Frontiers in Business, Economics and Management
ISSN: 2766-824X | Vol. 8, No. 1, 2023

Research on the Evolution Mechanism of Cross-border E-commerce Ecosystem Based on Self-organization Theory

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Abstract: Cross-border e-commerce ecosystem is a complex, open and far from balanced business ecosystem. Due to the nonlinear interaction among the subsystems within the cross-border e-commerce ecosystem and the complex international environment of "Internet + foreign trade", it is difficult to study its overall development with traditional linear thinking and mathematical methods. System theory provides a theoretical basis for studying the development law of cross-border e-commerce ecosystem more scientifically. Based on the analysis of the evolution of cross-border e-commerce ecosystem and from the perspective of self-organization theory, this paper makes an in-depth study of the internal mechanism and driving force of the evolution of cross-border e-commerce ecosystem. It is believed that the evolution of cross-border e-commerce ecosystem is under the influence of certain environment, and the complex system automatically changes from disorder to order and from low order to high order through "self-organization" mechanism. The subsystems within the system cooperate through competition, and competition and collaboration jointly determine the development and evolution of the cross-border e-commerce ecosystem. Core enterprises and government departments of cross-border e-commerce ecosystem should jointly control the self-organization of cross-border e-commerce ecosystem, lead the system to an orderly structure, and ensure the healthy, sustainable and stable development of the whole ecosystem.

Keywords: Cross-border e-commerce, Ecosystem, Evolution, Self-organization.

1. Introduction

As a dynamic and evolving concept, the cross-border e-commerce ecosystem is not bound by time and space. Changes in the international community and market environment necessitate continuous growth to meet market demands. As a result of this ongoing evolution, cross-border e-commerce has developed a range of functions and features, including industrial clustering, technological innovation, low market access thresholds, low transaction costs, multilateralization, facilitation, and diversified demand. Its business model has transformed from an online trade platform to a comprehensive service platform for the trade industrial chain. Today, cross-border e-commerce has replaced traditional foreign trade and has become the primary growth mode for large enterprises worldwide. With the rise of the network economy, the global commercial society has entered an era of commercial ecosystems characterized by co-evolution(Moore, 1996). As cross-border e-commerce has evolved, it has expanded to the territory of ecosystems, and the synergy and evolution of this ecosystem have become a foundation, prerequisite, and norm for high-level and fierce competition (Zhang Forrest et al., 2013). in the future, businesses will no longer compete solely on the basis of their business models, but also on the basis of the ecosystems they operate within. This will require not only a deep understanding of the ecosystem's structure and dynamics but also the ability to collaborate and innovate with ecosystem partners to create new value and opportunities (Jiang Yuantao, 2016). Current research in the field of cross-border e-commerce ecosystems focuses more on the construction of systems (Zhang Xiaheng, 2021; Xue Chaogai, 2019; Zhao Yu, 2014) The symbiotic evolution path of the system (Zhang Henan, Xu Zhengliang,2020) and the collaboration with cross-border logistics (Zhang Xiaheng, 2018,2020; Zhang Ronggang et al., 2020). It seems that the current research on cross-border e-commerce ecosystems is mostly focused on the construction and symbiotic evolution path of the system, as well as collaboration with cross-border logistics. However, there are limited discussions on the evolutionary mechanism of the ecosystem itself. Furthermore, the current understanding of the ecosystem is largely limited to its structure, function, and mode. It is important for future research to delve deeper into the evolutionary mechanisms and dynamics of cross-border e-commerce ecosystems to gain a more comprehensive understanding of their development and growth.

The success of cross-border e-commerce lies in achieving the purpose of co-evolution through interdependence and interaction with internal and external markets or society, thus manifesting itself as an ecosystem on a macro level(Moore, 1996; BasKin, 2016). As the role of ecosystems becomes increasingly important in the business world, more and more enterprises are looking to build their own ecosystems. However, many of these enterprises still lack a clear understanding of the cross-border e-commerce ecosystem. While existing literature provides some theoretical basis and guidance, systematic studies on the evolution of the cross-border e-commerce ecosystem are still lacking. Specifically, the internal operations of cross-border e-commerce enterprises are not yet fully understood.

To address this gap, this paper takes a self-organization theory perspective to conduct a systematic and comprehensive process analysis of the evolution of the cross-border e-commerce ecosystem. The aim is to explore the

factors that influence the evolution of the ecosystem, as well as the self-organization operation mechanism hidden within it. The findings of this study will provide theoretical and practical insights to cross-border e-commerce enterprises and related organizations in the era of digital economy.

