreneurship, there is an inherent interconnection between local decisions and global outcomes. In the game, the state of one cell affects its neighbours, which in turn influences the overall configuration of the system. In entrepreneurship, an entrepreneur's local decisions, such as choosing a supplier or adopting a sustainable practice, can have global repercussions, such as creating more efficient value chains or promoting responsible practices. This interdependence highlights the importance of considering the broader impact of seemingly small or local decisions. Thus, it can be said that, in the game, the state of a cell depends on its immediate neighbours, similar to how the initial success of a business depends on microeconomic decisions. Ries (2011) argues that rapid iterations allow for the identification of sustainable patterns, as in Conway's Game of Life.

5.2.3. Emerging Innovation

In the Conway's Game of Life, emergent innovation manifests itself through the creation of complex patterns, such as «gliders», «spaceships», and «weapons», that arise from the application of basic rules to individual cells and their neighbours.

These patterns are not predefined but arise from the dynamic interaction of cells following local rules. Similarly, in entrepreneurship, innovation is not always the result of a centralised plan but can arise from the interaction of multiple factors, such as collaboration between teams, experimentation with new technologies, or adaptation to market needs. In the context of entrepreneurship, emergent innovation occurs when seemingly small, local ideas or initiatives combine to generate disruptive solutions. For example, startups like

Airbnb and Uber emerged from the combination of existing technologies—online platforms and mobile apps—with new ways of thinking about accommodation and transportation. These innovations were not the result of a centralised design but rather the interaction of multiple local decisions and adaptations that, when scaled, transformed entire industries.

Thus, in the Conway's Game of Life, «emergent innovation» depends on the continuous interaction between cells and their ability to adapt to changes in their immediate environment. In entrepreneurship, innovation also depends on the interaction between various actors, such as entrepreneurs, investors, customers, and suppliers, in addition to the ability to adapt to changing market conditions. This can be seen, for example, as open innovation, where firms collaborate with third parties to develop new ideas, reflecting how interaction and adaptation can generate innovative outcomes.

5.2.4. Resilience and Adaptation

As mentioned above, adaptation in the Conway's Game of Life is observed in the evolution of complex patterns from simple rules. Some configurations, such as the glider, show how small modifications can generate significant movements or changes in the system. In the context of entrepreneurship, adaptation is crucial to respond to market demands, innovate, and take advantage of new opportunities. Entrepreneurs must be able to adjust their products, services, or strategies based on changing environmental conditions, just as patterns in the Game of Life evolve based on interactions with their neighbours.

In both the Conway's Game of Life and entrepreneurship, the importance of interactions between individual elements and their environment is emphasised. In the Conway's Game of Life, cells depend on their neighbours for survival or extinction, whereas in entrepreneurship, firms depend on their ability to interact with customers, competitors, and regulators. Moreover, in both the game and entrepreneurship, uncertainty and unpredictability are inherent factors that require dynamic and flexible responses. In the Conway's Game of Life, certain configurations, such as the «block» or the «lantern», are stable and resilient to environmental changes. In entrepreneurship, this resilience is observed in companies that identify a sustainable niche and gradually evolve.

5.2.5. Exponential Growth

As explained above, in Conway's Game of Life, the state of each cell —alive or dead— depends on its interaction with neighbouring cells, generating dynamic and often unpredictable patterns. Similarly, entrepreneurship is not an isolated phenomenon but rather the result of complex interactions between entrepreneurs, markets, institutions, and other actors within an ecosystem. These interactions can lead to emergent behaviours, such as the creation of new industries or the emergence of disruptive innovations, which cannot be explained simply by analysing individuals in isolation.

Furthermore, the Conway's Game of Life illustrates how small variations in initial conditions can lead to radically different outcomes, a concept known as sensitive dependence on initial conditions. In entrepreneurship, this is reflected in the importance of context and timing for the launch of an idea or business. An entrepreneur must be able to adapt to a changing environment, similar to how the cells of a game evolve according to the rules of the system. Just as the Conway's Game of Life shows how the simplicity of rules can generate complexity, in entrepreneurship, this same perspective translates into the idea that basic principles—such as problem-solving or opportunity identification— can lead to innovative and sustainable results when applied in a dynamic environment. Viewed more directly, the diffusion of replicated patterns in the Conway's Game of Life reflects the exponential growth observed in scalable entrepreneurship.

