Research on the Coordinated Development of Zhejiang Cross-border E-commerce and Regional Industrial Clusters Based on Coupling Theory

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Abstract—There is theoretical and practical significance in the research on the collaborative development of cross-border e-commerce and regional industrial clusters. Based on the system coupling theory and population evolution theory, an isomorphic model of cross-border e-commerce and industrial clusters is constructed, and the stable points of the predator-prey model are used to analyze the synergistic evolution characteristics of industrial clusters with upstream and downstream relationships and cross-border e-commerce. Meanwhile, the evolution mechanism of the synergistic development of cross-border e-commerce and industrial clusters is constructed. According to my research, positive feedback effects of knowledge are stronger than competitive effects, and a large number of SMEs can thus obtain the aggregation effect of facing cross-border trade.

Keywords-cross-border e-commerce; system coupling; industrial clusters

1 INTRODUCTION

Cross-border e-commerce is increasingly influencing the world economic, trade, and industrial development, with total global e-commerce sales now reaching US$4.28 trillion. In 2020, China's cross-border e-commerce transaction scale exceeded 1.69 trillion yuan, up 31.1% year-on-year. Zhejiang, boasting a large export-oriented economy, is particularly active in cross-border e-commerce activities in the context of industrial upgrading [1]. Zhejiang's cross-border e-commerce development is even more rapid. As seen in Table 1, Zhejiang witnessed the rapid development of cross-border e-commerce during the 13th Five-Year Plan period, despite the impact of COVID-19 and changes in the global economic situation, and the provincial cross-border network retail import and export still reached 138.71 billion yuan in 2020, a year-on-year increase of 31.9%. Cross-border online retail exports increased from 31.93 billion yuan in 2016 to 102.30 billion yuan in 2020, an average annual growth rate of 33.79% [2].

Table 1 Zhejiang cross-border e-commerce import and export (unit: trillion yuan)

Year	Export & Import		Export		Import	
	Volume	*Growth*	*Volume*	*Growth*	*Volume*	*Growth*
2016	403.6	43.4%	319.3	41.7%	84.3	50.1%
2017	603.9	48.9%	438.1	37.2%	165.8	93.0%
2018	810.3	34.8%	574.4	31.1%	235.9	44.9%
2019	1051.5	29.7%	777.1	35.3%	274.41	16.1%
2020	1387.1	31.9%	1023.0	31.6%	364.1	32.9%
Total	4256.0	/	3131.9	/	1124.1	/

Data source: Department of Commerce of Zhejiang Province

In 2020, Zhejiang's cross-border online retail exports amounted to 102.30 billion yuan, an average annual growth rate of 33.79%. The export cross-border online stores exceeded 118,000, involving traditional industries such as light textiles, small household appliances, jewelry, and leather industries.

The development of cross-border e-commerce in Zhejiang, especially the rise of cross-border export e-commerce, has catalyzed the development of various regions and their related industries. As mentioned in the "Thirteenth Five-Year Plan of Zhejiang Province" cross-border e-commerce development report, two batches of 51 provincial industrial clusters of cross-border e-commerce development pilot were launched, a three-year provincial-level special incentive fund totaling 200 million yuan was set up, and more than 1,200 independent cross-border e-commerce brands were cultivated, which promoted the traditional foreign trade enterprises to accelerate the digital transformation and achieved remarkable results. Therefore, cross-border e-commerce has pushed forward the upgrading and reconstruction of Zhejiang's regional industrial chain.

The development of cross-border e-commerce in Zhejiang is inseparable from the favorable international and domestic environment as well as popular support. Thanks to Zhejiang's strong manufacturing system and long-existing foreign trade system for many years, Zhejiang's home textiles, clothing, home decorations, small household appliances, pet supplies, and other industries underwent a continuous iterative upgrade, professional marketization, market specialization. Industrial clusters give full play to the main characteristics of Zhejiang's regional industry-the advantages of the main economic body dominated by small and medium-sized enterprises (SMEs). The regional economic strength has been increasing, thus withstanding the test of mature foreign consumer markets, product standards, etc.

There are many key factors amid the rapid development of cross-border e-commerce in Zhejiang, such as a favorable policy environment, a developed regional economy dominated by SMEs, influential professional markets, the resulting industrial clusters, a leading professional talent training system for cross-border e-commerce, and leading platform enterprises, etc. Among them, the industrial clusters, which serve as one of the typical characteristics of Zhejiang's regional industries, are particularly critical.

