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An empirical analysis of Container related Maritime Services basic on Symbiosis Theory – Case of Shanghai

by

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Abstract

As an economic structure, industrial clusters play an important role in promoting industrial, regional and national economics development. As the foundation of the maritime industrial economy, ports are the key to bridging the land-based and the maritime economy. The composition structure and functions of port clusters also change over time. High value-added industries (e.g. maritime services) are found to be more conducive to the upgrading of port clusters. The similarity of industrial clusters and biological populations in structure, function and evolutionary process has led scholars to study industrial clusters from an ecological perspective. As with ecosystems in nature, only each sector within a cluster finds its own ecological niche to keep the cluster stable. In this paper, based on symbiosis theory, by modeling the interactions between the port and marine sectors, the Lotka-Volterra model is used to investigate the requirements for industrial clusters to reach ecological equilibrium.

In this study, Shanghai, China will be the subject of the empirical analysis. The empirical findings demonstrate that the port and the maritime services have a straightforwardly competitive relationship. In order to achieve ecological equilibrium in industrial clusters, policy makers and entrepreneurs should pay attention to maintain the differentiation of port and maritime services in a non-homogeneous direction.

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IMC International Maritime Centre

IMERC Irish Maritime and Energy Resource Cluster

IO Input-Output

Introduction

1.1 Background and Objectives

There has been a lot of interest in the study of port clusters during the past fifteen years (Doloreux, 2017). Port clusters support the growth of the urban and maritime economies. A port cluster is a collection of interrelated maritime sectors within a specific geographical area, including ports, shipping agencies, maritime law, maritime insurance, ship registration and ship economics, and other maritime related institutions (Shi, Jiang, Li, & Xu, 2020). In a study by Doloreux (2009), it was shown that for maritime sectors that already have a cluster base, government policy incentives can further increase their innovation and competitiveness. Ports are a crucial marine industry among all those included in the cluster because they are seen to play a crucial function in enabling commerce and a more active involvement in the supply chain (Lam, 2015).

A combined global economy and integrated global transportation systems are being created through expanding international commerce. Ports are incorporated naturally into this large, dynamic, and intensely competitive system. As a result, port functions have changed to fit this dynamic architecture (Wang & Cheng, 2010). In order to deliver better and more effective marine services, the port cluster's role is developing at the same time (Chang, 2011).

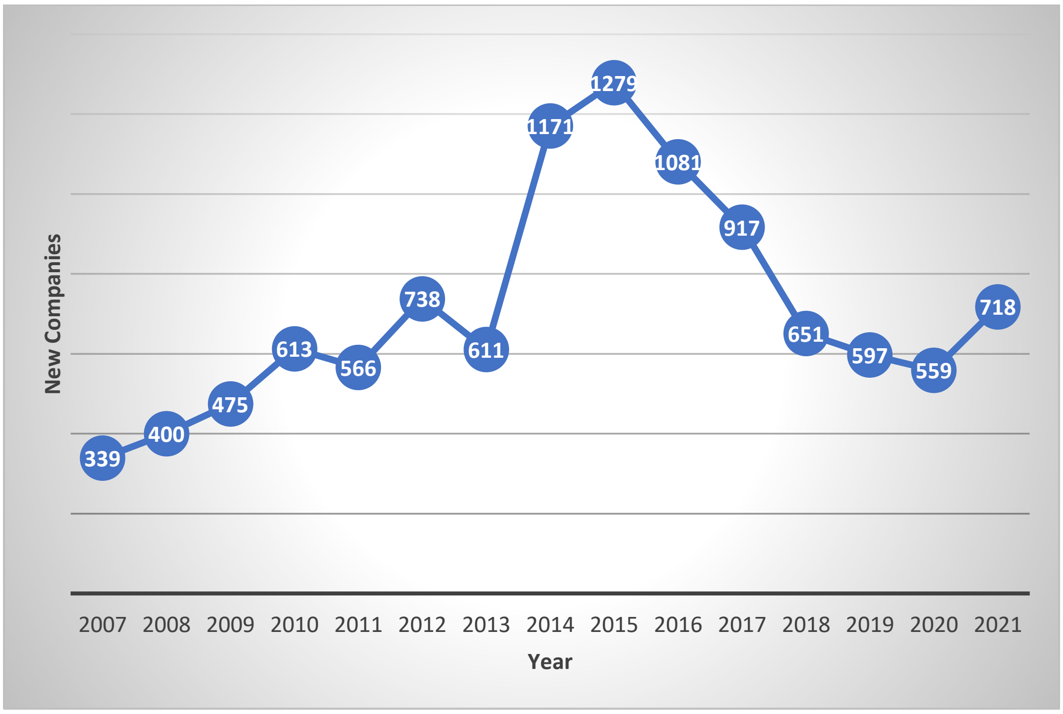
In practice, we find that port clusters evolve in a variety of ways. Some focus on traditional port activities, while some include providing more specialized and professional maritime services. For instance, Singapore's objective is focused on the creation of both an "international maritime centre (IMC)" and a "premier global hub port." (Singapore, 2023). The Hong Kong Maritime Industry Council was established to encourage the growth of maritime services in order to "consolidating Hong Kong’s status as an international transportation centre." (Sai-hung, 2023).

Since different port clusters have varied forms and roles, the question of what sort of port clusters should be accepted or attained in various cities or locations now that these objectives have been identified. Despite the fact that there appears to be some overlap between the growth of ports and the development of port clusters. To achieve a coordinated port development with other marine sectors, what should the port's role and function be in the cluster? There are several sorts of port clusters, depending on the grouping of maritime industries that make up the cluster and their relative importance within it. Therefore, while talking about the growth of a port cluster, a study of the relationships between the marine sectors within a cluster is a suitable starting point.

1.2 Problem identification

For cluster upgrading, Shi et al. (2020) suggested that for a port cluster to improve and become more competitive, it is necessary to build a high-value-added marine industry. To put it another way, marine services are a crucial strategy for ports to increase their level of competition. Marine services cover shipping, ports and high value-added services, and are a general term for services related to fuel supply, material supply, ship registration, ship maintenance, ship financing, ship insurance, crew management, and maritime dispute handling for ships, ship owners and crew (Wei, 2019) (Gui, Hu, & Shao, 2020). In terms of quantity, Figure 1 illustrates the growth trend of the high-end maritime services industry in Shanghai over the past 14 years.

Figure 1 The trend in the number of new shipping insurance and shipping agency companies in Shanghai over the past 14 years



Source: draw by author, based on (Tianyan Cha, 2022)

At the regional and national scales, De Langen (2002) found that common labour resources, a broad supplier and customer base, knowledge spill over effects, and low transaction costs were the main factors contributing to the agglomeration of port and maritime services. Through the changes of industry revenue and employment in Hong Kong's shipping service industry, it is suggested that high-value-added service activities such as finance, insurance, and supply chain management will be further concentrated in Hong Kong (Cao W. , 2012).

Based on the construction of a conceptual model of multiple trade centres, Wang et al. (2010) analysed the obstacles and transformation approaches of Hong Kong Port from a freight hub to a global value chain centre. Logistics services should be shifted to inland areas such as Shenzhen and Guangzhou, while high-value shipping services such as finance, insurance, and modern logistics should be concentrated in Hong Kong. Robinson (2002) sees ports as an element of the value chain system, by establishing a port value chain model, it explores the interaction among shipping companies, shipping brokers, customs agents, terminal loading and unloading, freight forwarders, etc.

From the perspective of value division of labour, Cao et al. (2017) used circle and hotspot analysis to show that high-end enterprises in Shanghai's value chain are clustered in the city centre, while low-end enterprises such as warehousing and transportation are distributed in suburban areas. From 1996 to 2014, the number of enterprises in the transport and storage, agency and technical services and advanced services categories accounted for 77.81%, 20.15% and 2.04% of the total number of enterprises, respectively, changing to 47.78%, 46.20% and 6.03%, with the industrial structure obviously climbing up the value chain. As the largest throughput port in the world, (Li & Luo, 2021) mentioned “Maritime clusters are the starting point of an IMC”. The topography of Shanghai Port, maritime trade, and global competitiveness have all been the subject of numerous studies. The association between maritime services and port growth in Shanghai's hasn't yet been empirically studied, either.

1.3 Research question

Based on the research progress on port clusters and maritime services as described in the previous article, this paper will be developed based on the following research question.

What is the performance of port and maritime services between maritime sectors in Shanghai?

Based on symbiosis theory, this study empirically investigates the interactions between the port and other marine sectors in the Shanghai case through the Lotka-Volterra model to provide managers and researchers with theoretical references for the coordinated development and upgrading of marine clusters.

It is essential to come up with answers to the sub-research questions listed below by critically reviewing the analysis's findings. To fully respond to the core study issue, these questions are important.

1) What are the industrial cluster and port cluster?
2) How to classify the maritime services?
3) How symbiosis theory analyses the interrelationships among clusters?
4) What is the strategy of maritime cluster service sectors in Shanghai?
5) How to quantify the interaction between the port and other sectors within a port cluster?

1.4 Thesis structure

The paper is organized as follows:

Chapter 1 describes the background of the port cluster and the motivation behind the research on the effects of the expansion of maritime services. This chapter presents the research topics and objectives together with justifications for the relevance of the research.

Chapter 2 describes the state of the art, in which the existing literature on industrial cluster used in the maritime context is discussed. The reason why symbiosis theory has become an analytical tool for studying industrial clusters.

Chapter 3 describes the approach choice. The principle and formula calculation method of Lotka-Volterra model.

Chapter 4 present the findings and conclusions drawn from the investigation. Empirical analysis of historical data in Shanghai, China, regression results, and discussion

Chapter 5 provides the conclusion of the study with corresponding policy implications and recommendations.

2 State of the art

In this chapter we discuss the principles and formative context of several concepts relevant to this thesis. These include industrial clusters and port clusters. Further, it is reasoned that marine services have become a necessity part of port cluster upgrading. We conclude by describing the reasons why symbiosis theory is applicable to cluster research, and the applicable empirical model.

2.1 What is Industrial Cluster?

The first definition of cluster is by Alfred Marshall as “concentration of specialized industries in particular localities” (Marshall, 1890). He analyzed in detail the reasons for industrial agglomeration from the perspective of external economy are multifaceted. In addition to natural conditions and government policy guidance, the pursuit of external economies of scale is the root cause. The clustering of a large number of similar industries can greatly improve the efficiency of auxiliary industries, which is conducive to both lower production costs and higher income. Michael Porter, on the other hand, analyzed the reasons for the formation of industrial clusters from the perspective of competitive advantage, where Porter argued that “Clusters are geographic concentrations of interconnected companies and institutions in a particular field” (Porter M. , 1990). Based on this theory, Porter established a "Diamond model" of competitive advantage with demand conditions, industrial strategies and competitors, related industries, and supporting industries as the components. Using this model, Porter examined the businesses and industries that had competitive advantages and underlined the significance of allied and supporting sectors in the formation of such advantages. For example, special or appropriate infrastructural conditions, unusual local demand, etc. may lead to the emergence of industrial clusters.