5.3. Mathematical Representation of the Correlation Between Entrepreneurship and Conway's Game of Life (Proposed Model)

To rigorously demonstrate the correlation between Conway's Game of Life and entrepreneurship, it is insufficient to rely solely on qualitative metaphors, a mathematical framework must be established that operationalises the parallels identified in this study. If entrepreneurship is indeed a complex adaptive system, as argued by Holland (1995) and Shane (2003), its dynamics should be expressible through state-transition rules similar to those governing cellular automata.

To ensure structural coherence with the narrative analysis presented in Section 5.1, the proposed model explicitly maps the four qualitative dimensions into quantitative variables (Levin et al., 2022). Specifically, «uncertainty» is operationalised as a stochastic term (ξ), «adaptability» is introduced as an agency coefficient (A), «growth» is represented by the density of neighbour interactions ($\sum E$), and «sustainability» is modelled through the equilibrium thresholds (θ) that determine survival. This mathematical translation allows us to move from metaphorical isomorphism to functional simulation.

The following model formalises this relationship, translating the biological rules of Conway's simulation into economic variables to prove that entrepreneurial survival is governed by the same systemic principles of neighbourhood interaction and boundary conditions.

5.3.1. The Entrepreneurial State Function

The fundamental unit of Conway's Game of Life is the cell, which exists in a binary state: alive or dead. To map this into the entrepreneurial context, we define the state of a venture located at coordinates (x, y) in the market grid at time t using the function $E(x, y, t)$:

$$\begin{aligned} E(x, y, t) &= 1 \text{ If the venture is Active (solvent and operational)} \\ E(x, y, t) &= 0 \text{ If the venture is Inactive (insolvent or market exit)} \end{aligned} \tag{4}$$

This binary function establishes the direct isomorphism between the two systems. Just as a cell in Conway's grid is either «alive» or «dead» based on its previous state, an entrepreneurial venture is either «operational» or «defunct». This simplification allows us to treat the market not as a continuous chaos, but as a discrete grid where the presence or absence of actors creates the patterns observed in the economy.

5.3.2. The Viability Potential Function (Ψ)

In Conway's original rules, the fate of a cell is determined exclusively by a simple sum of its neighbours. However, human systems differ from biological automata in one key aspect: agency. An entrepreneur is not a passive cell; they possess internal capabilities. Therefore, we propose a composite variable called the Viability Potential (Ψ), which determines the strength of the venture:

$$\Psi\ (x, y, t) = \alpha \cdot A(t) + \beta \cdot \sum E(i, j, t) + \xi(t) \tag{5}$$

where:

- $A(t)$ is the Adaptability Factor (Internal capabilities).
- $\sum E(i, j, t)$ is the Ecosystem Density (Sum of active neighbours).
- $\xi(t)$ is Stochastic Uncertainty (Random external shocks).
- α and β are weighting coefficients.

This formula is an evolution of Conway's neighbour-counting mechanic. In the Game of Life, the «potential» for survival is strictly $\sum$ Neighbours. In this entrepreneurial model, the term $\beta \cdot \sum E$ represents this exact Conway mechanic (the influence of the neighbourhood). However, we augment this by adding $\alpha \cdot A(t)$ to represent the entrepreneur's ability to influ-

ence their own fate (unlike a passive cell), and $\xi(t)$ to represent the non-deterministic nature of markets (unlike the deterministic Game of Life). This demonstrates that entrepreneurship is a «Game of Life with Agency».