2. Self-organizing Evolution of Cross-border e-commerce Ecosystem

The concept of "evolvement" is derived from ecological concepts. Feistel argues that "evolution is an irreversible historical process that involves an infinite sequence of self-organizing steps, each of which is triggered by a critical fluctuation and causes an initial stable state to become unstable." Feistel distinguishes evolution into two aspects: the generation of new layers, namely the evolution of the overall structure, and the formation of cross-level or new hierarchical relationships, that is, the evolution of the overall function.(Feistel,2000).

2.1. Principle of self-organization

Self-organization is a concept that is relative to other organizations. "Other organizations" refer to the organization instruction and organization ability from outside the system. In contrast, self-organization theory refers to a theory of self-organizing phenomena in which the internal subsystems of the system can form a certain structure or function according to specific rules without external instructions, resulting in intrinsic and autogenous characteristics. The principle of self-organization explains that under specific conditions of external energy flow, information flow, and material flow, the system can form a new time, space, or functional ordered structure through the synergy of numerous subsystems.

The key to transforming the cross-border e-commerce ecosystem from disorder to order lies in the nonlinear interaction between subsystems, which does not depend on the proximity to a stable equilibrium state. The cross-border e-commerce ecosystem's stable equilibrium state can evolve into an unstable equilibrium state or a new stable equilibrium state under certain conditions, and its evolution trend is uncertain. When the parameters of the stable equilibrium system fall within a certain wide value range, the cross-border e-commerce ecosystem's state becomes unstable. When the system experiences fluctuations, the unstable equilibrium state gradually evolves into a new stable equilibrium state. However, in the nonlinear region far from equilibrium, a small random disturbance in the cross-border e-commerce ecosystem, amplified by coordinated action, may also create an overall macro fluctuation, causing the ecosystem to transition from an unstable state to a new stable and ordered state. Therefore, the evolution of the cross-border e-commerce ecosystem does not depend solely on external factors, but also on its self-organizing characteristics, which allow it to achieve an orderly state through coordination.

Self-organization is indeed a fundamental way for the cross-border e-commerce ecosystem to improve itself. The self-organization principle of synergetic theory aims to explain the process of system evolution from disorder to order, which is essentially the process of self-organization within the system, and synergy is the form and means of self-organization. Therefore, it can be concluded that self-organization is the fundamental way for the cross-border e-commerce ecosystem to develop from a disordered and unstable state to an orderly and stable state, and to achieve self-improvement and development.

2.2. Structure of self-organization theory

1. Dissipative structure theory. Dissipative structure theory was proposed by Ilya Prigogine and his colleagues in the 1960s and 1970s. It focuses on the dynamics of open systems that are far from thermodynamic equilibrium and can self-organize into complex, ordered structures through the exchange of matter and energy with the environment. Prigogine's work showed that under certain conditions, such as a high rate of energy and matter exchange, nonlinear feedback loops, and strong fluctuations, an open system can create new structures and patterns that allow it to adapt to its environment and increase its complexity over time. This theory has been applied to many fields, including physics, chemistry, biology, and social sciences, and has helped to explain phenomena such as turbulence, chemical oscillations, and biological evolution.

2. Synergy theory. This paper focuses on the coordination mechanism among internal elements of a system, and argues that coordination is the foundation of the self-organizing process. The competition and synergy among order parameters in the system is the direct source of the system's new structure. During the system's transition from one stable state to another, the independent movement of system elements and various local cooperative movements reach the equilibrium stage. At this point, any small fluctuation will be rapidly amplified into a significant fluctuation, affecting the entire system and pushing it into an ordered state.In other words, synergistic interactions among the system elements can drive the emergence of new structures within the system.

3. Mutation theory. The mutation theory is based on the concept of stability theory, which posits that the mutation process involves a transition from one stable state to another. According to this theory, even if the same process corresponds to the same critical value of control factors, the resulting mutations can lead to different outcomes. Specifically, the process may reach several different neosteady states, each with a certain probability of occurrence.

4. Theory of cooperative dynamics. There are three main points to consider. Firstly, competition must be stimulated in order to form a network of influence and interaction among the numerous subsystems that exist, based on the input of necessary material, energy, and information. Secondly, it is important to advocate for cooperation, which creates the necessary tension to contend with competition. This allows the advantages of cooperation to spontaneously and independently form greater advantages without interference. Thirdly, it is important to note that once order parameters are established, their dominance cannot be organized; rather, they should be organized according to the self-organization process of the system under the rule of the dominance of the order parameters. This can result in two types of orderly movements: one is the evolution of complexity and degree of organization at a quantitative level, while the other is the dynamic evolution of sudden jumps in the degree of organization.

