Article

A Study on the Bilateral Trade Relations between China and ASEAN Ten Countries Based on Lotka-Volterra Model

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Abstract

The bilateral trade relationship between PRC and ASEAN is close. As early as 2012, China has been the largest trading partner of ASEAN, and ASEAN has also taken the place of the United States as PRC's second largest trading partner in 2019.This paper uses the theory of ecological population evolution, selects the total import and export volume of PRC and the ten ASEAN countries from 2000 to 2019 as the data sample, studies the bilateral trade relations between PRC and the ten ASEAN countries, analyzes the competition and symbiotic relationship of bilateral trade between PRC and the ten ASEAN countries and the possibility of trade friction according to the results, and proposes corresponding improvement strategies. According to the results of the population evolution competition model, China has a competitive relationship with Indonesia, Malaysia, the Philippines, Singapore and Thailand, which is most likely to cause trade friction. China has a biased relationship with Brunei, Cambodia, Laos, Myanmar and Vietnam, which is more likely to cause trade friction. On this basis, in order to further strengthen the trade relations between PRC and the ten ASEAN countries, this paper puts forward policy suggestions on improving infrastructure, strengthening independent innovation, seeking cooperation fields and actively investing abroad.

Keywords: Ten ASEAN countries; Bilateral trade; Lotka-Volterra model; commensalism; competition

Introduction

After the GFC in 2008, the rise of trade protectionism in various countries has made China constantly subject to anti-dumping review, which has an impact on domestic foreign trade enterprises, leading to increased market uncertainty. Therefore, in order to reduce the obstacles to China's trade, we need to further expand the effective market.[1]Some of China and ASEAN countries are connected by land and some are across the sea. Thus, both sides will conduct foreign trade more conveniently and quickly. In addition, most ASEAN countries are still developing countries, but they have a large natural resource advantage, a large regional population, a broad market range, and huge development space.[2]

The continuous deepening of ASEAN regional economic integration has improved ASEAN's international economic status, promoted the regional cooperation between countries and ASEAN to be more extensive, and successively established a series of regional economic cooperation mechanisms with ASEAN as the center. In particular, the formation and development of the cooperation mechanisms between China, Japan and the ROK and ASEAN (10+3), China and ASEAN (10+1).In addition, Japan, the United States, Australia, the European Union,New Zealand, and other countries and organizations have established economic cooperation partnerships with ASEAN. Among them, the United States and Japan are the most active.[3][4][5]With the extensive influence of the "Belt and Road" initiative, economic and trade exchanges between PRC and ASEAN countries are increasingly close, and

 doi:10.20944/preprints202211.0216.v1

bilateral trade volume is rising rapidly. In 2020, ASEAN has become China's largest trading partner. On November 15, 2020, the RCEP was officially signed, bringing new opportunities and challenges for China ASEAN trade cooperation.[6]

In this context, based on Lotka Volterra model, this paper will analyze the competition and symbiotic relationship of bilateral trade between PRC and the ten ASEAN countries and the degree of trade friction, deeply analyze the major factors of the change of bilateral trade volume between PRC and ASEAN, and make more explicit and reasonable policy suggestions for the future development of China ASEAN cooperation. From the theoretical level, although there are many researches on the trade relations between PRC and the ten ASEAN countries at present, there are few researches according to the Lotka Volterra model. This paper shows the relationship between the two based on the ecological perspective, so as to research the trade relations between them more comprehensively. This is a supplement to the existing research, and also has certain reference value for the follow-up research. In practical terms, although China and ASEAN are important trading partners for each other, bilateral trade has been developing continuously, and regional cooperation has been advancing continuously, both China and ASEAN are emerging economies and export-oriented economies, both of them are in the middle and lower levels of global industrial transfer, and their export structures are similar. There are also some competitive relationships between them. This paper studies the cooperation and competition relationship between PRC and the ten ASEAN countries and the level of trade friction from an ecological perspective, analyzes relevant factors and puts forward effective suggestions. It is not only conducive to building a new open economic system to promote high-quality trade development, but also can accelerate the implementation of PRC's "Belt and Road", "Community of Shared Destiny" and other initiatives, bringing new development opportunities for the recovery of the global economy in the post epidemic era.

Literature Review

Lotka-Volterra interspecific competition model is one of the theories of ecological research on population development. It is developed on the basis of one-dimensional logistic growth equation. It is a two-dimensional logistic model growth equation. In 1925, Lortka put forward an important model in the study of Elements of Physical Biology: predator-prey interaction model, which quantitatively described the interaction between organisms. [7] Volterra described the quantity change of two species in the commensalism of biological world in the study of Variazioni e fluttuazioni del numero d'individui in specific animali conventi [8], which laid the theoretical foundation of interspecific competition model, and also greatly affected the development of modern ecological competition theory. In the ecological environment, the relationship between biological species is complex. For a single species, there are three possible effects on other species: inhibition, promotion and no impact. Therefore, there are many kinds of interaction relationships among various groups of things. Hannan and Freeman [9] were the first scholars to use the theory of population ecology to study enterprise clusters. They took the entire enterprise cluster as the research object and studied the adaptability of individuals in the enterprise cluster. In terms of bilateral trade relations between PRC and ASEAN, Holst&Weiss (2004) [10] concluded through panel data analysis that in the short term, China and ASEAN have fierce competition in the export of many industries. However, in the long run, with the continuous adjustment of bilateral trade structure and continuous upgrading of industries, bilateral trade will change. In the future export market, China and ASEAN can play their respective competitive advantages. Tovar and Patricia (2012) [11] believed that China's economic development potential is great and there is a lot of demand. After the Free Trade Area was founded, it will greatly promote ASEAN's exports to China, with significant trade creation effects. Kawai and Naknoi (2016) [12] found that the bilateral product trade between ASEAN and China and the absorption of FDI would boost the economic growth of member countries and strength the degree of internal investment liberalization of ASEAN member countries by using the expanded trade gravity model. T Tambunan (2006) [13] pointed out that

 doi:10.20944/preprints202211.0216.v1

although ASEAN and China have established a free trade area, for individual countries, countries outside the alliance are still their most important market and trading partners, and the increase of bilateral trade volume is mainly the increase of intra industry trade volume.