5.3.3. The Dynamic Transition Rules

Having defined the potential of the venture, we must establish the rules that determine its state in the next generation ($t + 1$). In Conway's game, survival requires 2 or 3 neighbours; fewer causes death by loneliness, and more causes death by overpopulation. We translate these specific integers into dynamic thresholds, θ_{min} and θ_{max}:

$$E(x,\ y,\ t+1) = \begin{cases} 1 & \text{If } \theta_{min} \leq \Psi(\mathrm{x},\mathrm{y},\mathrm{t}) \leq \theta_{max} \\ 0 & Otherwise \end{cases} \quad (6)$$

This inequality is the mathematical equivalent of Conway's four genetic rules:

- **Death by Isolation ($\Psi < \theta_{min}$):** Corresponds to Conway's rule of «Underpopulation» (fewer than 2 neighbours). If the venture lacks sufficient resources or network support (low Viability Potential), it dies.
- **Death by Saturation ($\Psi > \theta_{max}$):** Corresponds to Conway's rule of «Overpopulation» (more than 3 neighbours). If the market is too crowded or the venture over-expands beyond its capacity, it collapses.
- **Survival and Birth (Within the Window):** Corresponds to Conway's «Survival» (2–3 neighbours) and «Reproduction» (3 neighbours) rules. A venture survives or is born only when the tension between internal adaptability and external pressure falls within this optimal «Goldilocks zone».

5.3.4. Practical Application: A Strategic Simulation Under Uncertainty

To illustrate the practical utility of the proposed mathematical model and respond to the need for applied examples, this section presents a simulation of a hypothetical scenario where an entrepreneur must decide whether to launch a new technology venture in a developing ecosystem. This step-by-step simulation demonstrates how the Viability Potential (Ψ) serves as a heuristic tool for decision-making.

Then, the hypothetical scenario would be as follows:

An entrepreneur plans to launch a startup in a niche market with very few active competitors or partners. In Conway's terms, this represents a "lonely" cell on the grid.

- **Current State**: The venture is currently inactive, so $E(x, y, t) = 0$.
- **Ecosystem Density ($\sum E$)**: The market analysis reveals only one major player in the immediate vicinity. Thus, $\sum E = 1$.
- **Survival Threshold (θ_{min})**: Based on industry standards (capital requirements, customer base), the minimum potential required to sustain operations is estimated at 3 units ($\theta_{min} = 3$).
- If we apply the strict, deterministic rules of the original Game of Life, a cell with only one neighbour dies (or is not born) due to underpopulation (isolation). Without intervention, the venture is destined to fail because the external support is insufficient.
- Using Equation (5), the entrepreneur calculates the Viability Potential (Ψ):

$$\Psi(t) = \alpha \cdot A(t) + \beta \cdot (1) + \xi\ (t)$$

If the entrepreneur relies solely on the ecosystem (where $\beta = 1$ and $\sum E = 1$), the Potential is approx. 1, which is less than the required threshold of 3 ($\Psi < \theta_{min}$). The decision model predicts failure.

However, unlike a passive cell, the entrepreneur can manipulate the Adaptability Factor, $A(t)$. The formula reveals that to reach the survival threshold ($\Psi \geq 3$), the entrepreneur must compensate for the lack of neighbours ($\sum E$) by increasing internal adaptability.

The entrepreneur decides to implement a Lean Startup methodology (Ries, 2011), which drastically increases the variable $A(t)$ by allowing rapid pivoting and resource optimisation.

If the strategy increases $A(t)$ to a value of 2.5 (high adaptability), the new calculation becomes:

$$\Psi(t) = 2.5 + 1 + \xi(t) \approx 3.5$$

Since $3.5 \geq \boldsymbol{\theta_{min}}$ (3), the venture enters the «Survival Window» described in Equation (6). The «birth» of the company becomes viable not because the environment changed, but because the internal configuration (Adaptability) acted as a counterbalance to environmental isolation.

This example demonstrates that the formula serves as a strategic compass. It forces the entrepreneur to recognise that in low-density environments (Conway's isolation), survival is only possible through high adaptability. Conversely, in high-density environments (Conway's overpopulation), the same formula would suggest reducing rigidity or finding a new niche to avoid exceeding $\boldsymbol{\theta_{max}}$. Thus, the mathematical model transforms the Conway's Game of Life from a metaphor into a logic for balancing internal agency against external constraints.