2.3. System evolution

System evolution refers to the process by which a system moves from one equilibrium and stable state to another. During this process, the structure and function of the system's main body, as well as the interrelations between its components and the system's interaction with the external

environment, undergo fundamental changes, leading to a new macro situation. The elements of the system work together to achieve the system's overall goal, and are interconnected and constrained by this overarching objective.

In the case of the cross-border e-commerce ecosystem, the system's overall function differs from that of its constituent elements, and its overall behavior cannot be inferred from the behavior of its individual parts. The evolution of the cross-border e-commerce ecosystem typically involves two stages: gradual change, also known as quantitative change, and mutation, also known as qualitative change. The fluctuations caused by these gradual changes and mutations are the primary drivers of order within the cross-border e-commerce ecosystem.

Over a certain period of time, the distribution of indicators among various enterprises and departments within the cross-border e-commerce ecosystem has the ability to maintain or restore balance in the face of small perturbations, which is known as system stability. However, due to the complexity of the ecosystem's evolution and the non-uniform distribution of resources, factors of production can easily flow among different enterprises, leading to new aggregations and combinations, which is referred to as system fluctuation. This fluctuation can be divided into micro-fluctuation and mega-fluctuation. Mega-fluctuation evolves from micro-fluctuation under certain conditions, typically when specific critical values are reached or exceeded by certain elements. When this occurs, micro-fluctuation can evolve into mega-fluctuation (Wu Tong,2001). Fluctuation in the cross-border e-commerce ecosystem refers to the deviation of a certain variable or behavior from the average value, which can cause the system to constantly deviate from its original state and trajectory. When the ecosystem is in a stable state, fluctuation can be viewed as interference, causing confusion in the operation of the cross-border e-commerce ecosystem. However, when the ecosystem is in an unstable critical state, fluctuation may not be attenuated, but instead amplified into a "huge fluctuation," leading to a transition from the unstable state to a new, orderly state.

An in-depth study of the evolution process of the cross-border e-commerce ecosystem reveals that the enterprises that survive and continue to grow in the system competition are those with strong innovation ability and rapid productivity growth. The fluctuations of these enterprises are more likely to cause the system structure to deviate from the original equilibrium position. The real cross-border e-commerce ecosystem is highly complex, with many variables affecting the self-organizing evolution of the system. At the critical point of system evolution, multiple order parameters with equal weights may appear. To study the behavior of a complex business system, we must consider the whole picture. The self-organization methodology requires us to view the evolution of cross-border e-commerce as a complex and self-organizing process. Cross-border e-commerce has its own development and evolution track, and core enterprise managers must follow the development of the cross-border e-commerce "context" to implement appropriate management.

3. Self-organizing Conditions for the Evolution of Cross-border e-commerce Ecosystem

The evolution of the cross-border e-commerce ecosystem does not depend solely on external means, but can also rely on its self-organizing characteristics to achieve an orderly state through coordination.

The self-organization theory is a theory that explains the phenomenon in which each subsystem within a system can form a specific structure or function based on certain rules without external instructions. This theory mainly studies how a system evolves from a chaotic initial state to a stable and orderly final state. It is believed that the evolution from disorder to order requires several basic conditions: (1) The self-organizing system must be open and exchange material, energy, and information with the outside world to produce and maintain a stable and orderly structure. (2) Non-equilibrium is the source of order, and the open system must be in a non-equilibrium state, far from equilibrium, developing from disorder to order. (3) There must be nonlinear interactions among the subsystems in the system. This interaction allows the subsystems to act in concert, which can transform a disorganized system into an orderly one. In addition to these conditions, the self-organization theory also suggests that the system can only make order a reality by departing from the fluctuation of the original state or orbit, thus completing the self-organization process of the new ordered structure.

The cross-border e-commerce ecosystem is a complex and open system comprised of various related enterprises, institutions, and organizations in the industrial chain. These subsystems have "non-linear" interactions and mutual influences, resulting in a dynamic evolution model where new features continually emerge. The evolution of the cross-border e-commerce ecosystem involves changes in the proportion of enterprises of different species within the system. This includes the entry of emerging species and the exit of declining species. The self-organizing evolution process of the cross-border e-commerce ecosystem is driven by the innovation and reorganization of enterprises and organizations of various species under certain external environmental conditions.