Although Porter has made a more detailed discussion of the concept of industrial clusters, however, many researchers have also put forward different opinions. Jacobs et al. (1996) have made a more in-depth analysis of the concept of industrial clusters. They contend that clusters exhibit various properties from various angles. Therefore, the definition of a cluster must take into account the essential components it consists of, such as the links between industrial sectors on a horizontal and vertical level and the degree of spatial and geographic clustering of economic activity. The closeness of company networks or cooperation in the cluster, and the presence of active "movers", such as startup village, R&D center, and educational institution. Rosenfeld (1997) argues that clusters are collections of geographically concentrated, interrelated, and complementary companies that are formed to share well-developed labor markets, services, and urban infrastructure, to face opportunities and challenges together, and thus to establish diverse trade exchanges and transaction channels. He also emphasizes the importance of mutual cooperation between companies and the interaction between society, and companies in determining cluster dynamics. Roelandt et al. (1999) illustrates that clusters are defined as a group of interdependent and interconnected companies, which are formed to obtain new and complementary technologies, reduce transaction costs, and obtain collaborative economic benefits.

Industry clusters build competitive advantage because a large number of companies (which may belong to different industries) cluster together, creating a clustering effect that goes beyond a single firm or industry. Industrial clusters concentrate suppliers, customers, and complementary manufacturers in the industrial chain in the same geographical location, creating a rich resource base for the enterprises in the cluster, which has a significant resource clustering effect. The geographical proximity of enterprises in the cluster can establish a mutual trust mechanism to the greatest extent and greatly reduce relevant transaction costs, such as transportation costs, information costs, negotiation costs (Gao & Liu, 2013).

Since the study of industrial clusters covers multiple areas, including economics, geography, and sociology. The concept of industrial cluster can be defined from different perspectives. In this paper, we follow the concept of industrial clusters as currently agreed internationally ---- given by Porter (1998): **an industrial cluster is a geographical concentration of companies, production suppliers, service providers and related institutions in specialized fields within the industry in question, which not only compete with each other but also cooperate with each other.**

The idea of industrial clusters gives us a refreshing way to consider, evaluate, and create policies that will support local and national economic development. The concept's central tenet is the dense concentration of industries within a given geographic area, which is advantageous for lowering institutional costs for businesses (such as production and exchange costs, etc.), increasing the advantages of scale and scope economies, and improving the benefits of market competition for businesses and industries. Industrial clusters focus on the interaction of businesses, related institutions, governments, and civil organizations with competitive and cooperative relationships in a particular region, breaking through the boundaries of companies and single industries to tap the competitive advantages of a specific region from the whole. Instead of being constrained to thinking about the interests of a few specific industries and a constrained geographical area, this enables them to think about the coordinated economic and social development of a region as a whole, to examine the industrial groups that may constitute the competitive advantage of a specific region, and to consider the competition and cooperation between neighboring regions. The main function of industrial clusters is to increase the value of competition amongst businesses. This partnership not only makes it easier to achieve economies of scale, but it also offers comparatively more freedom and hastens innovation through shared learning.

2.2 The definition of Port Cluster

From the above, it is clear that industrial clusters are used extensively in practice. Ports are naturally clustered in terms of geography, industrial structure, and economic attributes. Research on port economic regions has focused on multiply areas. The most frequent is the study of the competitiveness of ports by looking at them as a part of the logistic chain. This part of the research is generally limited to the competition of cargo transportation. Most of the scholars emphasize the importance of the geographical location of ports. According to Pinto et al. (2015), 'the cluster concept takes on different meanings depending on the sectors in which it is being examined and varies according to a spectrum that can range from geographical perspectives to socio-cultural factors or even territorial dimensions.' Doloreux (2017) reviewed the research studies conducted over a period of 15 years, a maritime cluster is defined is summarized as three fundamentally distinct definitions: '**an industrial complex, an agglomeration of interlinked industries, and a community-based network.**'

As an industrial complex, Morrissey et al. (2016) illustrates the Irish Maritime and Energy Resource Cluster (IMERC) is a varied, multi-functional cluster. In order to examine the relationships between enterprises' inputs and outputs in the four maritime sub-sectors of marine energy, shipping, logistics, and transport, maritime safety and security, and yachting products and services, researchers utilize an input-output model. They demonstrate that while sharing a large number of linked inputs and outputs (such as financial intermediation services, computer services, and other business services), these sectors have limited intra-cluster linkages (wholesale trade and post and communication). The economic relationships formed by input-output relations can reveal that the companies in the port cluster are interconnected in terms of technology and production.

The second definition of port clusters, "an agglomeration of interlinked industries", is the dominant idea, led by Porter. In particular, professor Haezendonck, is the first introducer to the concept of the port cluster (Haezendonck, Pison, Rousseeuw, Struyf, & Verbeke, 2001). She refers to a series of mutually independent companies engaged in port-related services, clustered in a unified port area and employing almost identical competitive strategies to gain a joint competitive advantage relative to companies outside the cluster. She applies Porter's "Diamond Model" to analyze port industry clusters (Haezendonck & Rousseeuw, 2000). She believes that fourteen factors influence the competitiveness of ports, such as internal competition, internal cooperation, customer relationships within the cluster, the existence of interrelated and mutually supportive industries, and government behavior. Similarly, Monteiro et al. (2013) conducts comparison analytics by using a reconceptualization of the "Diamond Model" for diagnosing the competitiveness of port clusters in European regions. This paper proposes that some factors that can affect the performance of clustered areas are combined. Including advantages derived from geography, marine centers of excellence enhance public-private collaboration, which can reduce transaction costs while providing an enabling environment for active interaction between the marine industry and actors. This perspective argues that the formation of port clusters is an agglomeration phenomenon driven by competitive relationships and cooperative factors, resulting from geography.

Other scholars have taken a spatial perspective (community-based) of port clusters to study the economic activities and interconnections among different companies. The port cluster is a "network of enterprises, research and innovation units, and training institutes, often funded by national or local agencies, that interact with a view to driving technical innovation and enhancing the performance of the maritime industry" (Chang, 2011). According to this viewpoint, the economic activities of port clusters are organized spatially. This definition emphasizes the importance of the region as a key driver for strengthening the innovation capacity of companies and regional maritime industries. It is effective for comprehension port clusters in a given region and the local conditions and assets that are typically present in these clusters. However, it risks ignoring the extra-regional economic activities associated with the port cluster.

No matter how scholars define port clusters, they cannot ignore the emergence of port clusters is the inevitable result of the booming world economy. With the continuous economic and social progress, the economic form of port clusters emerged early in some maritime countries, such as in cities like Rotterdam and London, where the port clusters are huge and efficient, significantly promoting the development of the port economy (Zhuang, Ma, & Zhao, 2013). Port cluster growth takes time and is guided by a number of key port businesses, including ship service, cargo transshipment service, and comprehensive terminal service. The aforementioned top port businesses have some inherent agglomeration, which will draw additional companies connected to them to congregate in the vicinity of the port. The stronger the port's economic development, the more pronounced this clustering effect will be. The so-called industries associated with the growth of the port mostly refer to the production of transportation equipment, trade, petrochemical, construction, and financial services businesses, among others. Due to the port's prime geographic location, favorable business climate, and excellent infrastructure, these industries are regularly drawn to the region around the port. The clustering area will grow as the number of businesses grows, first from the port's immediate vicinity to the city's commercial district, then to the entire city economy, until eventually developing a distinctive port economy built on industrial clusters. The structure of the port cluster is also continuously adjusted in dynamic development, which is the process of continuous adjustment of the focus and market share of different industries.

2.3 Definition and classification of Maritime Services

Since the mid-1980s, some of the world's major hub port cities (London, New York, Singapore, Hong Kong, etc.) have begun and are now undergoing a transformation from hub port centers to global trade centers or global supply chain centers (Wang & Cheng, 2015) (K, 2010). In this unprecedented transformation process, the accelerated concentration and continuous upgrading of port and maritime services have become the driving force for the transformation and development of hub port cities.The maritime service industry is known as the port service industry (Slack, 1982) (Slack, 1989) (Chen, Yan, & Cao, 2010), port and shipping service industry (Cao, Liang, Wu, & Chen, 2017) (Liang, Cao, & Wu, 2013), maritime services (De Langen, 2002). It is a traditional industry that relies on the port to provide related services for shipping activities. Maritime services arise with the demand of the shipping market and are formed with industrial innovation, information revolution and economies of scale. It can be conclude that the formation and development of maritime services came with the evolution of the shipping industry, with the stages and industry characteristics in Table 1. Share and upgrade between companies and services in the industry chain of maritime services through resource integration and reconstruction. Continuously improve the quality of maritime services, reduce costs and promote the improvement of customer value.

As expressed by Wang (2018), for the shipping market, besides the traditional maritime services mainly providing warehousing, logistics, port handling, etc., the division of maritime services has become more and more detailed with the demand of the market, and the content of services has become more and more specialized and modernized. Gao et al. (2013) proposes that modern shipping service is a complete industry chain formed by providing shipping finance, maritime law, policy consulting, shipping information, ship trading and other services, which is an important inner element of IMC development.

Therefore, when examining the industry structure of maritime services, we classify companies according to their value performance and impact into low, medium and high value-added industries, and shows in Table 2 (Gao & Liu, 2013) (GB/T 23833-2022, 2022) (Chen, Zhen, & Zong, 2008).

Table 1 The evolutionary stages of maritime services

STAGES	PERFORMANCE	CHARACTERISTICS
CONCEPTION	The basic system of the shipping industry has not yet been formed and contains only the waterway transportation industry. Auxiliary industries such as port services are still in their infancy.	The emergence of low value-added maritime services.
DEVELOPMENT	Marine services have been developed with the formation of shipping industry. At the same time, industries such as agency services, supply services, ship labor, brokerage services, inspection services and ship repair have also developed rapidly.	Cluster of medium added value maritime services.
FORMATION	Both low and medium added value maritime services have been developed and completed the agglomeration process. The knowledge-intensive high value-added maritime services also joins in the integration and clusting process of the first two.	The concentration of high value-added maritime services is the essential characteristic of this stage and also the sign of the beginning of the formation of shipping services.
MATURITY	At this stage, the low, medium and high value-added maritime services are highly integrated and clustered in a regional scope. The maritime services is formed by the core of high-end maritime services with mutual support and coordination.	A broader range of shipping-related services clustered in certain areas.