Ecological theory is considered to be one of the scientific bases for human beings to seek solutions to major social problems in the contemporary society. The application of ecological theory to social and economic problems began with Schumpeter's theory of economic evolution at the beginning of the twentieth Century. In the past hundred years, the increasing number of studies have applied ecological theory to social and economic problems, For example, A general equilibrium model of renewable resources and population dynamics related to Lotka Volterra interspecific competition model is proposed by Bander and Taylor (1998) [14], which analyzes the development process of social civilization. The economic activity field of human society also belongs to an ecosystem, because it has the ecological characteristics of ecosystem integrality and competition, so the growth of economic society will also adhere to the basic development law of social system. Iansiti, Levien (2004) [15] also explained the concept of business ecosystem in social economy by analogy with the concept of ecosystem in ecology, which is considered to be very similar to that in ecology. However, there are few literatures on the introduction of Lotka-Volterra model into international trade relations.

Based on the research of relevant scholars at home and overseas, it can be seen that the development of trade between countries is more similar to the evolution of population in the "ecosystem"[49]. The development of commerce between countries and the evolution of biological populations have the following similar characteristics: First, the importance of natural environment to biological population is consistent with that of trade environment to trade population. The neoclassical theory holds that the endowment environment, including the degree of economic development, trade policy, geographical environment and resource supply, is vital to the evolution of trade relations[39]. Second, trade populations, like biological populations, have the ability to constantly adapt to and change the environment. The endogenous growth theory and the new growth theory believe that the improvement of the endowment environment of both sides of trade[43]. Trade population is similar to biological population, they can constantly adjust and improve the circumstances. Endogenous growth theory and new growth theory consider that the improvement of the endowment environment of both trading parties can promote their own economic manufacturing and economic development[28]. Third, trade populations, like biological populations, are affected by the laws of reproduction and death. According to the theory of marginal industry expansion, the scale of bilateral trade is not only impacted by the endowment environment of both sides, but also related to the development of related industries in both countries[33]. Fourth, different populations in the same environment have heterogeneous relationships such as predator and prey, competition, and mutualism. Nations of distinct trade groups also have different level of competition and cooperation in the world market, and some nations use this relationship to improve the local endowment environment. Fifth, similar to biological populations, the development of trade populations is also impacted by dual effects. The growth of a country's import and export trade is affected by internal factor endowment and external international environment[29].

Although the research of relevant scholars at home and overseas has provided plenty of academic support for this paper, and analyzed the bilateral trade relationship between PRC and ASEAN from different perspectives, as well as the impact of different factors on bilateral trade, this paper still has room for further in-depth research and analysis. However, the introduction of Lotka Volterra interspecific competition model to the research on economic and social issues in the previous literature rarely studies issues related to bilateral trade relations between countries. Therefore, this paper constructs Lotka Volterra interspecific competition model from the perspective of population evolution, evaluates bilateral trade relations between PRC and the ten ASEAN nations, and analyzes the influence of different

 doi:10.20944/preprints202211.0216.v1

conditions on trade relations, Propose development strategies to further improve bilateral trade relations between PRC and the ten ASEAN nations.

Methodology

1.Overview of bilateral trade between China and ten ASEAN countries

(1)General situation of trade between China and the ten ASEAN countries

Overall, Brunei's total trade volume is the lowest among the eleven countries. Before 2017, its total trade volume was less than US $10 billion, and only US $2.51 billion in 2009. The total trade volume of Brunei, Cambodia and Vietnam is also at a low level among the ten ASEAN countries, and the total trade volume in ten years is not more than 100 billion US dollars. Singapore's total trade volume is at the highest level in ASEAN, exceeding 800 billion US dollars between 2011 and 2014. The total trade volume of China far exceeds that of the ten ASEAN countries, reaching US $445.481 billion in 2018. It can be found that from 2009 to 2019, the total trade volume of ASEAN nations and PRC showed an overall upward trend, and the rate of rise in trade volume of each country was different. The growth in trade volume of Cambodia, Laos and Vietnam is relatively high, exceeding 15%, ranking the top three ASEAN countries, up to 17%, 16.4% and 15.3% respectively. The high growth rate of the trade rise of the three nations shows that the economic development of the three nations is more and more dependent on foreign markets, and this orientation will also bring benefits to their trading partners. The trade volume of Brunei and Malaysia has been relatively stable in the past decades, both below 3%, and the annual growth rate of trade has been at a low level of 2.6% and 2.8%. China and the Philippines have similar annual growth rates, 8.1% and 8% respectively, which are at the middle level among the eleven countries. The AARG of Indonesia and Thailand is also similar, with a gap of only 0.2%:

Table1 and table2: Total trade volume and growth rate between China and ASEAN countries(billion dollars,%)