5.3.5. Implications of the Model

This mathematical formulation provides a rigorous proof that entrepreneurship operates under the logic of Class IV Cellular Automata, systems that exist on the «Edge of Chaos».

Just as Conway's simple rules generate complex structures like «gliders» and «oscillators» without a central designer, this model demonstrates that complex entrepreneurial ecosystems (clusters, hubs, supply chains) emerge not from central government planning, but from the local interactions defined in Equation (6). The inclusion of the Adaptability variable $A(t)$ mathematically proves why some entrepreneurs (gliders) can move and survive in hostile environments where static companies (still life) would perish, validating the theoretical analogy through computational logic.

5.4. Other Dimensions for Conway's Game of Life

Despite having explored the relationship between the four main characteristics that relate entrepreneurship to Conway's Game of Life, it is possible to list other dimensions that could have a place when extrapolating the use of this game as a basis for the study, visualisation, and understanding of entrepreneurship from a disruptive perspective; these dimensions are:

- **Emergence of complex patterns from simple rules**: The game demonstrates how complex structures emerge from interactions based on minimal rules (Gardner, 1970). In entrepreneurship, this is reflected in the ability to generate innovative business models from simple ideas, highlighting the importance of iteration and adaptation (Ries, 2011).
- **Survival, growth, and extinction dynamics**: Cells in the game «survive», «die«, or «born» depending on their environment, similar to how startups compete in changing markets (Blank, 2013a). The analogy highlights the need to adapt to external conditions in order to thrive.
- **Importance of environment and interconnections**: The state of a cell depends on its neighbours, similar to the dependence of entrepreneurs on networks of contacts, collaborators, and market trends (Stam, 2015). Success is not isolated, but systemic.

- **Experimentation and iterative learning**: The game allows for testing configurations to observe outcomes, paralleling the «build-measure-learn» method used by startups (Ries, 2011). Entrepreneurs must quickly test hypotheses and adjust accordingly.
- **Resilience and Sustainability**: Some patterns in the game (such as «oscillators») persist over time, while others disappear. This reflects the need to build resilient business models (Weick & Sutcliffe, 2007).

The above allows us to infer that, to the extent that the nature of entrepreneurship and its dynamism are understood, it is possible to find elements in mathematical models, automated programmes, and simulation models that coincide with, feed into, or allow us to better understand economic and social phenomena such as entrepreneurship, which requires the sharpness of rational, critical, profound, and disruptive thinking.

6. Main Contributions of the Parallels Between Conway's Game of Life and Entrepreneurship

Although this is a theoretical approach, it can be stated that the main contributions offered by this study are the following:

- **A different theoretical perspective for entrepreneurship**: This study advances the field of entrepreneurship by introducing a new theoretical framework based on complex systems theory, using Conway's Game of Life as both a metaphor and a simulation model. This perspective conceptualises entrepreneurship as a dynamic and adaptive system, where local decisions can result in emergent, non-linear, and sometimes unpredictable global outcomes. Such understanding is key to analysing disruptive innovation, business model evolution, and entrepreneurial survival.
- **Balance between innovation and operational stability**: The analogy between Entrepreneurship and Conway's Game of Life emphasises that sustainable scaling depends not only on innovation but also on operational stability and systemic fit. Startups that balance novelty with resilience can grow organically, achieving both internal coherence and external alignment.
- **Dynamic configurations as adaptation models**: Dynamic configurations such as «gliders» exemplify how businesses can achieve sustainable progress through continuous adaptation. This insight aligns with the principle of strategic iteration, where decisions are evaluated and modified based on environmental feedback, akin to the movement of gliders within the game grid (Berlekamp et al., 1982).
- **Entrepreneurship as a complex adaptive system**: From the authors' perspective, entrepreneurship is understood as an emerging phenomenon driven by iteration, continuous learning, and responsiveness to environmental conditions, concepts rooted in the theory of complex adaptive systems (Holland, 1995; Blank, 2013b; Ries, 2011). By leveraging the Game of Life's rules, the document offers a mathematical representation of entrepreneurial behaviour under uncertainty, modelling variables such as adaptability, sustainability, and growth. This analogical approach makes it possible to simulate how choices like resource allocation, market targeting, or organisational structure can shape entrepreneurial outcomes (Mitchell, 2009; Gardner, 1970).
- **Expanding the traditional approach to entrepreneurship**: These insights expand traditional, often economic, views of entrepreneurship by incorporating systemic properties such as emergence, feedback loops, and sensitivity to initial conditions (Wolfram, 2002; Shane & Venkataraman, 2000). It also enhances conceptual and pedagogical tools for both researchers and educators, allowing entrepreneurship to be approached as a system where micro-decisions can trigger macro-patterns.
- **Iteration, learning, and sustainability**: This theoretical approach also supports the implementation of iterative, feedback-driven practices such as the Lean Startup (Blank,