Source: (Gao & Liu, 2011)

Table 2 Classification, structure of maritime services

CLASS	SUBCLASS	CHARACTERISTICS	BENEFIT PERFORMANCE	GEOGRAPHICAL SCOPE
LOW VALUE ADDED	Warehousing; stevedoring; handling; container road transport; water cargo transport (ocean, coastal, inland waterways); freight ports; multimodal transport	Labor-intensive, small-scale enterprises	Low value-added	Decentralized
MEDIUM VALUE ADDED	International shipping agency; international cargo transportation agency; ship inspection; ship repair; ship and equipment supply; shipping and ship technology development and transfer	Capital-intensive, with outstanding scale effect and intensification characteristics	Medium added value	Centralized
HIGH VALUE ADDED	Shipping finance; shipping insurance; maritime arbitration; shipping information; ship classification; shipping economy; financial leasing; insurance valuation; maritime legal consulting; international ship management; industry organizations	Knowledge-intensive, usually related to the finance and insurance industry	High added value	Centralized

Source: (Lin, 2010)

The classification of maritime services is useful for ports when developing their strategies. Ports can use their different strengths to tailor policy options, such as geography, trade, human resource and technology. For instance, IMCs which mainly provide basic and auxiliary maritime services generally have very superior geographical location and trade advantages. They prefer develop port trade, shipping and warehousing, port handling industry, logistics and other port service industries. At present, most of the IMCs in the world are in this development mode, and the competition is extremely fierce. Singapore has taken advantage of its superior location, gathered maritime services, shipbuilding and ship repair industry, radiated the whole Southeast Asia, formed an IMC featuring water-to-water transit, and occupied a place in the competitiveness of IMC (Wang P. , 2018).

Other ports are focusing more on high-end maritime services. Theses maritime clusters mainly provides derivative maritime services, such as shipping finance, maritime insurance, shipping information and ship trading. For example, London has a large scale, complete service function and more mature development of high-end maritime services. According to, in 2014, London's services output accounts for more than 85% of GDP, and the total lending of maritime services financing in London in 2014 was about £31.23 billion, accounting for about 22.3% of the global market share; ship financing accounted for 17.8%, marine insurance accounted for 24.3%, and shipping insurance accounted for 21.8% of the global market. (Xu & Luo, 2015).

2.4 Symbiosis Theory applied Industrial Cluster Research

Port clusters, as a type of industrial clusters, are consistent in their research methods. This section will discuss the theoretical basis of symbiosis theory application in port cluster research.

One of the points of current research on industrial clusters is: How are the competitive advantages of industrial clusters formed? Do they rely on government or are they formed spontaneously? How do industrial clusters develop and evolve? Do industrial clusters decline? In fact, this is the study of the life cycle process of industrial clusters, which has similarities with the study of ecology (Gao Q. , 2008).

The earliest application of the principles of population ecology to the study of clusters was Hannan and Freeman in the late 1970s. They argued that the object of analysis of the theory of racial ecology is not a single company, but a cluster of companies. The racial ecology perspective differs from other cluster theories because it emphasizes the diversity of clusters and the adaptability of individuals within clusters. Borrowing from the racial ecology approach, cluster research emphasizes exploring issues at the group level rather than treating individuals within a cluster as the unit of analysis, which is the most obvious aspect that distinguishes it from other cluster theories. Using this approach, population ecology attempts to explain why some types or forms of clusters survive while others die out (Hannan & Freeman, 1993).

In addition to similarities in subject relationships, more scholars have found additional similarities in the behavioral and organizational structures of industrial clusters and races. Wholey et al. (1991) pointed out that the number, entry, and exit activities of companies throughout an industry are determined by a range of mechanisms, and that race ecology theory provides a very good framework to effectively explain the direct and indirect effects of firm entry, exit, and changes in market structure. And they applied race theory to do empirical analysis and research on the organizational changes of healthcare firms. He et al. (2005) argued that industrial clusters have certain similarities with biological populations, and established a mathematical model of competition, mutual benefit and upstream and downstream relationships among companies in industrial clusters by using the theory of population ecology to study the interrelationships among individuals of species, and argued that the conditions for reaching equilibrium among members with different relationships in industrial clusters are that cluster members with competitive relationships must maintain a certain degree of variability and The members with mutually beneficial relationships must maintain fierce competition and not be too dependent on each other. Moreover, the conditions for maintaining ecological balance in industrial clusters are: maintaining certain differences among enterprises in the cluster, forming a well-functioning division of labor and collaboration network, maintaining material and information exchanges with the outside world, and forming an open ecosystem. Xia (2005) used the principle of bionomics to classify the interaction system of enterprises in the business ecosystem into six types of relationships: symbiosis, co-habitation, bias harm, mutual benefit symbiosis, competition, and predation, and defined them through mathematical language. Then, on this basis, models of business interactions, time-varying models, mutual competition models, symbiosis models, predator-prey models, and business competition models are constructed. Finally, an in-depth economic analysis of these models is presented. A theoretical basis is provided for firms to analyze their interactions with other firms in the business ecosystem and to develop long-term and sustainable development strategies.

Industrial clusters are like ecological races or communities, where individuals and the whole in a business population or community undergo a new city metabolic process in order to continuously adapt to environmental changes, which is a manifestation of a race or community with vitality. The reason why individual enterprises are willing to gather and survive and develop in the clusters formed by agglomeration is that the unique biological environment formed by agglomeration has the interdependence and inter-constrained internal structural relationship and external interaction relationship of synergistic adaptation. This kind of enterprise race or community formed by agglomeration generates new quality that is not possessed by the functional superposition of individual enterprises through the internal organic synergy and external adaptive interaction, which is the essence of enterprise cluster. Therefore, the concept of industrial clusters from an ecological perspective encompasses the phenomenon of enterprise agglomeration based on various associative attributes. Relative to the clustering relationship in different five in nature, industrial clusters also have various organizations of different forms and nature, which are closely related to each other and have interdependent, competitive and cooperative interactions, thus forming a symbiotic and coexisting social network system (Zhong, 2007).

Once we observe the aggregation of clusters, it is not difficult to analyze the impact that this has. Datao (2003) used symbiosis theory in his study to point out that the symbiosis of clustered companies helps to reduce the market transaction costs and internal management costs of company clustering and proposed the mode of company derivation under the symbiosis relationship, the selection mechanism of clustered companies for symbiotic objects, and the mediation mechanism of the cluster development process. Zhou (2003) argued that the phenomenon of company clustering in economic life and the phenomenon of symbiotic evolution of biological populations in nature have some similarities. Borrowing from the logistic equation in biology, the phenomenon of company clusters is described dynamically through the portrayal of the output level of companies in cluster formation. Two cluster models, satellite and reticulate, are discussed separately in the industrial cluster, and the conditions and economic explanations for the stable symbiosis of the two cluster models are given. A main conclusion is obtained that the intense competition within the cluster is the key for the enterprise clusters to reach stable symbiosis. In addition, (Qiu, 1999) found that the stability of a cluster can only be maintained if each firm within the cluster can find its own ecological niche.

Through the above scholars' application of symbiosis theory to cluster research, it can be seen that industrial clusters and biomes have some other common features in addition to similarities in terms of constituents, structure, function and evolution. To illustrate these similarities and common features more clearly, this paper compares the similarities of biomes, industrial clusters, and port clusters in terms of constituents, structure, function, and evolution and shows Table 3.

It is evident the industrial cluster or the port cluster is a hierarchical, enterprise-oriented system that is similar to an ecosystem in that it is composed of certain structures. It can be said that an industrial cluster is an ecosystem with companies as the main body. Based on the similar relationship between industrial clusters and ecosystems, we believe that the development of symbiosis theory has brought new ideas and concepts to the study of industrial clusters (Li Y. , 2006) (Chen & Yang, 2004).

Table 3 Comparison of similarities between biomes, industrial clusters, and port cluster

		Biomes	Industrial Cluster	Port Cluster
Components		Biological populations	Companies and organizations	Port, logistics companies, maritime services, education institutions, etc.
Structure	Connection	Interaction	Interaction	Interaction
	Assessment	Positive and negative assessment	Positive and negative assessment	Positive and negative assessment
	Spatial	Distribution by resource	Distribution by geographic	Distribution by geographic
	Nutrition/Value structure	Food chain	Value chain	Value chain
	Hierarchy Structure	Individuals, Populations, Communities, Ecosystems	Company, Industry Cluster, Cluster Ecosystem	Company, Industry Cluster, Cluster Ecosystem
Function		Species flow, energy flow, material circulation, information transfer, resource destruction, maintenance of ecological balance	Material flow, value flow, information transmission, production activities, and economic promotion	Cargo flow, supply value chain, logistic hub, information sharing, and global economic promotion
Evolutionary Process		From simple to complex, from lower to higher organisms	From simple to complex, from small scale to large scale	From simple to complex, from small scale to large scale
Evolutionary Features		Different levels of morphological structures are gradually complicated and refined	Expansion and improvement of the industrial chain	Expansion and improvement of the industrial chain
Evolutionary specificity		Specialization and degradation	Specialization tends to strengthen	Specialization and industry integration
Method of evolution		Progressive or explosive	Survival of the fittest	Survival of the fittest
Environmental influences		Natural selection, survival of the fittest	Adaptation to the environment	Adaptation to the environment
Self-adaptation		Has some adaptive capability	Has some adaptive capability	Has some adaptive capability
Dynamic Features		Occurrence, formation, development, evolution	Birth, formation, development, evolvement	Birth, formation, development, evolvement

Source: (Gao Q. , 2008)

2.5 Lotka-Volterra model

More than 100 years ago, the British economist and sociologist Malthus (Malthus, 1998), after studying more than 100 years of demographic data, found that the increase in population per unit time was proportional to the total population at that time, and proposed the famous Malthusian growth model in 1798. The basic assumption of the model is that the growth rate of the population is constant, or that the growth of the population per unit of time is proportional to the number of people at that time.

Gao (2008) mentioned in practice, the Malthus growth model has proved to be relatively accurate for short-term population projections, and the demographic data are more consistent when the resources are abundant, and the population is relatively sparse. But using it for long-term projections is inaccurate and would lead to the conclusion of infinite population growth, which is clearly not true. This error stems from the limitations of the Malthus model assumptions - it cuts the link between racial growth and resources, assuming that populations show an exponential growth trend in the absence of resource constraints. However, in reality, as species populations expand in size and factors of survival and development, such as food, water, and living space, decrease, continued population growth is stunted by the limited resources in the environment.

Based on the above considerations, in 1838, on the basis of the Malthus growth model, considered the influence of natural resources and environment on the growth rate of the race and proposed a logistic model to describe the evolution of the race size (Bacaër, 1838). The maximum number of individuals N within the population that can be allowed under certain natural resources and environmental conditions was introduced and called the environmental accommodation. x denotes the number of the population and r denotes the fixed growth rate of the population. Eq. (1) can be obtained as below.

$$\frac{dx}{dt} = rx\left(1 - \frac{x}{N}\right) \tag{1}$$

When the number of individuals within the race reaches N, the population stops growing, as shown in Eq. (2).

$$\frac{dx}{dt} = 0 \tag{2}$$

When the population size is less than N, the population will continue to grow, however, as the population density increases, the growth rate of the population will gradually decrease proportionally. This can be interpreted as, for each additional individual in the population, this individual takes up $\frac{1}{N}$ of the resources, and if there are x individuals in the population, it will take up $\frac{x}{N}$ of the resources, and the remaining available resources will only be $\left(1 - \frac{x}{N}\right)$.