	Philippines	Cambodia	Laos	Malaysia	Myanmar
2009	721.5	81.4	25.1	2753.9	92.2
2010	904	104.9	38.1	3362.7	111.9
2011	969.8	131.9	42.8	3843.9	151.9
2012	1116.9	149	52.4	3809.5	158.5
2013	1066.9	177.2	53.2	3739.9	189.2
2014	1169.8	201.9	82.5	3803.6	219.3
2015	1097	226.2	93.3	3213.2	237.3
2016	1210.2	243.9	96.2	3065.1	220.5
2017	1438.4	267.3	105.4	3458.6	253.9
2018	1549.3	317.7	117.2	3828.9	262.8
2019	1562.7	372.3	120.8	3644.2	245.3
Growth rate	8.0	16.4	17	2.8	10.3

	Thailand	Brunei	Singapore	Indonesia	Vietnam	China
2009	2723.3	94.5	5311.4	1942.5	1218	20027
2010	3591.3	113.7	6856.3	2689.3	1496.1	27180.6
2011	4306.1	161.3	8219.3	3483.9	1942.6	33869.1
2012	4552.8	170	8271.6	3660.1	2194.8	36354.6

 doi:10.20944/preprints202211.0216.v1

2013	4548.7	167.5	8371.9	3583.5	2553.5	39382
2014	4360.6	147.8	8145.3	3436	2883.1	40524.8
2015	4006.1	93.4	6998.7	2842	3166.6	37093.2
2016	3912	74.7	6565.3	2736.2	3421.2	34901.5
2017	4347.9	85.5	7334.2	3189.5	4193.9	39564.9
2018	4798.3	105.8	8170.1	3616.8	4708.5	44548.1
2019	4586.8	122.1	7870.9	3334	5068.8	43802.9
Growth rate	5.4	2.6	4.0	5.6	15.3	8.1

In terms of nations, calculated by the total import and export volume of goods trade with PRC, the 10 ASEAN countries ranked Malaysia, Vietnam, Singapore, Thailand, Indonesia, the Philippines, Myanmar, Cambodia, Laos and Brunei in terms of trade volume with China in 2015. Among them, Malaysia and Vietnam have the largest trade volume with China, 972.9 trillion dollars and 959.7 trillion dollars respectively, both exceeding 900 trillion dollars. However, the total import and export trade between Cambodia, Laos and Brunei and China lags far behind the total trade between other ASEAN countries and China, which is less than 50 trillion dollars. Although the trade volume between Myanmar and China exceeds 100 trillion dollars, it is relatively small compared with the trade volume between the Philippines and China. Therefore, although most ASEAN countries have close trade with China, and the trade volume is large, there are still a few countries that have less trade volume of goods with China[51]. We should further analyze the reasons to promote further trade and development between China and these countries.

Table3: Ranking of total goods trade between ASEAN 10 countries and China in 2015

Ranking	Country	Trade volume (billion dollars)
1	Malaysia	972.9
2	Vietnam	959.7
3	Singapore	795.7
4	Thailand	754.6
5	Indonesia	542.3
6	Philippines	456.5
7	Myanmar	152.8
8	Cambodia	44.3
9	Laos	27.8
10	Brunei	15.1
Total		4721.7

(2)China's position in the ASEAN international trade country (region) structure

At present, China has become an vital trade partner of ASEAN[22]. On the whole, the main trade objects of the ten ASEAN countries are China the European Union, the United States, Hong Kong, Japan, China, and South Korea, which are concentrated in the United States, Europe, and East Asia.[20] The exports to these six economies account for 53.10% of ASEAN's total exports, and their export concentration is significantly lower than China. In addition, ASEAN neighboring countries or regions, such as India, Taiwan, China, China and Australia, are also among the top ten export targets. The main import sources of ASEAN are China, Japan, the European Union, the United States,

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South Korea and Taiwan, China, which are also concentrated in the United States, Europe and East Asia. The imports from these six economies account for 60.17% of ASEAN's total imports. Other major import sources are distributed in the Middle East and its surrounding areas.

Therefore, China, as an important trade partner of ASEAN, can contribute to the economic development of ASEAN countries through trade, especially for Vietnam, Cambodia, Laos and other countries with rapid economic development.[25]

Table4: ASEAN's Major Import and Export Trading Partners in 2015(Billion Dollars,%)

Export			Import		
Export Object	Export Volume	Proportion	Import Object	Import Volume	Proportion
China	13.42	11.40	China	21.15	19.40
U.S.A	12.92	10.90	Japan	12.44	11.40
European union	12.76	10.80	European union	10.01	9.20
Japan	11.37	9.60	U.S.A	8.32	7.60
Hong Kong, China	7.73	6.50	the republic of Korea	6.67	7.00
the republic of Korea	4.58	3.90	Taiwan, China	6.13	5.60
India	3.91	3.30	The United Arab Emirates	2.15	2.00
Taiwan, China	3.31	2.80	Saudi Arabia	2.03	1.90
Australia	3.30	2.80	India	1.95	1.80
The United Arab Emirates	1.93	1.60	Australia	1.88	1.70

(3)Types of import and export products of China and ASEAN countries

Table5: the proportion of five major fields in all import and export products in 2019(%)