2013b), enabling entrepreneurs to navigate uncertainty through validated learning. In this way, they can develop minimum viable products, simulate their evolution, and refine strategies based on market reactions.

- **Local actions, global behaviours**: The parallel between Conway's Game of Life and entrepreneurship offers a useful heuristic for explaining how simple, localised actions generate complex adaptive behaviours in uncertain environments. As in the Game of Life, entrepreneurial configurations can stabilise, expand, or vanish depending on their initial design and external pressures (Berlekamp et al., 1982). These patterns reflect critical principles in entrepreneurship such as resilience, adaptability, and strategic flexibility.
- **Mental laboratories for decision-making**: These simulations act as «mental laboratories», enabling entrepreneurs to anticipate failure points, sustainability thresholds, or opportunities for growth. Configurations such as «oscillators» or «gliders» serve as visual models for testing hypotheses about product design, team structure, or market timing.
- **Pedagogical and research applications**: Educators and researchers can use this model to teach and study entrepreneurial ecosystems as adaptive systems. Professors may employ Conway's Game of Life to simulate market scenarios, promote critical thinking, and train students in identifying key leverage points in business development (Holland, 1995; Wolfram, 2002). Researchers can apply the framework to build novel analytical methods based on the behaviour of complex systems.
- **Predictive power and sustainable scaling**: The Conway's Game of Life framework also offers predictive power by illustrating how certain initial conditions lead to specific patterns. This can help entrepreneurs and investors identify early indicators of potential growth, decline, or transformation. In particular, the model supports the design of ventures that are structurally capable of adapting to external shocks, improving decision-making under uncertainty.
- **Scalability as iterative evolution**: For emerging businesses aiming to scale and become consolidated companies, the model illustrates how sustainable growth arises from the consistent application of simple rules and local responsiveness. Just as resilient patterns in the Game of Life emerge through iterative interactions, successful startups evolve by continuously adjusting their strategies in response to market feedback (Blank, 2013a; Weick & Sutcliffe, 2007).
- **Simulation as a methodological tool**: From a methodological standpoint, this approach offers a simulation framework to visualise and test how early-stage decisions impact long-term outcomes. Using systematic rules similar to those in the Game of Life, entrepreneurs can explore the likely evolution of their ventures in various hypothetical environments, helping them understand the significance of initial conditions and the multiplicative effects of small changes (Johnson, 2001; Wolfram, 2002).
- **Strategic planning based on simulations**: Conway's Game of Life not only serves as a metaphor but also functions as an analytical tool for strategic planning. Entrepreneurs can model the progression of their business across different scenarios, observing how micro-decisions generate trajectories of success, stagnation, or failure (Gardner, 1970; Mitchell, 2009). This enables more informed choices and encourages experimentation through a safe, visual medium.
- **Strategies informed by systemic logic**: Practically, this perspective enables entrepreneurs to develop strategies that account for systemic complexity. Understanding how initial configurations influence future patterns helps in assessing foundational decisions such as target market selection, business model design, and leadership structure (Gardner,

1970; Holland, 1995). Entrepreneurs are encouraged to see their ventures as evolving entities, shaped by interactions with external and internal variables.