In addition, in addition to the limiting effect of environmental resources, in a certain ecological environment, there are usually living populations of multiple species, and the changes in the number of individuals in each species population are not only limited by competition for resources and so on within the population, but also influenced by other populations. This influence is also diverse, some populations compete with each other for the same resources on which they depend, some populations feed on another population, and some populations are symbiotic with each other.

The Lotka-Volterra model proposed by Lotka (1910) and Volterra (1928) precisely describes the quantitative changes in the predation relationship between two populations in the biological world, and lays the theoretical foundation of inter-race competition, which has an important influence on modern ecology (Cai, 2000). The Lotka-Volterra model is based on the predation-prey relationship in the ecological environment, and the quantities of food bait and predators at moment t are denoted as x(t) and y(t), and the following four scenarios are made.

- *Scenario I:* In the absence of predators in the environment, the food bait grows exponentially and infinitely, and the growth rate is denoted as r (r>0);

- *Scenario II:* In the presence of predators in the environment, the growth rate of food bait decreases, and the rate of decrease is proportional to the number of predators, and the proportionality coefficient a (a>0) reflects the predator's ability to take food bait.

- *Scenario III:* When food bait is not present in the environment, the mortality rate of predators is exponential and is recorded as d (d>0).

- *Scenario IV:* When food bait is present in the environment, the mortality rate of predators decreases and the decrease is proportional to the amount of food bait, and the proportionality coefficient b (b>0) reflects the feeding ability of food bait on predators.

At this point, the Lotka-Volterra model can be described as Eqs. (3) and (4).

$$\frac{dx}{dt} = x(r - ay) \tag{3}$$

$$\frac{dy}{dt} = y(-d + bx) \tag{4}$$

Although this model has the drawback of assuming an overly idealized environment, it still has a high relevance to the real situation, reflects real life, and has research value. Its applications are not limited to ecosystems, but appear in the fields of chemistry, logistics, population, economy, finance, etc. Drawing on the interactions between ecological populations, Xu (2018) considered each firm as a group and analyzed the specific situation of firms at the equilibrium point in the competitive relationship in the market. Further, Wang et al. (2018) introduce contribution and competition coefficients based on the stagnant growth model and proposed an improved Logistic-Volterra model to study the cooperative relationship between manufacturing and logistics enterprises, and finally concluded that only the linkage development of the two enterprises can achieve the equilibrium stability of the system.

In addition to exploring the ecological relationships of specific enterprises, many scholars have also applied it to the field of industrial ecosystems. Zhou et al. (2014) used the Lotka-Volterra model to measure the symbiotic coordination degree of the two in 30 provinces in China based on the analysis of the interaction between industrial economic development and industrial ecology and classified the types of industrial eco-economic system coordination from two dimensions of symbiotic relationship and development level, and finally obtained the result that the two change patterns are not the same. Yang et al. (2019) also draw on the symbiotic theory of biology to analyze the synergistic development mechanism between productive service industry and modern manufacturing industry, and the results showed that there is a mutually beneficial symbiotic relationship between the two industries, which can achieve synergistic upgrading development.

Lotka-Volterra model is also applied to study the maritime industry in a number of articles. Wang (2018) uses symbiosis theory to analyze the symbiotic three elements of shipping service factor clusters, symbiosis index and symbiosis mechanism, establishes the industrial and commercial system of shipping service factor clusters, and theoretically analyzes the symbiosis mode of shipping service factor clusters development and the symbiotic effect of shipping service elements agglomeration development was analyzed theoretically. Gao (2008) verified the competition relationship among container terminal companies by numerical simulation with the help of the Lotka-Volterra model reflecting interspecies relationship in two cases of no time lag and with a time lag. By drawing on biological science via conceptual development, Zhang et al. (2013) investigates the symbiosis theory and the Lotka-Volterra model and suggests a practical strategy as a useful tool for empirical study on the evolution of marine clusters. Furthermore, Zhang et al. (2017) demonstrates the opposite relationship between the port and maritime services (marine insurance and shipbroking) between London and Hong Kong. The outcomes are consistent with the actual policy approach. The growth of marine services favors the port of London, whereas the port of Hong Kong only competes with the services industry. Liao et al. (2021) analyzes the Chinese port of Dalian using the Lotka-Volterra model. demonstrates how ports used resources to support the shipping industry and marine insurance throughout the cluster's non-decline period (NDP). On the other hand, port expansion during the cluster's decline phase (DP) had negative effects on maritime industry connections due to increasing resource competition and lock-in effects.

3 Methodology

This section describes the methodological framework used for the Lotka-Volterra model, the criteria for selecting variables, the handling and arrangement of the data, and the definition and implementation of the model.

3.1 Model selection

As analyzed by Li (2021) for maritime cluster research methods, descriptive analysis, comparative case analysis, survey analysis, and input-output (IO) analysis have all been used in maritime cluster research since 1999. Perhaps because first-hand data are difficult to obtain in the maritime industry, the use of quantitative analysis is lacking. As stated in 2.5, considering the evolution of marine clusters from the perspective of port development, the Lotka-Volterra model is ideally suitable for analyzing the relationships and interactions between ports and other marine sectors.

The Lotka-Volterra model was originally used to describe predator-prey relationships, and as the theory of differential equations became more widely used, this ecological model evolved to allow for a wider range of applications. The general form of Lotka-Volterra model are Eqs. (5) and (6).

$$\frac{dx}{dt} = x(a_1 + b_1 x + c_1 y) \tag{5}$$

$$\frac{dy}{dt} = y(a_2 + b_2 x + c_2 y) \tag{6}$$

x and y denote the numbers of the two populations, respectively, and a_i, b_i, c_i $(i = 1{,}2)$ are constants: $a_i (i = 1{,}2)$ denotes the endogenous growth rates of the two populations, that is, the maximum instantaneous growth rates of populations with stable age groupings under given conditions; $b_1$and c_2 reflect the action coefficients of the two populations themselves; $b_2$and c_1 denote the coefficient of action of one specie on another specie, respectively, also known as the interspecific coefficient of action. The Lotka-Volterra model can be classified into the competition model, predation-baiting model and reciprocal cooperation model according to the population interactions (Yang Q. , 2022).

Table 4 Classification of Lotka-Volterra model

Model Classification	**Population relations**
Competition model	When there are two or more populations living together, competition between populations will form in order to compete for limited living resources. In this case, there are four possible outcomes for each individual population: strong competitiveness leading to population growth, weak competitiveness leading to extinction, coexistence of the two populations but instability, and stable coexistence of the two species.
Predation-baiting model	In this relationship, one species exists as bait for the other. They compete together for limited resources and the relationship between the two groups is one of reciprocal action.
Reciprocal cooperation model	Reciprocal cooperation refers to the relationship between two populations that are interdependent and cooperate with each other for mutual benefit. A typical example is honeybees and flowers, where pollination by bees is beneficial to both parties and has a co-promoting effect.

Source: (Yang Q. , 2022)

In this paper, we will combine the maritime cluster theory and the ecological Lotka-Volterra model to build a model that can reflect the relationship between port and maritime sectors. The development of maritime sectors is not only related to the competition of companies in the same industry, but also related to the upstream and downstream companies in the maritime cluster. According to the definition of clusters in 2.1, the competitive relationship between market players is its theoretical basis. Highly competitive players can growth rapidly, while others may drop out of the market due to a lack of profitability. The coexistence of multiple players reflects the stable performance of the market in different periods. The relationship between different players is inverse, and the interspecific coefficient of action is negative. Also, the intra-species coefficient is negative due to the constraints within the cluster. The formulations are Eqs. (7) and (8) (Tsai & Li, 2009).

$$\frac{dx}{dt} = x(r_1 - \alpha_1 x - \beta_1 y) \tag{7}$$

$$\frac{dy}{dt} = y(r_2 - \beta_2 x - \alpha_2 y) \tag{8}$$

In the Eqs. (7) and (8), x and y represent the economic performance of two maritime sectors.

$r_i (i = 1,2)$ reflects the free growth rate (endogenous growth rate) of the industry in the absence of external disturbances. The change caused by each group only by its own internal factors when no other group exists in the whole ecosystem and is not limited by other conditions in the system. If $r_i > 0$, it can be interpreted as the degree of development of a single group in the case that the external world reflects positively on it. The larger this value is, the better the internal development. That is, when no other external factors are considered, maritime cluster has a positive effect on the development of this sector.

$\alpha_i (i = 1,2)$ represents the limitation of system size to itself. In order to obtain the limited resources in the maritime cluster, there is a competitive relationship between firms. There is a certain market share within the entire cluster system, and even a single individual in a monopoly situation cannot expand indefinitely. Specifically, there are inherent factors in the ecosystem that inhibit the growth of firms in a cluster, such as policy, strategic upscaling, and technological innovation. If $\alpha_i > 0$, it means that the subject received the inhibitory effect of these factors, and the higher the value of the coefficient, the higher the degree of inhibition.

$\beta_i (i = 1,2)$ is the coefficient describing the competitive interaction between maritime sectors x and y. The magnitude of the specific value of β_i indicates the extent of this competitive role and reflects the different ecological relationships between sectors, as shown in Table 5 (Modis, 1999).

Table 5 The implication of coefficients β_1 and β_2

$\boldsymbol{\beta_1}$	$\boldsymbol{\beta_2}$	**Type of relationship**	**Implication**
+	+	Pure competition	Two populations inhibit each other by competing for the same resource
+	-	Predator-prey	β_1 is the predator of β_2 and β_2 is the food bait of β_1
-	-	Mutualism	Benefits both populations
+	0	Amensalism	$\beta_1$is inhibited, β_2 is not affected
-	0	Commensalism	$\beta_1$benefit, β_2 no benefit and no harm
0	0	Neutralism	The two populations do not affect each other

Source: (Yang Q. , 2022) (Zhang & Lam, 2013)

Since the maritime cluster is quantified as discrete-time data, the equations in this paper need to be converted from the Lotka-Volterra model for continuous data to a discrete mode, as illustrated into Eqs. (9) and (10) (Leslie, 1958).

$$x(t+1) = \frac{f_1 x_{(t)}}{1 + g_1 x_{(t)} + h_1 y_{(t)}} \tag{9}$$

$$y(t+1) = \frac{f_2 y_{(t)}}{1 + g_2 y_{(t)} + h_2 x_{(t)}} \tag{10}$$

With this, we can conclude the relationship between the coefficients as Eqs. (11), (12) and (13).

$$r_i = \ln f_i \tag{11}$$

$$\alpha_i = \frac{g_i \ln f_i}{f_i - 1} \tag{12}$$

$$\beta_i = \frac{h_i \ln f_i}{f_i - 1} \tag{13}$$

In Eq. (13), the coefficient c_i of the relationship between populations is determined by h_i because $f_i > 0$ and $f_i \neq 0$, such that $\frac{\ln f_i}{f_i - 1}$ is always positive.