With the advancement of cross-border e-commerce in China, an increasing number of researchers have begun to pay attention to the correlation between cross-border e-commerce and Zhejiang's industries. Among them, Yang Lihua and Zhong Yu (2018) pointed out through analysis that the scale of China's cross-border e-commerce industry is expanding, and the development level of manufacturing industry clusters is also rising[3]. Liuzhou (2015) pointed

out that the development of "Internet plus" industry clusters depends on the role of Internet technology in industry clusters, thereby achieving the innovation and development of the industry [4]. Through scholars' analysis and research, the development trajectory of cross-border e-commerce and regional industrial clusters in Zhejiang also indicates that there is a coupling relationship between the development of cross-border e-commerce and regional economy, as well as regional industrial clusters in Zhejiang. However, although the current research involves the evolution between cross-border e-commerce and industrial clusters and related models, qualitative and quantitative empirical research is still insufficient, let alone the construction of theoretical models.

This paper, based on the coupling theory and population evolution theory, analyzes the upstream and downstream industry chain coupling relationship between cross-border e-commerce and industrial clusters in Zhejiang, constructs a population model to analyze the co-evolutionary characteristics of cross-border e-commerce and professional markets as well as the industrial clusters they formed, and studies the evolutionary mechanism of the key factors of cross-border e-commerce development and the coordinated development of Zhejiang industries.

2   THEORETICAL BASIS

2.1   System coupling theory

Any system is a collection of elements linked together by a chain of causality, and this relationship among elements is called coupling. Coupling theory was first used in physics research, referring to the phenomenon that two or more system factors interact with each other. Lahr (2005) further expanded the research on industrial relevance, enriched the basis of new economic theory by using the evaluation analysis method, and laid the foundation for the research on industrial coupling [5]. Kim (2015), with the model of industrial integration as the core of the research, found that the US industry has become more and more stable with the advancing of time, and predicted the future development trend of industrial integration [6]. Wu Qintang demonstrated the coupling mechanism between industrial clusters and regional economic development [7]. Li Haidong and Zhang Chun (2018) demonstrated through research and analysis that the connection strength and heterogeneity of the innovation network of industrial clusters and the embeddedness of the cluster positively affect the upgrading of the cluster; among the social capital of the cluster, only the vertical social capital positively affects the upgrading of the industrial clusters [8]. From the above research of scholars, it is found that the regional industrial economy is coupled with some factors that affect it, such as industrial clusters, and the integration of industry and technology.

2.2   Population evolution theory

As early as 1982, Nelson and Winter laid the foundation of modern evolutionary economics research in their book Evolutionary Theory of Economic Change, which formed numerous evolutionary dynamics models and technical tools, and gradually transitioned to emphasize the characteristics and mechanisms of co-evolutionary dynamics between different subjects and levels, such as individuals and individuals, as well as systems and systems, which interact and

reinforce each other [9]. Huang Kainan systematically explained the theory, characteristics, and evolution mechanism of co-evolution, and carried out theoretical modeling and partial simulation experiments to verify the co-evolution of enterprises and industries [10,]. Zhang Shihua (2018) constructed a cross-border e-commerce internal and external synergistic development and innovation network. Under the influence of markets and policy environment, elements such as industrial selection power and technological innovation power develop in synergy with e-commerce innovation, and thus the evolutionary path of e-commerce synergy development is analyzed [12]. In their research, Lu Lijun (2011) analyzed the micro-mechanism of the integration of Zhejiang professional market and e-commerce, and theoretically constructed a multi-level and multi-stage co-evolution analysis model and framework for the interaction of professional markets and industrial clusters, thus deriving some laws and evolutionary mechanisms of the interactive development between professional markets and industrial clusters [13].

3 THE HOMOGENEOUS MODEL OF CROSS-BORDER E-COMMERCE AND INDUSTRIAL CLUSTERS

There is a complex and orderly hierarchical system in the field of ecology: ecosystems, communities, populations, and individuals. Cross-border e-commerce and industrial clusters also have similar hierarchical systems: cluster ecosystems, industrial clusters, enterprise populations, and individual enterprises. Through comparative research, we can find the similarities among them.