Country	Proportion of agricultural raw materials		Proportion of food		Proportion of fuel		Proportion of minerals and metals		Proportion of finished products	
	Export	Import	Export	Import	Export	Import	Export	Import	Export	Import
Philippines	1.13	0.68	9.06	12.04	1.48	12.01	5.12	1.70	81.15	73.53
Cambodia	1.69	1.93	4.59	7.02	6.86	11.58	0.49	1.69	90.60	77.32
Laos	10.80	2.19	13.47	15.68	27.05	15.98	22.48	1.17	22.35	64.90
Malaysia	1.70	1.88	9.27	7.74	14.43	14.55	3.86	6.23	70.12	67.86
Myanmar	2.17	0.53	24.22	11.70	25.11	19.77	5.28	1.12	43.20	66.87
Thailand	3.85	1.52	14.54	6.47	3.63	16.18	1.60	4.02	72.98	68.64
Brunei	0.03	0.09	0.15	9.95	91.09	33.69	0.33	0.64	8.31	55.48

 doi:10.20944/preprints202211.0216.v1

Singapore	0.50	0.32	3.52	3.70	12.26	20.97	0.72	1.06	74.19	69.12
Indonesia	5.45	2.74	20.30	10.61	20.34	13.72	5.45	3.56	46.29	68.03
Vietnam	1.90	2.73	9.42	7.53	1.38	6.13	1.09	3.88	84.52	78.24
China	0.40	3.16	2.87	7.02	1.87	17.86	1.26	11.90	92.87	57.07
Arithmetic mean	2.69	1.62	10.13	9.04	18.68	16.59	4.33	3.36	62.42	67.91

It is clear from the above data that the most important import and export goods of China and ASEAN countries are manufactured products, accounting for more than 50% of their respective imports and exports. The proportion of manufactured products in China's exports is the highest, up to 92.87%. The percentage of fuel, minerals and metals in ASEAN's exports is much higher than that of China, indicating that ASEAN's exports are more dependent on natural resources[50]. From the perspective of specific countries, the types of major import and export products of ASEAN countries are quite different. In terms of exports, Laos has the highest proportion of agricultural raw materials in exports, accounting for 10.8% of its total exports, while Brunei and Singapore have almost no agricultural exports. In the field of food, the export proportion of Indonesia and Myanmar reached 20.3% and 24.22% respectively, higher than the average level of ASEAN, while Brunei had almost no food exports. The differences among countries in the field of fuel exports are even greater. Brunei's fuel exports account for 91.09% of its total exports, while the Philippines, Thailand and other countries' fuel exports account for less than 5%. In the field of minerals and metals, the export proportion of Laos, Indonesia, the Philippines and Malaysia is in the forefront of ASEAN, while that of Brunei, Cambodia, Vietnam and Myanmar is very low. This is obviously related to the distribution of natural resources in different ASEAN countries. In the field of manufactured goods, both China and Cambodia account for more than 90% of their exports, indicating that these two countries are most dependent on manufactured goods exports, while Brunei and Laos are the least dependent on manufactured goods exports. In terms of imports, in the field of agricultural raw materials, the proportion of imports by all countries is not high, and they can basically achieve self-sufficiency. The largest imports are China and Indonesia, but less than 4%. In the food sector, Myanmar, the Philippines and Indonesia account for more than 10% of food imports, indicating that these three countries are more dependent on imported food than other countries. In the field of fuel, Brunei and Singapore have the highest dependence on fuel imports, reaching more than 20%, followed by Indonesia, Thailand and China, and Vietnam has the lowest dependence on fuel imports, only 6.13%. In the field of minerals and metals, China has the highest proportion of imports, while the 10 ASEAN countries have less imports of minerals and metals. Except Malaysia, the imports of other ASEAN countries are less than 5%. In the field of manufactured goods, all countries rely more than 50% on manufactured goods, especially Cambodia, which is as high as 77.32%. Relatively speaking, China has the lowest dependence on imports of manufactured goods.

2. Index selection and data source

This paper uses the grey estimation method [16] to analyze the model. The grey estimation method has less requirements on the number of indicators, and only one indicator is needed for parameter estimation.[26] In the relevant literature, many scholars regard the total import and export volume of goods trade as a vital factor to study a country's trade level. Therefore, this paper selects the total import and export volume of goods trade of a country from 2000 to 2019 as the measurement indicator. The data of the total imports and exports of goods trade of a country is derived from the World Bank database.

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3. model building

Firstly, the logistic model, which was first used to study the evolution of biological populations, is introduced into the study of bilateral trade evolution. Establish a single population trade evolution model, and use the method of (Zhao Xu, Gao Suhong, etc., 2008) for reference:

$$\frac{dx(t)}{dt} = rx(1 - \frac{x}{N}) \quad (1)$$

X (t) is the total volume of goods import and export of country x to the world in year t; r is the growth rate of the total trade of goods; N is the maximum import and export volume of goods in country x determined by the environment; $(\frac{x}{N})$ is the ratio of the existing import and export scale of goods in country x to the potential maximum import and export scale of goods, $(1 - \frac{x}{N})$ indicates the relative trade gap between imports and exports of goods, which reflects the blocking effect of the current import and export scale of goods in country x on the growth of the future import and export scale of goods. Its general form is:

$$\mathrm{X} = \frac{N}{1+e^{(\beta-\delta t)}}, (N > 0, \delta > 0) \quad (2)$$

$(t^*, x^*) = (\frac{\beta}{\delta}, \frac{N}{2})$ is the inflection point of the evolution trend of import and export trade, δ control the rate of rise in trade. Then, further expand the idea to reflect the evolution of two species of bilateral trade relations between PRC and the ten ASEAN nations, and establish the Lotka Volterra model for the evolution of two species:

$$\begin{cases} \frac{dt_1(t)}{dt} = r_1 x_1 (1 - \frac{x_1}{N_1} + \lambda_1 \frac{X_2}{N_2}) \\ \frac{dt_2(t)}{dt} = r_2 x_2 (1 - \frac{x_2}{N_2} + \lambda_2 \frac{X_1}{N_1}) \end{cases} \quad (3)$$

Among them, λ_1 and λ_2 are the population evolution impact coefficients of bilateral trade relations, which respectively represent the impact of the scale growth saturation of country B's goods imports and exports on the scale growth of country A's goods imports and exports, and the impact of the scale growth saturation of country A's goods imports and exports on the scale growth of country B's goods imports and exports. If λ_1>0, it means that country B has a role in boosting the increase of country A's import and export of goods, if λ_1<0, it means that country B has a retarding influence on the growth of country A's import and export scale. Similarly, λ_2>0 and λ_2<0, respectively, indicate that country B can promote and retard the growth of country A. According to the symbols, we can judge the type of interaction between competing species. The following uses mathematical symbols to define various action relationships.