3.2 Equilibrium analysis

In the Lotka-Volterra model, studying the equilibrium point can help to understand what the stabilization relationship between maritime sectors. How does the trajectory of stabilization work? In other words, an unstable equilibrium state will lead to one of the parties being in a suppressive position to the detriment of the other party, while there is a chaotic state describing an intermediate state between stability and instability, which is considered to be the most ideal equilibrium state in ecological competition relationships (Yang Q. , 2022) (Volterra, 1928).

On the premise of an equilibrium, Eqs. (7) and (8) are zero at the same time. Then, we can obtain the following Eqs. (14) and (15).

$$\frac{dx}{dt} = x(r_1 - \alpha_1 x - \beta_1 y) \ = 0 \tag{14}$$

$$\frac{dy}{dt} = y(r_2 - \beta_2 x - \alpha_2 y) \ = 0 \tag{15}$$

By decomposing the above Eqs., we get (16) and (17).

$$\mathrm{x} = \frac{r_1 - \beta_1 y}{\alpha_1} \tag{16}$$

$$\mathrm{y} = \frac{r_2 - \beta_2 x}{\alpha_2} \tag{17}$$

The four solutions of Eqs. (16) and (17) are:

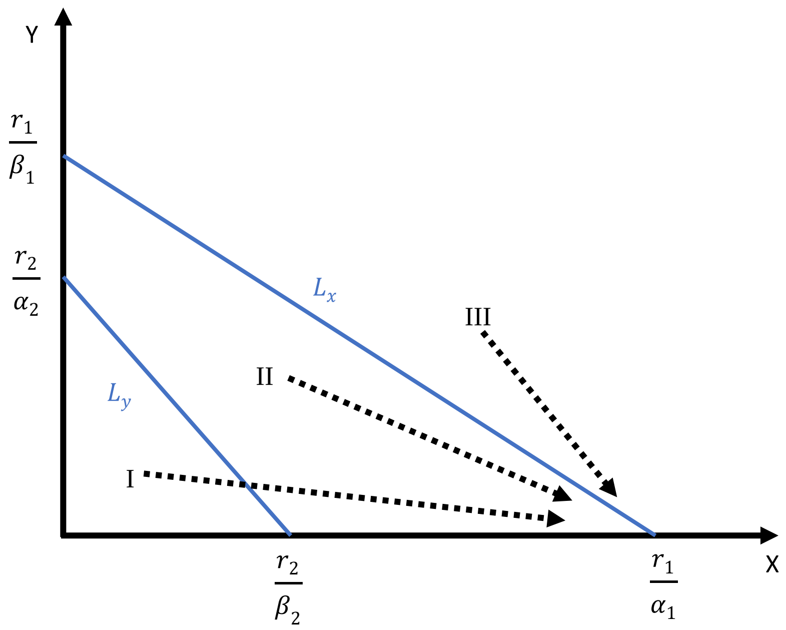
$$E_1(0,0), E_2\left(\frac{r_1}{\alpha_1},0\right), E_3\left(0,\frac{r_2}{\alpha_2}\right), E_4(x^*,y^*)$$

In the above result, where $E_4(x^*, y^*)$ is the intersection of the lines $L_x = r_1 - \alpha_1 x - \beta_1 y = 0$ and $L_y = r_2 - \beta_2 x - \alpha_2 y = 0$. Again, here the equilibrium point has practical significance only when it is located in the first quadrant of the plane coordinate system, and the evolution of the equilibrium point is analyzed below in conjunction with the different cases of the specific positions of the two lines L_x and L_y on the right-angle coordinate system.

3.2.1 Equilibrium point analysis in the case of two lines that do not intersect

Figures 2 depicts the case where two lines, L_x and L_y do not intersect. The line L_x lies above the line L_y in the first quadrant, and the two lines divide the system into three regions, which gives the Eqs. (18), (19) and (20), as $\frac{r_1}{\alpha_1} > \frac{r_2}{\beta_2}$ and $\frac{r_1}{\beta_1} > \frac{r_2}{\alpha_2}$.

Figure 2 Analysis of the case that two lines do not intersect and line L_x is located above



Source: Drawn by author

$$I: \frac{dx}{dt} < 0, \frac{dy}{dt} < 0 \tag{18}$$

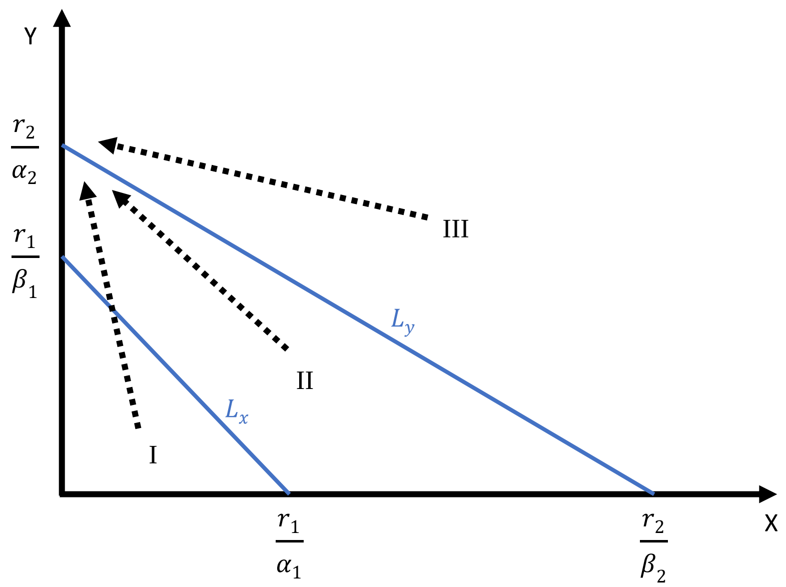
$$II: \frac{dx}{dt} < 0, \frac{dy}{dt} > 0 \tag{19}$$

$$III: \frac{dx}{dt} > 0, \frac{dy}{dt} > 0 \tag{20}$$

From this, we can prove that the final trajectory will converge to the equilibrium point E_2 regardless of the point in the region from which it starts. If the trajectory starts from region I, according to Eq. (18), as time t increases, all the points in region I will move to the upright and enter into region II. The points in region II are influenced by Eq. (19), and it is impossible to pass through X-axis into region III, so they can only move down to the right to reach the equilibrium point E_2. While in region III, we can know from Eq. (20) that the trajectory will move down to enter region II and finally converge to the point E_2.

The line L_x lies above the line L_y. In other words, the maritime sector x has a more competitive market share than the maritime sector y. As the ecological relationship evolves, it eventually reaches the equilibrium point E_2, which means that the maritime sector y receives substitution and squeeze from the maritime sector x. Over time, only the maritime sector x will eventually remain within the cluster and reach the maximum capacity of the environment.

Figure 3 Analysis of the case that two lines do not intersect and line L_y is located above



Source: Drawn by author

The same result is obtained for Figure 3, where the line L_x is located below the line L_y. The first quadrant is also divided into three regions, which can be expressed as Eqs. (21), (22) and (23), where $\frac{r_2}{\alpha_2} > \frac{r_1}{\beta_1}$ and $\frac{r_2}{\beta_2} > \frac{r_1}{\alpha_1}$.

$$I: \frac{dx}{dt} > 0, \frac{dy}{dt} > 0 \tag{21}$$

$$II: \frac{dx}{dt} < 0, \frac{dy}{dt} > 0 \tag{22}$$

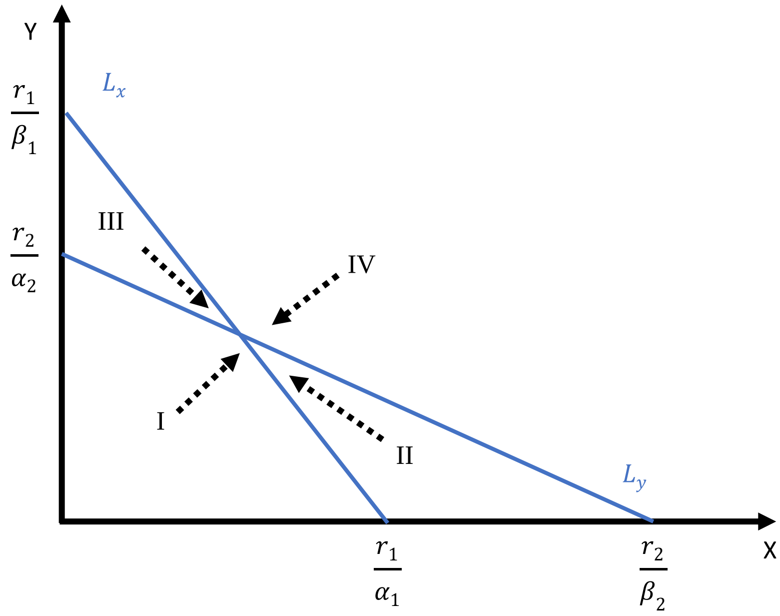
$$III: \frac{dx}{dt} < 0, \frac{dy}{dt} < 0 \tag{23}$$

In Figure 3, the trajectories of the points in each region are different. The points in region I are affected to move upward and gradually into region II. The points in region III will move downward to the left and enter region II via straight line L_y. The point in region II will move to the point E_3, and reach the equilibrium state at this point. In contrast to Figure 1, in the case of Figure 2 maritime sector y is more competitive than maritime sector x. The final dynamic evolution results in an equilibrium at E_3, indicating that maritime sector y preys on maritime sector x and eventually occupies the entire market.

3.2.2 Equilibrium point analysis in the case of intersection of two straight lines

The next analysis is for the case where two lines exist in the first quadrant with intersection points. Unlike the first two trends that evolve in only three directions, this case of straight lines L_x and L_y divides the first quadrant into four regions, and the interaction and evolution between x and y are more complex, as in Figure 4 and Eqs. (24), (25), (26) and (27), where $\frac{r_1}{\beta_1} > \frac{r_2}{\alpha_2}$ and $\frac{r_2}{\beta_2} > \frac{r_1}{\alpha_1}$.