The biological population is the sum of individuals of the same species in a certain space and time. A population is made up of individuals of the same species, but in an ecosystem, individuals within a population are neither isolated from each other nor simply adding up to each other, but a unified organic whole constituted through various relationships, showing the special regularity of the species. The biological community is the sum of various biological populations that live in a certain natural area and are directly or indirectly related to each other. It is composed of a variety of organisms, each of which has certain requirements for the environment and is also a response to the ecological environment. They are in different positions and play different roles in the community, and they live together as an organic whole, depending on each other and interacting with each other, thus forming an organic whole. An ecosystem is an inseparable natural whole formed by the interaction between organisms and their living environment as well as between organisms and organisms in a certain time and space, through material circulation, energy flow, and information exchange.

Within cross-border e-commerce and industrial clusters, there are also organizations of different forms and natures, which are closely related and interdependent, thus forming a symbiotic and coexisting social network system. A group of enterprises with similar processes and technologies in the same region constitutes an enterprise population; a collection of closely related enterprise populations are called an industrial cluster, which also has life characteristics and resembles a network organization, influenced by the surrounding environment. The cluster ecosystem is formed by the slowing down of information dissemination and material values of the industry clusters and their surroundings.

Organisms exist in a common ecosystem, just as cluster enterprises exist in a common cluster ecosystem; the relationship between organisms in an ecosystem and their surroundings is studied in ecology, just as the relationship between enterprises in industrial clusters, cross-border e-commerce and their surroundings is studied in economics.

Based on the above comparison of the concepts, internal structure, and evolution mechanism of industrial clusters and biological communities, it is found that cross-border e-commerce and industrial clusters have obvious population characteristics. There are three main types of ecological relationships between species in the ecosystem: competitive relations, mutually beneficial relations, and predator-prey relations. Since industrial clusters and cross-border e-commerce have population characteristics, we can use ecological relations to describe the internal relations of industrial clusters and cross-border e-commerce. Obviously, there are also competitive and mutually beneficial relationships between the industrial clusters and enterprises of cross-border e-commerce. If the behavior that downstream enterprises in the cluster purchase the products of upstream enterprises leading to the reduction in upstream enterprises' inventory is regarded as the interaction between predators and preys, we can also apply the predator-prey model to study the relationship between the upstream and downstream enterprises, namely the upstream-downstream relationship model.

This supply and demand relationship that upstream enterprises in a cluster provide intermediate products to downstream enterprises, from a certain perspective, can be described by the Lotka-Volterra model between predators and preys in ecology. Assumptions and model

Assuming that there are only two enterprises in the cluster, A is the upstream enterprise, and B is the downstream enterprise. x_1, x_2 represent the output of A and B, respectively; a_1 is the growth rate of enterprise A in an ideal environment, and b_1 represents the purchase rate of downstream enterprise B to A's product, b_2 is the sales rate of professional market A to the products purchased from industry cluster B, and the reduction of industrial cluster A is $b_1 x_1 x_2$, then the differential equation of enterprise A is:

$$\frac{dx_1}{dt} = a_1 x_1 - b_1 x_1 x_2 \tag{1}$$

For downstream enterprise B, it is assumed that in the absence of upstream enterprises to provide products, its output level will be reduced geometrically: $\frac{dx_2}{dt} = -a_2 x_2$, where a_2 is the killing rate that enterprise B will go bankrupt due to the absence of enterprise A. It is supposed that the conversion rate for downstream enterprise B to convert the products purchased by enterprise A into its own product is b_2, then the growth rate of the downstream enterprise is $b_1 b_2 x_1 x_2$, and the differential equation of enterprise B is obtained as:

$$\frac{dx_2}{dt} = -a_2 x_2 + b_1 b_2 x_1 x_2 \tag{2}$$

The analysis of stable point

By solving the algebraic equation

$$\begin{cases} \dfrac{dx_1}{dt} = a_1 x_1 - b_1 x_1 x_2 = 0 \\ \dfrac{dx_2}{dt} = -a_2 x_2 + b_1 b_2 x_1 x_2 = 0 \end{cases},$$

the equilibrium point $E\left(\dfrac{a_2}{b_1 b_2}, \dfrac{a_1}{b_1}\right)$ of Equations (1) and (2) can be obtained.