①Positive influence. There is a positive relationship between the scale of imports and exports of goods. When the scale of imports and exports of goods in country A increases, the scale of country B also increases. When the scale of imports and exports of goods in country A decreases, the scale of country B also decreases, then A（+）→B.

②Negative influence. There is a negative relationship between the scale of import and export of goods. When the scale of import and export of goods in country A increases, the scale of country B decreases. When the scale of import and export of goods in country A decreases, the scale of country A increases, then A（-）→B.

*Competition. When A（-）→B, and B（-）→A, the relationship between country A and country B is competitive.

*Commensalism. When A（-）→B, and B（+）→A, the relationship between country A and country B is biased.

* Mutualism. When A（+）→B, and B（+）→A, the relationship between country A and country B is mutually beneficial.

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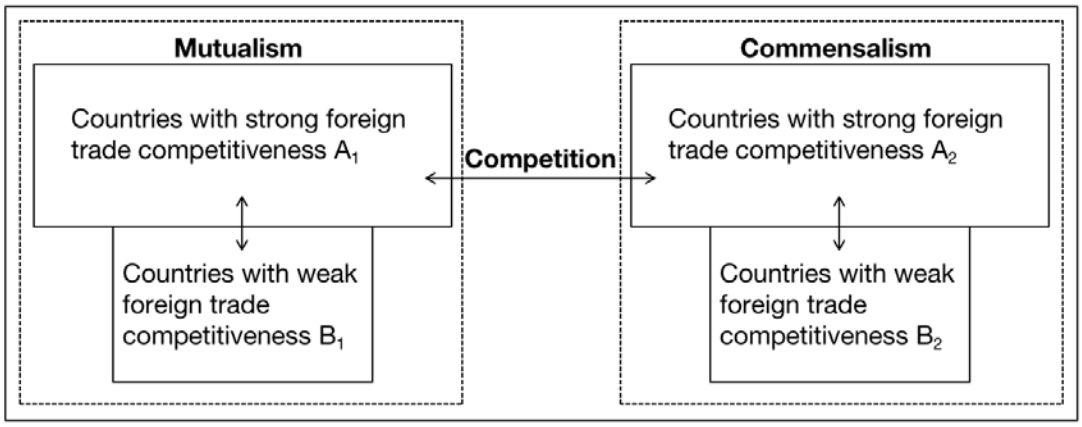

Figure1 diagram of the interaction between countries in the process of trade evolution

What needs to be further indicated is that: since the state of competition and cooperation shown in the bilateral trade relations between PRC and neighboring countries in this paper is based on the empirical results in the above model (3), this relationship is based on the perspective of ecosystem evolution. Although the indicator used in the model is the total import and export trade, the trade relations in this paper do not refer to the impact on the national trade volume. What this trade relationship shows is that in the trade ecosystem formed by China and the ten ASEAN countries, there is a symbiotic or competitive relationship between the two sides from the perspective of biological populations, which represents the possibility of trade frictions between PRC and the ten ASEAN countries. The specific friction degree is shown in the table.

Table6 Comparison Table of Trade Relations

Relationship	λ Symbol	Explanation
Competition	$-\ -$	The possibility of trade friction is the highest
Commensalism	$+\ -$	The possibility of trade friction is high
Mutualism	$+\ +$	The possibility of trade friction is the least

4. Equilibrium point and stability analysis

(1) Balance point analysis

To study the evolution results of country 1 and country 2, that is, the trend of x (t) and y (t) when t→+∞,it is only necessary to analyze the equilibrium point of equation (3) and its stability, and the equilibrium point of stability strength can represent the competition results of the two ports.

Order $\frac{dx_1(t)}{d(t)} = 0, \frac{dx_2(t)}{d(t)} = 0$:

$$\begin{cases} r_1 x\left(1 - \frac{x_1}{N_1} + \alpha\frac{x_2}{N_2}\right) = f(x_1, x_2) = 0 \\ r_2 y\left(1 - \frac{x_2}{N_2} + \beta\frac{x_1}{N_1}\right) = g(x_1, x_2) = 0 \end{cases}, (\alpha \in R, \beta \in R) \quad (4)$$

The four equilibrium points are: $E_1(N_1, 0), E_2(0, N_2), E_3\left(\frac{N_1(1+\alpha)}{1-\alpha\beta}, \frac{N_2(1+\beta)}{1-\alpha\beta}\right), E_4(0,0)$.

Analyze the balance state of the four balance points. E_1 means that country 1 has an absolute advantage in the competition, has obtained all market shares, and made country 2 withdraw from the market; E_2 means that country 2 has an absolute advantage in the competition, and has sold all the market shares, making country 1 withdraw from the market; E_4 means that the two countries are over competitive, and the final import and export scale of goods becomes zero; It indicates that country 1 and country 2 have reached a balanced state in the evolutionary interaction

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process. The state of E_1, E_2 and E_4 is not conducive to the development of conscience between countries' bilateral trade, so this paper only studies the evolution process of bilateral trade between countries under the state of E_3.