Figure 4 Analysis of the case that two lines intersecting and line L_x intercect is larger



Source: Drawn by author

$$I: \frac{dx}{dt} > 0, \frac{dy}{dt} > 0 \tag{24}$$

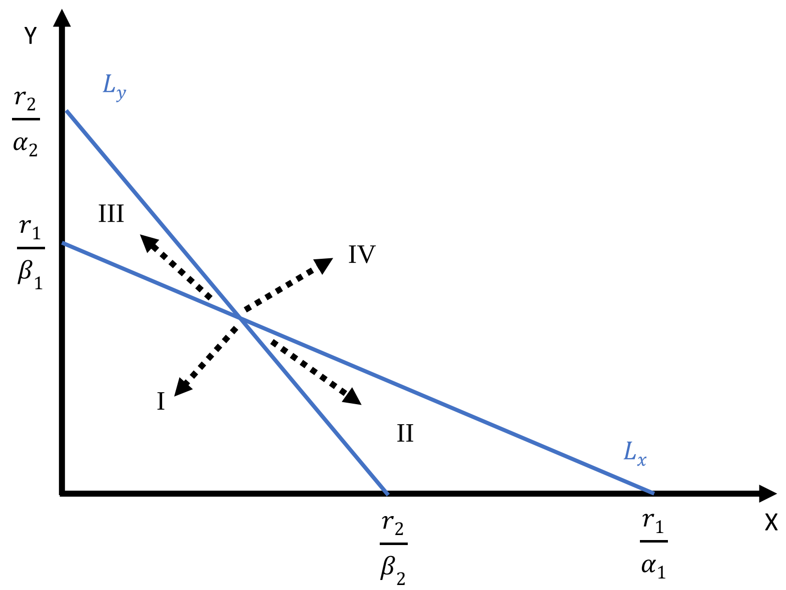
$$II: \frac{dx}{dt} < 0, \frac{dy}{dt} > 0 \tag{25}$$

$$III: \frac{dx}{dt} > 0, \frac{dy}{dt} < 0 \tag{26}$$

$$IV: \frac{dx}{dt} < 0, \frac{dy}{dt} < 0 \tag{27}$$

From the dynamic line of the trajectory, the point in region I is influenced by Eq. (24) to move up to the right; the points in regions I and II keep moving to the point E_4; due to Eq. (29), the points in region IV will move downward and finally reach the point E_4 and converge to the equilibrium state. Combined with the realistic analysis, all maritime sectors have a certain degree of competition with each other while developing themselves. When this degree of competition is still relatively small, the promotion effect brought by the competition between the two will be greater than the inhibiting effect. In other words, the effect of cooperation is greater than competition, and the balance will be maintained over time.

Figure 5 Analysis of the case that two lines intersecting and line L_y intercect is larger



Source: Drawn by author

However, Figure 5 presents a different result, where the point E_4 is unstable, which means there is no final stable equilibrium state. The specific performance of each region can be shown as Eqs. (28), (29), (30) and (31), and $\frac{r_2}{\alpha_2} > \frac{r_1}{\beta_1}$ and $\frac{r_1}{\alpha_1} > \frac{r_2}{\beta_2}$.

$$I: \frac{dx}{dt} > 0, \frac{dy}{dt} > 0 \tag{28}$$

$$II: \frac{dx}{dt} > 0, \frac{dy}{dt} < 0 \tag{29}$$

$$III: \frac{dx}{dt} < 0, \frac{dy}{dt} > 0 \tag{30}$$

$$IV: \frac{dx}{dt} < 0, \frac{dy}{dt} < 0 \tag{31}$$

In the four regions shown in Figure 5, the evolutionary tendency of the points will be to move upward toward the equilibrium point E_3 and to move downward to the right toward the regional equilibrium point E_2. The equilibrium points E_2 and E_3 at this point are called locally stable and cannot reach the overall stable equilibrium state. This means that there is much more competition than cooperation between maritime sectors, and that both are highly competitive and may even compete aggressively. The aim of such competition is to be extremely exclusive and to completely push each other out of the cluster by competing for market share, which is not conducive to the development of the cluster system as a whole.

This chapter takes the relationship between sectors within the maritime cluster as the research object, constructs a theoretical framework of the maritime cluster ecosystem based on the Lotka-Volterra model, and analyzes the mechanism of ecological competition relationship within cluster. In the current economic circumstances, the degree of competition between maritime sectors has deepened. According to the difference of coefficients in the constructed model, the ecological relations can be subdivided into six types. Further, the interaction between maritime sectors is analyzed using a combination of numerical and morphological methods, and the dynamic evolutionary trends when the ecosystem reaches the equilibrium point, and the steady state are illustrated in separate cases.

The results show that if the two lines intersect in the second or fourth quadrant, the equilibrium points E_2 and E_3 indicate that one maritime sector will survive in the future and the other will exit the maritime market; only if the two lines L_x and L_y intersect in the first quadrant can there be an equilibrium between the two competing maritime sectors.

4 An empirical analysis of the relationship between maritime services and maritime clusters

This chapter will empirically analyze the ecological competition relationship between port and maritime services and the dynamic evolution trend by constructing an Lotka-Volterra model. Therefore, the future composition of the marine sector is related to the strategic direction of each cluster.

4.1 Empirical Research Design

As discussed in Chapter 2, port clusters have different cluster formation and functions, and their characteristics are dynamic. As an advanced hub port in the Asia-Pacific region, Shanghai has become the economic, trade and shipping center of China. Shanghai port is located at the intersection of "21st Century Maritime Silk Road" and "Yangtze River Economic Belt" and is the main hub port along the coast of China and the largest container port in the world. 2014, Shanghai's shipping finance and insurance accounted for more than 26% of the country, ranking first in the country; the city has more than 250 foreign representative offices in Shanghai operating international maritime transportation and its auxiliary industry, nine major global classification institutions have opened their representative offices in Shanghai. The world's three largest cruise lines have also settled in Shanghai (Cao, Liang, Wu, & Chen, 2017). Therefore, not only high value-added marine insurance and shipping agency, but also labor-intensive traditional industries are the key sectors of Shanghai's maritime cluster. It is clear that the empirical analysis of Shanghai maritime services is typical and helps to provide a Chinese perspective and example for similar international studies.

4.1.1 Sample Selection

In Chapter 2, we discuss classifying maritime services into three levels: low-end, middle-end, and high-end. To conduct a more accurate case study, we selected one of the most representative and influential industries from each of the three levels as the objective of analysis between 2007 and 2021. Because of the opaque and difficult data availability in the maritime industry, using the same data type, such as turnover or volume of operations, is difficult. Hence, port and shipping data are related to container, which is handed volume and turnover. In contrast, ship agency and marine insurance are the sums of the number of new companies added during the 14-year period.

Table 6 Sample selection and data sources

Class	**Industry**	**Data**	**Data Source**
	Port	Throughput: Cargo Volume of Goods Handled	CEIC
Low-end value chain	Shipping	Turnover of water transport cargo	CEIC
Middle-end value chain	Ship agency	The quantity of ship agent businesses (the main business is the ship agency)	The data of enterprise (organization) attributes include registered name, registered capital, registered date, business coverage, registered address, and business status, mainly from the TianYanCha system (https://www.tianyancha.com/), the official record enterprise credit agency of the National SME Development Fund, as of January 9, 2023.
High-end value chain	Marine insurance	The quantity of maritime insurance companies (business involves marine insurance)	

Source: Complied by author, based on (Shanghai International Port (Group) Company Limited, 2022), (Ministry of Transport, 2022) *and* (Tianyan Cha, 2022)

4.1.2 Research Framework

The empirical study is mainly based on the construction of Lotka-Volterra model about the ecological competition model among maritime services to comprehensively describe the level of competitiveness among different classes of maritime sectors.

- Determine the basic model of the study. Combining the characteristics of maritime clusters, the ecosystem theory is applied to construct a nonlinear Lotka-Volterra ecological model about both, as shown in Eqs. (7) and (8).
- Organize the raw data according to the sample rules. Especially ship agency and marine insurance, the business coverage needs to be accurate.
- Estimating the specific values of the parameters in the model. According to the final data, the Stata software combined with the least squares method was used to estimate the parameters of the constructed nonlinear model and to derive the specific values of the coefficients.
- Analysis of ecological relationships of maritime transport services based on empirical results. The values of the scrupulous parameters are brought into the model, and the ecological relationships between maritime transport services are discussed from three perspectives: the coefficient of natural growth, the coefficient of competitive relations and the coefficient of restrictiveness.
- Analyze the interaction between maritime service industries based on the empirical results. To find the equilibrium state between industries with reference to the theory of differential equations. Combine with stability theory to analyze the stability of the equilibrium point in which it is located to simulate the evolutionary trend.

4.2 Empirical analysis

4.2.1 Data processing

In this paper, the four industries shown in Table 6 are selected as the study sample for the 14-year period 2007-2021.

4.2.2 Least squares method for parameter estimation

Since the constructed Lotka-Volterra model is a nonlinear model and the data are all discrete, it is first transformed into a discrete form. Then by substituting the variables, we get the Eqs. (32) and (33).

$$x(t+1) = \frac{f_1 x_{(t)}}{1 + g_1 x_{(t)} + h_1 y_{(t)}} \tag{32}$$

$$y(t+1) = \frac{f_1 y_{(t)}}{1 + g_2 y_{(t)} + h_2 x_{(t)}} \quad (33)$$

f_i and g_i represent the characteristic parameters when only the port x is present with the other three maritime service industries y, respectively, and h_2 represents the interaction between the two. With this, we can conclude the relationship between the coefficients as Eqs. (34), (35) and (36).

$$r_i = \ln f_i \quad (34)$$

$$a_i = \frac{g_i \ln f_i}{f_i - 1} \quad (35)$$

$$\beta_i = \frac{h_i \ln f_i}{f_i - 1} \quad (36)$$

The parameters of the constructed nonlinear model were estimated in Stata using the least squares method combined with Eqs. (32) (33), and then the specific parameter values in the model were calculated according to Eqs. (34) (35) (36), and the results are given in Table 7.

Table 7 Estimated results of the parameters of the model

Port and Shipping				Port and Ship agency				Port and Marine insurance			
$\boldsymbol{f_1}$	-1,014109	f_2	-0,9859175	f_1	-1,013613	f_2	-0,5692971	f_1	-1,014348	f_2	-0,0175312
$\boldsymbol{g_1}$	0,050576	g_2	0,0670306	g_1	0,0505369	g_2	0,0835565	g_1	0,0506087	g_2	0,0144118
$\boldsymbol{h_1}$	5,15E-07	h_2	0,0010267	h_1	0,0000202	h_2	0,0222586	h_1	0,000008027	h_2	0,0482536
$\boldsymbol{S.E.}$	0,0007336	$S.E.$	0,003419	$S.E.$	0,0007224	$S.E.$	0,0171478	$S.E.$	0,0007237	$S.E.$	0,0078612
$\boldsymbol{r_1}$	0,0140103	r_2	-0,0141826	r_1	0,013521	r_2	-0,5633529	r_1	0,0142456	r_2	-4,043776
$\boldsymbol{a_1}$	0,0502225	a_2	0,0675071	a_1	0,050196	a_2	0,1092906	a_1	0,0502491	a_2	0,0593182
$\boldsymbol{\beta_1}$	0,000000512	β_2	0,001034	β_1	0,00002	β_2	0,029114	β_1	0,00000797	β_2	0,1986086

4.2.3 Ecological relationship analysis

Based on the estimation of the model parameters above, the ecological relationships among maritime service industries are analyzed below specifically in terms of the natural growth coefficient, the restrictive coefficient and the competitive relationship coefficient.