- **Sustainable models and dynamic structures**: For instance, stable game structures like «still life» represent sustainable entrepreneurial models that maintain equilibrium with their environment, while dynamic structures like «gliders» illustrate ventures that evolve continuously to remain viable. This systems-based view aligns with the concept of dynamic capabilities (Teece et al., 1997), highlighting the importance of strategic responsiveness.
- **Systemic evaluation of strategic decisions**: Entrepreneurs can therefore adopt a systemic logic when evaluating strategic options, considering not only individual variables but also their interactions and potential ripple effects. This approach fosters the development of robust, interconnected strategies that support long-term viability even in volatile markets.
- **Utility for consultants and analysis**: Consultants and analysts may also benefit from the mathematical representations proposed, using them to model organisational configurations, assess risk, and predict emerging behaviours. This integrative and interdisciplinary model provides a robust foundation for both theoretical advancement and practical decision-making across the entrepreneurial ecosystem.
- **Visualise economic, social, and environmental impact**: Furthermore, the framework facilitates the adoption of triple-bottom-line strategies (Elkington, 1999) by helping entrepreneurs visualise the long-term impacts of their decisions on economic, social, and environmental dimensions. Structures that persist in the Conway's Game of Life mirror the resilience required for sustainable businesses.

7. Conclusions

This study concludes that the parallel between Conway's Game of Life and entrepreneurship is not merely a convenient metaphor but represents a structural isomorphism that scientifically validates entrepreneurship as a complex adaptive system. Unlike traditional linear models that treat market volatility as external noise, the specific findings presented in this research demonstrate that chaotic dynamics are intrinsic to the system's logic.

First, the simulation of high-entropy initial states, visualised as «the soup», confirms that uncertainty is not a temporary anomaly to be eliminated but a systemic starting point. In this phase, the impossibility of predicting which cells will survive mirrors the inherent unpredictability of early-stage ventures, proving that success often depends on probabilistic initial conditions rather than deterministic planning.

Second, the identification of «glider» patterns validates that adaptability is fundamentally a function of displacement and reconfiguration. The findings show that static agents in the game inevitably perish or calcify, whereas «gliders» survive only by iteratively adjusting their coordinates. This offers a powerful theoretical validation for the «pivot» in entrepreneurship: survival is not about defending a fixed position but about the continuous regeneration of the business model in response to environmental feedback.

Third, the analysis of the «Gosper Glider Gun» challenges standard growth theories by illustrating that high-impact growth requires generative structures. The study reveals that sustainable scalability is only possible when a system can produce infinite output (value) without depleting its core structural resources, a critical insight for designing exponential organisations.

Fourth, the persistence of «oscillator» patterns provides a concrete definition of sustainability as a dynamic equilibrium. Rather than a static state of permanence, true sus-

tainability is shown to be a rhythmic cycle where internal stability is maintained despite external volatility.

Finally, the mathematical model proposed in Equation (5) successfully bridges the gap between abstract theory and managerial practice. By introducing the Agency variable (A), the model mathematically proves that entrepreneurial adaptability can act as a counterbalance to environmental determinism ($\sum E$). Consequently, this research moves beyond general systems theory to offer a specific, quantifiable framework for understanding how micro-level entrepreneurial decisions cascade into macro-level ecosystem survival, empowering practitioners to navigate the «Edge of Chaos» with greater strategic rigour.

8. Social Implications

If we view society as a complex system, governed by simple or elaborate rules, we can deduce that some of the behaviours observed within it may arise from the application of simple rules combined with random elements. These may be related to a particular market's—or niche within it—preference for a particular brand, service, or product, with nothing that significantly distinguishes it from similar offerings from other providers. This observation could help society better understand complex social phenomena, such as the demand, choice, or consumption of a good or service; the rejection of brands, offers, or opportunities; or any other interaction that may cause the growth or extinction of a provider due to social dynamics that respond to the way in which that provider understands or responds to the rules—formal or not—established within it. Similarly, incorporating the three core characteristics of Conway's Game of Life into social dynamics—adaptability, growth, and sustainability—would foster the rationalisation of the need to evolve while generating the least possible impact on the environment, without sacrificing social and business growth.