(2) Stability analysis of equilibrium point

According to the judgment conditions of equilibrium point stability, $p = -(f_{x1} + g_{x2})|_{E_i} > 0, q = detA|_{E_i} > 0$, （i = 1，2，3，4）. Among them, A is the coefficient matrix:

$$A = \begin{bmatrix} f_{x1} & f_{x2} \\ g_{x1} & g_{x2} \end{bmatrix} = \begin{bmatrix} r_1(1 - \frac{2x_1}{N_1} + \frac{\alpha x_2}{N_2}) & \frac{r_1 \alpha x_1}{N_2} \\ \frac{r_2 \beta x_2}{N_1} & r_2(1 - \frac{2x_2}{N_2} + \frac{\beta x_1}{N_1}) \end{bmatrix} \quad (5)$$

According to equation (5), the stability conditions of E_3 can be obtained as shown in Table 2:

Table7 Stability Conditions of Equilibrium Point E_3

Equilibrium point	P	q	condition
$E_3\left(\frac{N_1(1+\alpha)}{1-\alpha\beta}, \frac{N_2(1+\beta)}{1-\alpha\beta}\right)$	$\frac{r_1(1+\alpha)r_2(1+\beta)}{1-\alpha\beta}$	$\frac{r_1 r_2(1+\alpha)(1+\beta)}{1-\alpha\beta}$	$\alpha > -1, \beta > -1$

5. Regression results

Considering the model form of differential equation and the nature of grey estimation, based on the mapping relationship between grey derivative and even logarithm, this paper slightly modifies model (3) and uses grey estimation method to estimate its parameters. The details are as follows:

$$\begin{cases} \frac{dt_1(t)}{dt} = r_{10}x_1 + r_{11}x_1^2 + r_{12}x_1x_2 \\ \frac{dt_2(t)}{dt} = r_{20}x_1 + r_{21}x_2^2 + r_{22}x_1x_2 \end{cases} \quad (6)$$

Based on the mapping relationship between grey derivative and even reciprocal, the following relationship can be obtained:

$$\begin{cases} x_1(t+1) - x_1(t) = \lambda_{10}\frac{x_1(t+1)+x_1(t)}{2} + \lambda_{11}\left[\frac{x_1(t+1)+x_1(t)}{2}\right]^2 \\ \qquad\qquad +\lambda_{12}\left[\frac{x_1(t+1)+x_1(t)}{2}\right]\left[\frac{x_2(t+1)+x_2(t)}{2}\right] \\ x_2(t+1) - x_2(t) = \lambda_{20}\frac{x_2(t+1)+x_2(t)}{2} + \lambda_{21}\left[\frac{x_2(t+1)+x_2(t)}{2}\right]^2 \\ \qquad\qquad +\lambda_{22}\left[\frac{x_2(t+1)+x_2(t)}{2}\right]\left[\frac{x_1(t+1)+x_1(t)}{2}\right] \end{cases} \quad (7)$$

The matrix equation can be obtained by introducing the data when t=1, 2..... n:

$$w_1 = \begin{bmatrix} \frac{x_1(1)+x_1(2)}{2} & \left[\frac{x_1(1)+x_1(2)}{2}\right]^2 & \left[\frac{x_1(1)+x_1(2)}{2}\right]\left[\frac{x_2(1)+x_2(2)}{2}\right] \\ \frac{x_1(2)+x_1(3)}{2} & \left[\frac{x_1(2)+x_1(3)}{2}\right]^2 & \left[\frac{x_1(2)+x_1(3)}{2}\right]\left[\frac{x_2(2)+x_2(3)}{2}\right] \\ \cdots & \cdots & \cdots \\ \frac{x_1(n-1)+x_1(n)}{2} & \left[\frac{x_1(n-1)+x_1(n)}{2}\right]^2 & \left[\frac{x_1(n-1)+x_1(n)}{2}\right]\left[\frac{x_2(n-1)+x_2(n)}{2}\right] \end{bmatrix}$$

$$w_2 = \begin{bmatrix} \frac{x_2(1)+x_2(2)}{2} & \left[\frac{x_2(1)+x_2(2)}{2}\right]^2 & \left[\frac{x_1(1)+x_1(2)}{2}\right]\left[\frac{x_2(1)+x_2(2)}{2}\right] \\ \frac{x_2(2)+x_2(3)}{2} & \left[\frac{x_2(2)+x_2(3)}{2}\right]^2 & \left[\frac{x_1(2)+x_1(3)}{2}\right]\left[\frac{x_2(2)+x_2(3)}{2}\right] \\ \cdots & \cdots & \cdots \\ \frac{x_2(n-1)+x_2(n)}{2} & \left[\frac{x_2(n-1)+x_2(n)}{2}\right]^2 & \left[\frac{x_1(n-1)+x_1(n)}{2}\right]\left[\frac{x_2(n-1)+x_2(n)}{2}\right] \end{bmatrix}$$

$$Y_{1n} = [x_1(2) - x_1(1), x_1(3) - x_1(2), x_1(4) - x_1(3), \ldots, x_1(T) - x_1(T-1)]^T$$

$$Y_{2n} = [x_2(2) - x_2(1), x_2(3) - x_2(2), x_2(4) - x_2(3), \ldots, x_2(T) - x_2(T-1)]^T$$