From the coordinates of the equilibrium point E, it can be seen that the balance of upstream and downstream enterprises will be affected by the purchase rate of downstream enterprises to upstream enterprises, the efficiency of downstream enterprises in converting purchased products into their own products, the growth rate of upstream enterprises themselves, and the reduction rate of products of downstream enterprises for the lack of supply from upstream enterprises. When, b_1 and b_2 increase, that is, when the downstream enterprises' purchase rate of upstream enterprises and the efficiency of converting upstream enterprises' products into their own products increase, the inventory of upstream enterprises at the equilibrium point decreases, and the corresponding output scale of downstream enterprises increases, which is beneficial to both enterprises; otherwise, it is detrimental to both enterprises.

It can be concluded from the above models that, the industrial cluster with upstream and downstream relationships in the industry chain and cross-border e-commerce has the characteristics of co-evolution, which has a certain regularity.

4 EVOLUTIONARY MECHANISM OF THE COORDINATED DEVELOPMENT OF CROSS-BORDER E-COMMERCE AND INDUSTRIAL CLUSTERS

Co-evolution refers to the existence of mutual feedback mechanisms between elements in the system. Their evolutionary dynamics are intertwined, and the adaptive changes of one interactor will change its evolutionary trajectory by changing the adaptation of another interactor. Changes will further restrict or promote changes in the former.

Cross-border e-commerce and industrial clusters are interactively generated. The interaction between the two is not only an important way of diffusion, but also an important path of knowledge innovation, that is, industrial innovation provides the necessary driving force. Therefore, the micro-evolution of the industrial cluster itself will diffuse new knowledge into the market through interaction and promote the macro-evolution of the market; at the same time, the macro-evolution of the market constitutes the learning environment and selection environment of the industrial evolution, which further affects the micro-evolution of the industry. Therefore, cross-border e-commerce and industrial clusters evolve together.

When the industrial cluster is adjusted to adapt to the market environment, the market environment is also adjusting and changing, which will further promote the adjustment and change of the industrial clusters. The innovation ability and imitation ability of industrial clusters and the interaction mode between industrial clusters will affect the speed and direction of the co-evolution of industry and market. Therefore, under different conditions, the degree of mutual influence between industrial evolution and market evolution is different.

Regarding the cross-border e-commerce and industrial clusters in the developing stage, with the accumulation of knowledge, the stock of industry and market knowledge gradually increases, the industry's awareness of the evolutionary environment has also improved, and the market has entered a stage of development. At this stage, the rapid growth of specific knowledge has improved the innovation ability of the industry, and the growth of general knowledge has also improved the absorptive capacity of the industry (including the imitation ability). In this process, the growth rate of special knowledge is faster than that of general knowledge, the innovation ability of the industry is higher than the imitating ability, and enterprises and industries are also adopting more innovative behaviors. This is the most obvious stage of the co-evolution of industry and market, that is, the knowledge innovation of the industry will lead to the knowledge innovation and diffusion of other industries through inter-industry interaction, thereby affecting the dynamics of knowledge in the market, and this market evolution will strongly affect the industry's knowledge dynamics. Therefore, at this stage, the relationship between industry and market behavior is relatively close. This is mainly due to the following two reasons: First, the increase in the stock of knowledge (special knowledge and general knowledge) has greatly enhanced the innovation and absorptive capacity of the industry. Second, the market has become an important learning environment (knowledge environment) for the industry. In this regard, the importance of cross-border platforms in the market environment as the endogenous evolution environment of the industry has become more prominent. At the same time, since the market is in a stage of increasing diversity, and selection criteria have not yet been formed, competition between industries is relatively flat, and industries can weaken various selection pressures through innovation. To this end, the knowledge environment of the market has a greater impact on the evolution of the industry, compared to the selection environment.

5   CONCLUSION

At present, cross-border e-commerce, which is rooted in Zhejiang's regional industries, is in a stage of rapid growth, and the externality, complementarity, and positive feedback effects of knowledge are stronger than competitive effects. Industrial clusters and cross-border e-commerce are in the most rapid period of co-evolution, which is also the period when the external economy and network economy (positive feedback effect) are the most obvious. The industries are in the network structure of the small world, that is, they have strong innovation and diffusion capabilities. The existence of cross-border e-commerce can aggregate related resources and industries, and a large number of SMEs can thus obtain the aggregation effect of facing cross-border trade.

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