(1) Analysis from natural growth coefficient

Table 8 The results of the natural growth coefficient r_i

	r_1	r_2	*Difference in absolute value*
Port and Shipping	0,0140103	-0,0141826	0,0001723
Port and Ship agency	0,013521	-0,5633529	0,5498319
Port and Marine insurance	0,0142456	-4,043776	4,0295304
Average	0,013925633	-1,540437167	1,52651153

According to the results of the natural growth coefficient shown in Table 8, between 2007 and 2021, the development of port is positive. The natural growth rates of the other three sectors of the maritime services industry (shipping, ship agency and marine insurance) are all in the plural. In particular, the maritime insurance industry as a high-end service industry, has an absolute difference of 4.0295304, which is much higher than the other two. From an ecological point of view, there are two main factors in the development of populations. One is that the natural environment is suitable for its growth, and the other is that the population itself is adapted to the ecological environment (Yang Q. , 2022).

This is exactly the case in the development of Shanghai's maritime service industry. The policy, traditional port and maritime industry, and the extension of local advantageous industrial chain together support the formation and development of shipping service industry. (Jiang, Jiao, & Guan, 2021) elaborates the evolution of functional meta-structure of Shanghai shipping services. It is found that the distribution of top 10 high-frequency keywords in 1992, 2005 and 2019 is highly overlapping, involving 3 industries of warehousing, international freight forwarding and transportation, with warehousing always occupying the first place in word frequency. Some of the new industries are not sufficiently developed and the boom is very short-lived, such as shipping agency and maritime consulting. This is related to both the degree of policy openness and the habits of end customers, as well as the high threshold of entry into such industries and the high concentration of resources.

In general, most of the maritime services in Shanghai is concentrated in the downstream enterprises with low added value such as shipping agency and cargo agency. And ship financing, or insurance and other high-end service industry fields account for a relatively low percentage. In the field of global shipping trading, information, pricing and legal services, such as shipping index futures, freight options and other shipping value derivatives are still blank (Lin, 2010).

(2) Analysis from the restriction coefficient

Table 9 is the result of the restrictiveness factor, which reflects the extent to which the maritime service receives influence from its own or system-wide internal factors. The results of this set of coefficients are the closest among the three, which means that the shipping services has a similar degree of influence on internal constraints. The level of performance of maritime services as a cluster can be influenced by the ability to commercialize, innovate, and communicate externally.

Table 9 The results of the restriction coefficient a_i

	a_1	a_2	*Difference in absolute value*
Port and Shipping	0,0502225	0,0675071	0,0172846
Port and Ship agency	0,050196	0,1092906	0,0590946
Port and Marine insurance	0,0502491	0,0593182	0,0090691
Average	0,050222533	0,0762522	0,0284828

A comparison of infrastructure and service sector development between the Port of Shanghai and several other IMCs (New York, Singapore, London, Hong Kong, Rotterdam, and Tokyo) was found by Lin (2010). The level of development and maturity of the financial industry, the level of activity and the level market value of shipping market transactions is low compared to other ports. This constrains the development of maritime services to a great extent. Not only that, the service efficiency score of local government is also low, especially the two indicators of government participation in industry planning and providing regional fair and safe environment for industry development.

On August 6, 2019, the State Council officially announced the General Plan of the New Lingang Area of China (Shanghai) Pilot Free Trade Zone to build a Special Economic Zone with more international market influence and competitiveness in Shanghai Lingang Area

(State Council, 2019). A recent study by Wang (2021) found that this Special Economic Zone still has institutional opening constraints in some areas of maritime services. For example, coastal piggybacking business is limited to non-five-star flag vessels owned or owned by Chinese companies in a controlling manner. Since many shipping companies have long chartered vessels from their own financed overseas subsidiaries, which are not Chinese companies, they are unable to conduct this business. Another pending improvement is the tax policy in the zone, where the corporate income tax for shipping companies is higher at 25%. Compared with other IMCs lack of competitive advantage, such as Singapore's corporate income tax rate is 17%, and there are many credits and concessions, and the comprehensive tax rate is only 10% (Wang C. , 2021).

(3) Analysis from the competitive relationship coefficient

According to the results of the competitive relationship coefficients in Table 10, all parameter values are positive, indicating that the two industries are in a purely competitive relationship. In this case, each industry has a negative impact on the growth rate of the other industries (Tsai & Li, 2009).

Table 10 The results of the competitive relationship coefficient β_i

	β_1	β_2	*Difference in absolute value*
Port and Shipping	0,000000512	0,001034	0,00103349
Port and Ship agency	0,00002	0,029114	0,029094
Port and Marine insurance	0,00000797	0,1986086	0,19870063
Average	0,000009494	0,0762522	0,07624271

In terms of absolute differences, Shanghai's marine insurance industry is the most competitive of the three. We can assume that marine insurance is considered as a substitute for port development (Zhang & Lam, 2017). Substitutes are considered to be a powerful force in competition. This force is considered to be one of the five forces in Porter's model of industry competition (Porter M. , 1990). If a competing option serves the same market niche as the current marine business, the latter will often be discouraged from continuing to do so. Marine insurance, in this case as a more lucrative industry, might be thought of as a powerful option in the event that a port, as a mature business, does not recognize the necessity of dynamic expansion and innovation. This alternative would fill the same market niche as the current port industry, resulting in a mutually constraining impact between the two sectors. Although ports and marine insurance may have a symbiotic connection in the early phases of the development of the port cluster, when transitional effects take hold, it may change to a competitive paradigm. Because of this, each of these two industries has recently had a negative effect on the growth rate of the other and will continue to do so in the near future.

The conflict for maritime resources, including human capital and investment, is represented by the link between ports and marine insurance. Marine insurance is regarded as a sophisticated marine service that calls for a greater reliance on maritime experts and specialists in this particular insurance industry. At the same time, more maritime specialists and professionals are needed than ever before due to the development and innovation of port operations and functions. The further growth and development of Shanghai's port and marine insurance industry may be constrained by the same need for maritime specialists. In addition to the lack of qualified workers in the marine sector, there are also restricted investment opportunities. In the early phases of the establishment of the maritime cluster, the interaction between ports and other marine service businesses may have been symbiotic, but it may have evolved into a competitive paradigm. Because of this, each of these industries has had a negative effect on the port's growth rate recently and will continue to do so in the foreseeable future.

The results are consistent with the policy direction in practice. The rapid rise of the Port of Shanghai as a hinterland port is mainly due to the strong support of China's rapid economic growth and large-scale imports and exports. 2009-2019 saw container throughput climb from 25 million TEUs to 42 million TEUs in the decade. The global economy is entering a recession due to the slowdown in global trade growth, especially the impact of the epidemic, and cross-border trade growth continues to be sluggish. This is combined with the increase in local labor costs, domestic industrial restructuring, and competitive diversion from neighboring ports. These factors predict that the container volume of Shanghai port is difficult to return to the previous growth rate. If not stimulated by a favorable external environment, port output can increase dramatically. Since these external influences are frequently unpredictable, authorities might not want to take a big financial risk (Wang, Peng, Chai, & Gu, 2020).

At the same time, this result implies that the mature port sector needs to consider diversifying into emerging advanced maritime services sectors (e.g. marine insurance, maritime finance) in order to bring the port cluster to a knowledge-based, high value-added stage. In contrast to other ports that are ambitious in expanding their area, the Shanghai government proposed in its plan that the port of Shanghai establishes a linked logistics network of seaports and airports to enhance the value of cargo (Central Committee for Network Security and Information Technology, 2021). In addition, increase the application of intelligent technology and develop standards and rules with global influence in order to expand shipping service functions. This strategy plan supports and verifies the findings of our empirical research.

4.2.4 Evolutionary trend analysis

According to the analysis of the Lotka-Volterra model above, let $\frac{dx}{dt}=0, \frac{dy}{dt}=0$ can be obtained as follows four equilibrium points.

$$E_1(0,0), E_2\left(\frac{r_1}{\alpha_1},0\right), E_3\left(0,\frac{r_2}{\alpha_2}\right), E_4(x^*,y^*)$$

The trend of $x(t)$ and $y(t)$ can be inferred from the isosceles of the two equations in the model, which can be used to analyze the evolutionary trend of the port and other maritime services. Based on the results of estimating the model parameters in the previous section, for port and shipping, we obtain the lines $L_x = 0.0140103 - 0.0502225x - 0.000000512y = 0$ and $L_y = -0{,}0141826 - 0{,}001034x - 0{,}0675071y = 0$. The coordinates of the four equilibrium points are calculated.

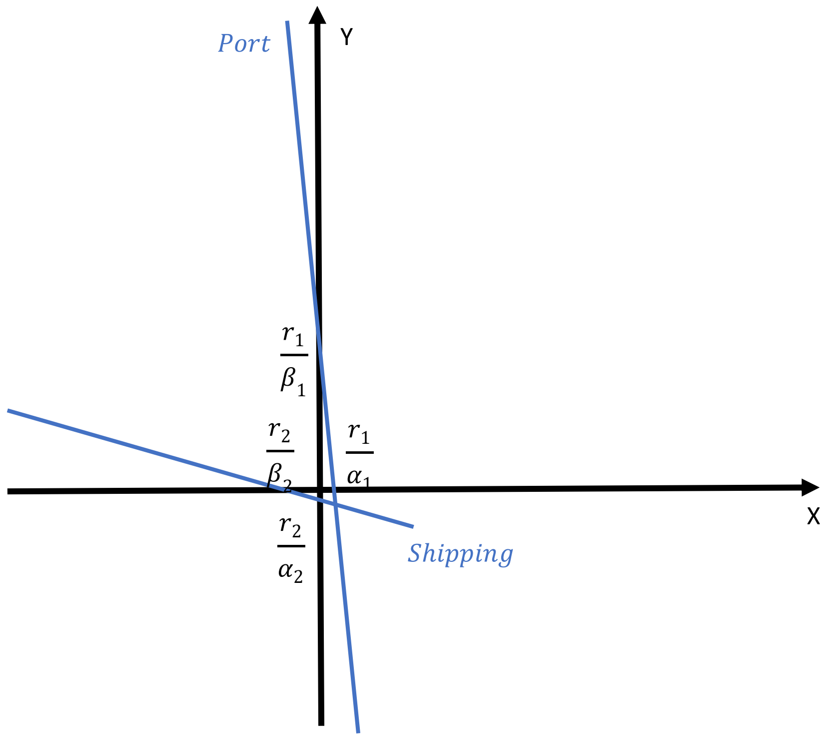
$$E_1(0,0), E_2(0.27896461,0), E_3(0,-13.716248), E_4(0.27896679,-0.2143634)$$

Obviously, L_y cannot satisfy both x>0 and y>0, it cannot be shown in the first quadrant. The x and y representing competitiveness are less than zero, indicating that shipping is not competitive in the cluster. That is, it is not economically meaningful to use the equilibrium point method in this case to discuss the trend of ecological competition relationships within the symbiotic cluster. The same happens with other data sets.