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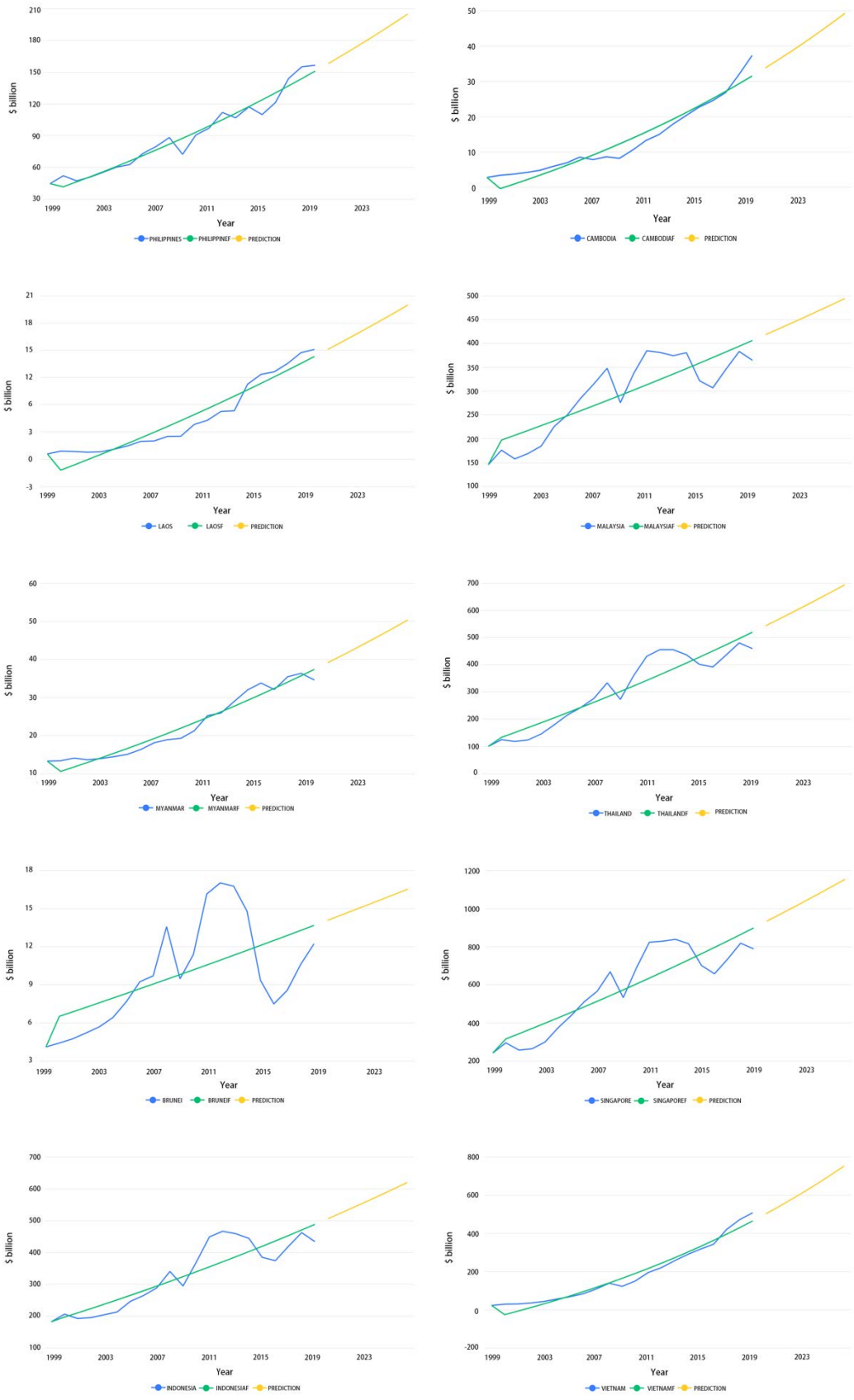
$\hat{\lambda}_1 = [\lambda_{10}, \lambda_{11}, \lambda_{12}]$ $\hat{\lambda}_2 = [\lambda_{20}, \lambda_{21}, \lambda_{22}]$

The matrix equation is: $Y_{1n} = W_1\hat{\lambda}_1$, $Y_{2n} = W_2\hat{\lambda}_2$ (8)

Using the least squares criterion, we can get: $\hat{\lambda}_1 = (W_1^T W_1)^{-1} W_1^T Y_{1N}$, Similarly, $\hat{\lambda}_2 = (W_2^T W_2)^{-1} W_2^T Y_{2N}$



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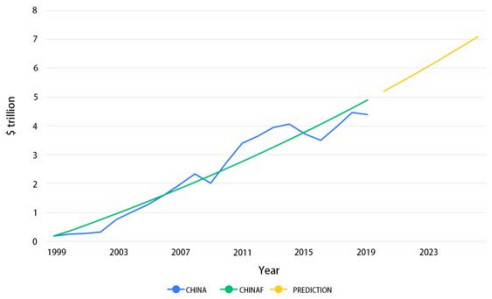

Figure2 Fitting and Forecast of Bilateral Trade Trend between China and ASEAN Ten Countries

Note: From the top left to the bottom right are the Philippines, Cambodia, Laos, Malaysia, Myanmar, Thailand, Brunei, Singapore, Indonesia and Vietnam

Take the import and export trade data of goods between PRC and the ten ASEAN nations from 2000 to 2019 into equation (6), calculate the values of vectors λ_1 and λ_2 through EXCEL software, and then bring the values in λ_1 into model $\lambda_{10} = r_1$, $\lambda_{11} = -\left(\frac{r_1}{N_1}\right)$, $\lambda_{12} = \lambda_1(\frac{r_1}{N_2})$ The rate of rise r_1 of the target country's import and export trade to China and the evolution impact coefficient λ_1 of the target country's import and export trade to China are obtained. Similarly, the value of λ_2 is brought in. It is clear from the table to see the empirical result.