There are two aspects that drive this process. First, competition and collaboration among various departments in the cross-border e-commerce ecosystem lead to the rapid development and increasing proportion of enterprise organizations and institutions that can adapt to the external environment. Related enterprise organizations and institutions also develop accordingly, forming stronger competitiveness under the synergistic effect of the system, and gradually becoming dominant within the cross-border e-commerce ecosystem. Those enterprise organizations and institutions that cannot adapt to the external environment will weaken in competition and be relegated to a secondary position, or even eliminated.

The second aspect driving the self-organizing evolution process of the cross-border e-commerce ecosystem is the efficiency and benefit of each subsystem and basic unit. By enhancing the efficiency and benefits of each subsystem and basic unit, the cross-border e-commerce ecosystem can evolve towards greater order and stability. Overall, the self-organizing evolution process of the cross-border e-commerce ecosystem is a dynamic and complex process that requires the cooperation and adaptation of various enterprises, institutions, and organizations within the system.

4. Self-organization and Evolution Mechanism of Cross-border e-commerce Ecosystem

The cross-border e-commerce platform is a core enterprise within the cross-border e-commerce ecosystem. Its function is to act as a traffic entry point for the platform while simultaneously designing, managing, and operating the N-side market of the ecosystem. Customers utilize the cross-border e-commerce platform to place orders. As the traffic entry point, the cross-border e-commerce platform can collect and master information related to customers, orders, and customer demands in real-time. This information can be shared with other members of the system through the platform, which helps to promote resource sharing and better cooperation among members of the ecosystem.

To facilitate this, cross-border e-commerce platforms rely on various technical conditions such as communication technology, e-commerce technology, network platforms, big data, artificial intelligence, blockchain, etc. By integrating and innovating with external resources, enterprises within the ecosystem form an extended network of relevant organizations. Members of the system rely on each other to carry out technology integration, business cooperation, decentralized innovation, and the mutual connection between products and markets. This allows each member of the system to generate business connections through services, thus forming an interdependent organic unity of higher-level cooperation.

Overall, the cross-border e-commerce platform plays a critical role in facilitating communication and cooperation among members of the cross-border e-commerce ecosystem. By utilizing the latest technology and fostering greater collaboration, the ecosystem can operate more efficiently and effectively, driving greater innovation and success for all members involved.

The distribution of matter and energy within each region of the cross-border e-commerce ecosystem is highly unbalanced, creating a significant gap. Members of the system exchange energy with the external environment and obtain negative entropy through material flow, energy flow, and information flow. This constant exchange maintains the system in a non-equilibrium state. Material, energy, and information flow among the basic units within the system, and the "non-linear complex factor influence" within the system - the complex nonlinear effect between different elements, subsystems, and levels - enables enterprises to fully leverage external resources, assets, and capabilities to establish a series of complex connections and interactions.

Different enterprises seek the most appropriate ecological niche through competitive strategies, resulting in the flow of resources needed by these enterprises. This, in turn, generates competition for resources and environmental factors within the existing ecosystem resource space. Adaptive behavior of enterprises leads to the search for their own competitive niche, enabling different enterprises to find their own "ecological niche." Moreover, enterprises can create the living space they require for survival through niche selection and innovation within the existing ecological space.

When sufficient negative entropy flow is formed between the subsystem and its members, i.e., when the threshold value is reached, fluctuation occurs, causing the system structure to deviate from the original equilibrium position. If the fluctuation breaks through the critical value and reaches the aggregation state, order parameters are generated. Sometimes, multiple order parameters with equal weight will appear, and these order parameters will dominate the behavior of the subsystem. This, in turn, promotes each level and subsystem between the "synergistic effect." All subsystems within the system cooperate through competition, so that one or several trends in the competition become dominant, thus dominating the whole system from disorder to order, and ultimately forming the evolution of the cross-border e-commerce ecosystem. The evolution of the cross-border e-commerce ecosystem also promotes the sustainable growth of core enterprises.

The cross-border e-commerce ecosystem has undergone a self-organizing process that resulted in a new and orderly structure emerging from its initial chaotic and disordered state. This is known as the formation of the dissipative structure of the cross-border e-commerce ecosystem, which suggests that the original system structure is gradually disappearing while a new stable structure has emerged under new conditions. The key factor that enabled the transformation of the cross-border e-commerce ecosystem from disorder to order is the nonlinear interaction among subsystems. The system's ability to achieve an ordered state relies on its self-organizing characteristics through coordination, rather than solely relying on specific external methods.