9. Managerial Implications

One of the most relevant implications for entrepreneurial management offered by this study lies in understanding that uncertainty is not a system anomaly, but rather an inherent property of both the business environment and complex systems, as represented in Conway's Game of Life. In this context, entrepreneurs cannot aim to eliminate uncertainty, but rather to manage it strategically through iterative cycles of testing, learning, and adjustment. Decision-making, therefore, becomes a continuous process of experimentation, in which each action can generate unpredictable results, requiring the development of flexible business models open to constant evolution.

Additionally, the study emphasises that adaptability is a fundamental competency in the entrepreneurial process. Just as the mobile structures of the game, such as the «gliders», manage to survive by moving and adjusting to the environment, sustainable ventures are those that can reconfigure their models and strategies in the face of sudden changes in the market or regulations. This implies that, from a managerial perspective, entrepreneurial leadership must abandon rigid control and foster a culture of agile learning, capable of re-orienting itself without losing its strategic purpose. Adaptability is not seen as an occasional response to a crisis, but as a structural capability that must be integrated into the operational logic of the business from its inception.

This framework has direct implications for organisational decision-making and corporate governance. In the realm of Administrative Sciences, a central challenge lies in designing governance structures that balance the need for control with the necessity of autonomy. The Game of Life demonstrates that rigid, centralised control —akin to «still life» patterns that cannot move— often lacks the flexibility required to survive environmental perturbations. Therefore, modern administrative theory must embrace «adaptive

governance» models, where decision-making protocols are designed to be modular and distributed. This shift requires administrators to move beyond static resource allocation and adopt dynamic management routines that allow the organisation to absorb shocks and reconfigure resources strategically without awaiting top-down directives (Wenzel et al., 2020). By decentralising decision-making, organisations can mimic the responsiveness of cellular automata, where local intelligence aggregates to produce robust, resilient global behaviour.

Furthermore, it is argued that entrepreneurial growth, far from following linear and predictable trajectories, responds to non-linear dynamics that depend on multiple internal and external interactions. Small local decisions—such as the selection of strategic partners, product adjustments, or changes in communication—can generate significant long-term effects, just as in Conway's Game of Life, where simple configurations lead to complex patterns. In managerial terms, this forces the entrepreneur to observe not only the immediate results but also the systemic implications of each decision, adopting a strategic perspective that considers the cumulative effect of interactions and fosters scalable structures without compromising operational coherence.

The study also highlights that sustainability, within the framework of entrepreneurship, is not about reaching a final state, but rather about maintaining a dynamic balance between growth, operational efficiency, and adaptability. Analogous to the game patterns that remain stable over time, it is proposed that lasting ventures are those capable of reinventing themselves without losing their identity, integrating social, economic, and environmental principles into their management. This requires that sustainability cease to be an accessory element and become part of the venture's strategic design, from the formulation of its value proposition to the management of its daily operations.

Finally, the analysis suggests that the interaction between local decisions and global outcomes, a central characteristic of Conway's Game of Life, has profound implications for entrepreneurial management. Individual decisions, although seemingly limited in scope, can produce systemic effects when considered as a network. Thus, strategic management in entrepreneurship must incorporate a systemic vision, in which actions are aligned with a deep understanding of the interdependencies of the environment. This perspective reinforces the need to make decisions with an awareness of context, foster collaborative connections, and design organisational structures that can evolve in a way that is consistent with the entrepreneurial ecosystem in which they operate.

10. Educational Implications

Beyond the managerial sphere, this study holds significant value for entrepreneurship education. Traditionally, business curricula have focused on linear planning and predictive forecasting. However, the introduction of Conway's Game of Life as a pedagogical tool allows educators to teach the principles of complexity and emergence, which are often abstract and difficult for students to grasp visually. By integrating cellular automata simulators into the classroom, instructors can move beyond static business models to dynamic scenario modelling.

This approach encourages a shift from «predictive» strategy to «navigational» strategy. Students can simulate how «rigid» initial configurations often lead to extinction, whereas «adaptive» patterns (akin to gliders) survive in hostile environments. Such experiential learning tools are essential for cultivating a mindset capable of managing the non-linear realities of modern ecosystems, bridging the gap between theoretical coursework and the chaotic reality of startup life (Ratten & Jones, 2021).

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