Figure 6 shows from a data perspective, conclusions $\frac{r_1}{\alpha_1} > \frac{r_2}{\beta_2}$ and $\frac{r_1}{\beta_1} > \frac{r_2}{\alpha_2}$ can be drawn by comparing the intersection of the two lines with the x and y axes. The detailed values are that

$$\frac{r_1}{\alpha_1} = 0.27896461, \frac{r_2}{\beta_2} = -13.716248,\ \frac{r_1}{\beta_1} = 27363{,}8672, \frac{r_2}{\alpha_2} = -0.2100905$$

Figure 6 Equilibrium point between port and shipping in Shanghai



Source: Draw by author

This situation shows that L_x, i.e., port, always outperforms shipping. Eventually, at the equilibrium point $E_2(0.27896461,0)$, the port completely replaces the shipping. In reality this is obviously not possible.

5 Conclusion and recommendation

Based on a review of industrial cluster theories, this paper analyzes in detail the history and current situation of port clusters, especially the maritime services. Based on racial ecology, a model responding to the characteristics of port clusters is established by combining the similarities and differences between industrial clusters and ecological populations. The Port of Shanghai, which has a high port throughput, is studied in this article based on the interaction between marine sevices and ports. The usually unpredictable and complicated port cluster system is explained empirically by examining the interconnections within the port and other maritime service clusters.

The essence of port clusters is the close connection between a series of integrated sectors so that the clusters can be truly competitive and sustainable. This paper constructs a nonlinear ecological model among port clusters based on Lotka-Volterra model. The ecological competition relationship among maritime industries is analyzed in terms of natural growth coefficient, own restrictiveness coefficient and competition coefficient respectively. After the analysis, it is found that port and maritime services belong to purely competitive relationship, which is the predator-prey relationship in biology. In the latest data, it is found that the throughput growth of Shanghai port is weak, and the policy and investment direction is changing from hardware investment to value upgrade. In the long run, revenues from the provision of high value-added services (e.g. ship agency, maritime finance) will help Shanghai port to develop into a competitive IMC. The competitive relationship within the cluster is related to limited human, capital, and land resources. How to coordinate the allocation of resources is also crucial for the development of the cluster. In order to inform strategies like sector priority and pairwise complementary development of sectors, this study makes a contribution by experimentally assessing the interaction between marine sectors.

In terms of interaction, this paper tries to analyze the interaction between maritime sectors with the help of the stability of the equilibrium point. That is, the evolution trend of the equilibrium point is simulated by using different cases of different sectors on the two-dimensional right-angle coordinate system. However, because x and y, which represents the competitiveness of L_y in other maritime service sectors, cannot be greater than 0 at the same time, this case analysis has no economic meaning. It can also be seen that the equilibrium state of these two is not stable in the dynamically interacting relationship.

6 Scope for future work

The study of maritime clusters is a complex proposition with a extensive design. This paper is a useful attempt to study the inherent complexity of port clusters using the Lotka-Volterra competition model. Future studies can also be conducted for other clusters, such as comparative empirical studies between different ports, and optimization models that incorporate more realistic uncertainties. More comprehensive parameters can enrich the analytical implications. For example, for how the intrinsic complexity of the model will change after it receives perturbations or even random factors. Or what other new phenomena will appear are worthy of further study.

7 Bibliography

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8 Stata code used in this paper

```
//Install the export command
ssc install outreg2

//导入数据 Import data
cd /Users/lupee/Downloads
import excel using "raw data.xlsx",firstrow sheet("data3") clear

//Average
egen port_m=mean(port)                        //egen: Create variables with functions
egen shipping_m=mean(shipping)
egen ship_agency_m=mean(ship_agency)
egen marine_insurance_m=mean(marine_insurance)

g port_2=port^2
g shipping_2=shipping^2
g ship_agency_2=ship_agency^2
g marine_insurance_2=marine_insurance^2

egen port2_m=mean(port_2)                     //egen: Create variables with functions
egen shipping2_m=mean(shipping_2)
egen ship_agency2_m=mean(ship_agency_2)
egen marine_insurance2_m=mean(marine_insurance_2)

//Variance
//D(x)=E(x^2)-(Ex)^2
g port_m_2=port_m^2
g shipping_m_2=shipping_m^2
g ship_agency_m_2=ship_agency_m^2
g marine_insurance_m_2=marine_insurance_m^2

g D_port=port2_m-port_m_2
g D_shipping=shipping2_m-shipping_m_2
g D_ship_agency=ship_agency2_m-ship_agency_m_2
g D_marine_insurance=marine_insurance2_m-marine_insurance_m_2

g SD_port=sqrt(D_port)
g SD_shipping=sqrt(D_shipping)
g SD_ship_agency=sqrt(D_ship_agency)
```

```
g SD_marine_insurance=sqrt(D_marine_insurance)

//Standardized variable
//(X-EX)/sqrt(DX)
g X_port=(port-port_m)/SD_port
g X_shipping=(shipping-shipping_m)/SD_shipping
g X_agency=(ship_agency-ship_agency_m)/SD_ship_agency
g X_insurance=(marine_insurance-marine_insurance_m)/SD_marine_insurance

order year X_port X_shipping X_agency X_insurance port shipping ship_agency marine_insurance


// Parameter Estimation Derivation
/*
x(t)=f1*x(t-1)-g1*x(t-1)x(t)-h1*x(t)y(t-1)
y(t)=f2*y(t-1)-g1*y(t-1)y(t)-h1*y(t)x(t-1)
*/

//Compare port&shipping, port&ship agency, port&marine insurance.
tsset year
/*
g port_1=l.port
g shipping_1=l.shipping
g agency_1=l.ship_agency
g insurance_1=l.marine_insurance
*/

//Process data
local a port_1  shipping_1 agency_1 insurance_1 LNport_1 LNshipping_1 LNagency_1
LNinsurance_1 LNport LNshipping  LNship_agency LNmarine_insurance
foreach i of local a{
capture confirm variable `i'
if !_rc {
                    drop   `i'
      }
}
else {
//
g port_1=l.port
g shipping_1=l.shipping
```

```
g agency_1=l.ship_agency
g insurance_1=l.marine_insurance
//
local b port_1  shipping_1 agency_1 insurance_1 port shipping  ship_agency marine_insurance
foreach i of local b{
g LN`i'=ln(`i')
}
}

//
order year LNport LNshipping  LNship_agency LNmarine_insurance LNport_1  LNshipping_1
LNagency_1 LNinsurance_1 X_port X_shipping X_agency X_insurance port shipping ship_agency
marine_insurance port_1 shipping_1 agency_1 insurance_1

//f,g parameter estimation
/*
x(t)=f1*x(t-1)-g1*x(t-1)x(t)-h1*x(t)y(t-1)
y(t)=f2*y(t-1)-g2*y(t-1)y(t)-h2*y(t)x(t-1)
*/

//Process data
local a LNport_1_LNport LNshipping_LNshipping_1 LNport_LNshipping_1 LNshipping_LNport_1
LNagency_1_LNagency LNagency_LNport_1 LNport_LNagency_1 LNinsurance_1_Lninsurance
LNinsurance_LNport_1 LNport_LNinsurance_1
foreach i of local a{
capture confirm variable `i'
if !_rc {
                        drop   `i'
       }
}
else {
//
g LNport_1_LNport=LNport_1*LNport
g LNshipping_LNshipping_1=LNshipping*LNshipping_1
g LNport_LNshipping_1=LNport*LNshipping_1
g LNshipping_LNport_1=LNshipping*LNport_1
//
g LNagency_1_LNagency=LNagency_1*LNship_agency
g LNagency_LNport_1=LNship_agency*LNport_1
g LNport_LNagency_1=LNport*LNagency_1
```

```
//
g LNinsurance_1_LNinsurance=LNinsurance_1*LNmarine_insurance
g LNinsurance_LNport_1=LNmarine_insurance*LNport_1
g LNport_LNinsurance_1=LNport*LNinsurance_1
}

//port&shipping
//f1,g1
reg LNport LNport_1 LNport_1_LNport LNport_LNshipping_1,r
est sto m1
g f1_shipping=_b[LNport_1]
g g1_shipping=_b[LNport_1_LNport]
g h1_shipping=_b[LNport_LNshipping_1]
g se1=e(rmse)

//f2,g2
reg LNshipping LNshipping_1 LNshipping_LNshipping_1 LNshipping_LNport_1,r
est sto m2
g f2_shipping=_b[LNshipping_1]
g g2_shipping=_b[LNshipping_LNshipping_1]
g h2_shipping=_b[LNshipping_LNport_1]
g se2=e(rmse)

//port&ship agency
//f1,g1
reg LNport LNport_1 LNport_1_LNport LNport_LNagency_1,r
est sto m3
g f1_agency=_b[LNport_1]
g g1_agency=_b[LNport_1_LNport]
g h1_agency=_b[LNport_LNagency_1]
g se3=e(rmse)

//f2,g2
reg LNship_agency LNagency_1 LNagency_1_LNagency LNagency_LNport_1,r
est sto m4
g f2_agency=_b[LNagency_1]
g g2_agency=_b[LNagency_1_LNagency]
g h2_agency=_b[LNagency_LNport_1]
g se4=e(rmse)
```

```
//port&marine insurance
//f1,g1
reg LNport LNport_1 LNport_1_LNport LNport_LNinsurance_1,r
est sto m5
g f1_insurance=_b[LNport_1]
g g1_insurance=_b[LNport_1_LNport]
g h1_insurance=_b[LNport_LNinsurance_1]
g se5=e(rmse)

//f2,g2
reg LNmarine_insurance LNinsurance_1 LNinsurance_1_LNinsurance LNinsurance_LNport_1,r
est sto m6
g f2_insurance=_b[LNinsurance_1]
g g2_insurance=_b[LNinsurance_1_LNinsurance]
g h2_insurance=_b[LNinsurance_LNport_1]
g se6=e(rmse)

outreg2 [m1 m2 m3 m4 m5 m6] using m12345.xlsx,tstat addst(R2,e(r2)) replace
//ereturn list  //scalar display

//port&shipping
g r1_shipping=ln(-f1_shipping)
g r2_shipping=ln(-f2_shipping)
g a1_shipping=g1_shipping*r1_shipping/(-f1_shipping-1)
g a2_shipping=g2_shipping*r2_shipping/(-f2_shipping-1)
g b1_shipping=h1_shipping*r1_shipping/(-f1_shipping-1)
g b2_shipping=h2_shipping*r2_shipping/(-f2_shipping-1)

//port&ship agency
g r1_agency=ln(-f1_agency)
g r2_agency=ln(-f2_agency)
g a1_agency=g1_agency*r1_agency/(-f1_agency-1)
g a2_agency=g2_agency*r2_agency/(-f2_agency-1)
g b1_agency=h1_agency*r1_agency/(-f1_agency-1)
g b2_agency=h2_agency*r2_agency/(-f2_agency-1)

//port&insurance
g r1_insurance=ln(-f1_insurance)
g r2_insurance=ln(-f2_insurance)
g a1_insurance=g1_insurance*r1_insurance/(-f1_insurance-1)
```

```
g a2_insurance=g2_insurance*r2_insurance/(-f2_insurance-1)
g b1_insurance=h1_insurance*r1_insurance/(-f1_insurance-1)
g b2_insurance=h2_insurance*r2_insurance/(-f2_insurance-1)
```