This paper proposes that the self-organizing evolution mechanism of the cross-border e-commerce ecosystem involves the system developing from a simple and unidirectional state to a more complex and detailed structure, gradually transitioning from disorder to regular or irregular order in the nonlinear region far from the equilibrium point. This process results in a nonlinear multi-body system with certain functions, exhibiting an increase in complexity, fineness, and orderliness.

The cross-border e-commerce ecosystem is a complex and open system that undergoes continuous changes in both its internal and external environments. Material, energy, and information are constantly exchanged between the system and the outside world. Under specific conditions, all species within the ecosystem interact and compete with each other while being influenced by various continuous changes in the internal and external environment. The characteristics of species within the system are either retained or eliminated, leading to adaptation. Through the combined action of adaptability and emergence, the system forms coevolution and progresses towards a more complex structure with a more powerful function. The self-organization evolution mechanism of the cross-border e-commerce ecosystem is illustrated in the figure below.

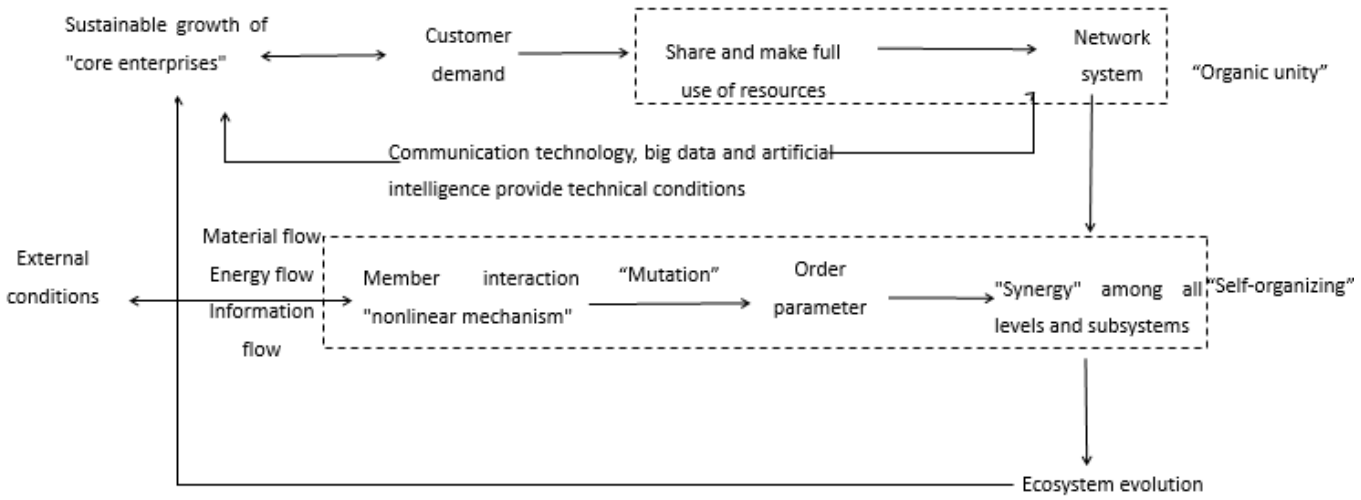

Figure 1. Self-organization and evolution mechanism of cross-border e-commerce ecosystem

5. Conclusion

The non-linear collaborative competition between the subsystems of the cross-border e-commerce ecosystem and its environment is the internal driving force and source of its self-organizing evolution. During this process, enterprises and departments exchange material, energy, and information with the environment, causing the system to evolve from an unstable equilibrium state to a stable one through "fluctuation amplification". Competition and collaboration between these subsystems determine the evolution and development of the cross-border e-commerce ecosystem.

The self-organization process of the cross-border e-commerce ecosystem is not stable, and random fluctuations can cause the system to deviate from its average state of evolution. To achieve an orderly structure and state, known as "order through fluctuations", local decision-making bodies must control the self-organization and guide the system towards the desired orderly structure.

The government should play a significant role in the evolution process of the cross-border e-commerce ecosystem by strengthening customs supervision to promote its development. Additionally, enhancing the informatization level and improving the development of cross-border e-commerce platforms and logistics will boost the competitiveness of cross-border e-commerce and facilitate its evolution. All relevant enterprises and departments of cross-border e-commerce should strive to improve their correlation effect to break the original equilibrium state of the system, increase the exchange of material, energy, and information between subsystems and the environment, and promote the self-organizing evolution of the cross-border e-commerce ecosystem.

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