Table8 Bilateral trade relations between China and Ten ASEAN countries

Bilateral trade between countries		Growth rate r	Evolutionary growth coefficient λ	Relationship
China	China to Brunei	0.16	0.11	Commensalism
Brunei	Brunei to China	0.09	-1.35	
China	China to Indonesia	0.11	-0.98	Competition
Indonesia	Indonesia to China	0.08	-1.07	
China	China to Cambodia	0.16	-0.44	Commensalism
Cambodia	Cambodia to China	0.04	1.02	
China	China to Laos	0.15	-0.02	Commensalism
Laos	Laos to China	0.03	7.82	
China	China to Burma	0.14	-0.20	Commensalism
Burma	Burma to China	0.09	2.99	
China	China to Malaysia	0.07	-3.18	Competition
Malaysia	Malaysia to China	0.04	-0.60	
China	China to Philippines	0.14	-0.47	Competition
Philippines	Philippines to China	0.03	-1.06	

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China Singapore	China to Singapore	0.11	-0.71	Competition
	Singapore to China	0.06	-1.28	
China Thailand	China to Thailand	0.04	-1.10	Competition
	Thailand to China	0.03	-0.94	
China Vietnam	China to Vietnam	0.16	1.29	Commensalism
	Vietnam to China	0.12	-0.43	

Table8 Classification of China ASEAN Trade Relations

Competition	**Commensalism**	
	Positive for China	**Positive for another country**
Indonesia	Cambodia	Burma
Malaysia	Laos	Vietnam
Philippines	Myanmar	
Singapore		
Thailand		

Results and Discussion

First of all, It is clear from Figure 2 that the trend of bilateral trade between PRC and the ten ASEAN countries conforms to the evolution law of logistics. From the calculation results in Table 3, it can be further seen that the bilateral trade relations between PRC and the ten ASEAN nations conform to the evolution law of Lotka-Volterra model, that is, they belong to a symbiotic relationship. The bilateral trade relations between five countries and PRC are competitive, and the bilateral trade relations between five countries and PRC are biased, indicating that most of the ten ASEAN countries have the possibility of trade friction with China.

Secondly, we will further analyze the different types of bilateral trade relations between PRC and the ten ASEAN nations:

First, from the bilateral trade relations between PRC and the ten ASEAN nations, we can see that the evolutionary growth coefficients between Indonesia, Malaysia, the Philippines, Singapore and Thailand and China are all negative, which shows that their bilateral trade relations with China are competitive. This is because, first of all, the main export markets of Indonesia, Malaysia, the Philippines, Singapore and Thailand are the United States, Japan and China. The common markets facing China and these five countries are the United States and Japan[21,48]. The identity of their foreign trade objects makes the two sides inevitably face fierce competition in the export market[20]. Secondly, China's exports of goods to Indonesia, Malaysia, the Philippines and Thailand are mainly concentrated in primary products and processing and manufacturing industries, so there is a certain degree of competitiveness[40,52]. With the growth of China's economy and the optimization and upgrading of China's industries and technological innovation, the coincidence ratio of products exported by China and Singapore in the world market has risen. In

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recent years, the product similarity is basically about 70%, so there is also strong competition between China and Singapore in trade[50].

Second, Cambodia, Laos and Myanmar have negative evolutionary growth coefficients for China, while China has positive evolutionary growth coefficients for these three countries. It can be seen that China has relatively benefited from bilateral trade with these three countries. First of all, these three countries are in the position of trade deficit with China, while China is in the position of trade surplus with these three countries[53]. For these three countries, the high trade deficit puts them at a disadvantage in their trade with China. Compared with China, these three countries enjoy less economic growth effect brought by trade growth. Secondly, these three countries are all developing countries. Most of the products exported to China belong to natural resources, which have low value, low profitability and less foreign exchange[34]. On the contrary, they import a large number of technology intensive products and daily necessities from China and lose more foreign exchange, which is not conducive to their future economic development in the long term.

Third, Brunei and Vietnam have positive evolutionary growth coefficients for China, while China has negative evolutionary growth coefficients for these two countries. It can be found that Brunei and Vietnam have relatively benefited from bilateral trade between PRC and these two countries. Overall, the bilateral trade relations between Cambodia, Laos, Myanmar, Brunei and Vietnam and China are commensalism. The types of goods exported from China to Brunei are single, mainly focusing on oil and natural gas. Such goods have higher foreign exchange earning capacity and higher benefits[38]. The goods exported from China to Brunei are generally technology intensive products and labor-intensive goods. The value of such goods is far lower than oil. With the substantial increase of China's oil imports from Brunei, there has been a serious trade deficit for a long time. Therefore, China has gained relatively few benefits in the bilateral trade between the two countries. Although Vietnam is also in a deficit position in China Vietnam trade, in recent years, Vietnam's domestic low value-added and low manufacturing industry has developed rapidly with low production costs. Textiles, footwear and other goods have become one of Vietnam's main export commodities. Although the production of these products requires a large amount of raw and auxiliary materials imported from China, resulting in a trade deficit, these products are exported to Europe The United States and other countries and regions will bring plenty of export foreign exchange to Vietnam, which is conducive to Vietnam's economic development in the long run[31]. In addition, in recent years, the political pattern of PRC and Vietnam has become more and more complex. The Vietnamese government has restricted the import of Chinese goods and encouraged the export of Vietnamese enterprises, making Vietnam more and more profitable in bilateral trade between China and Vietnam[47].

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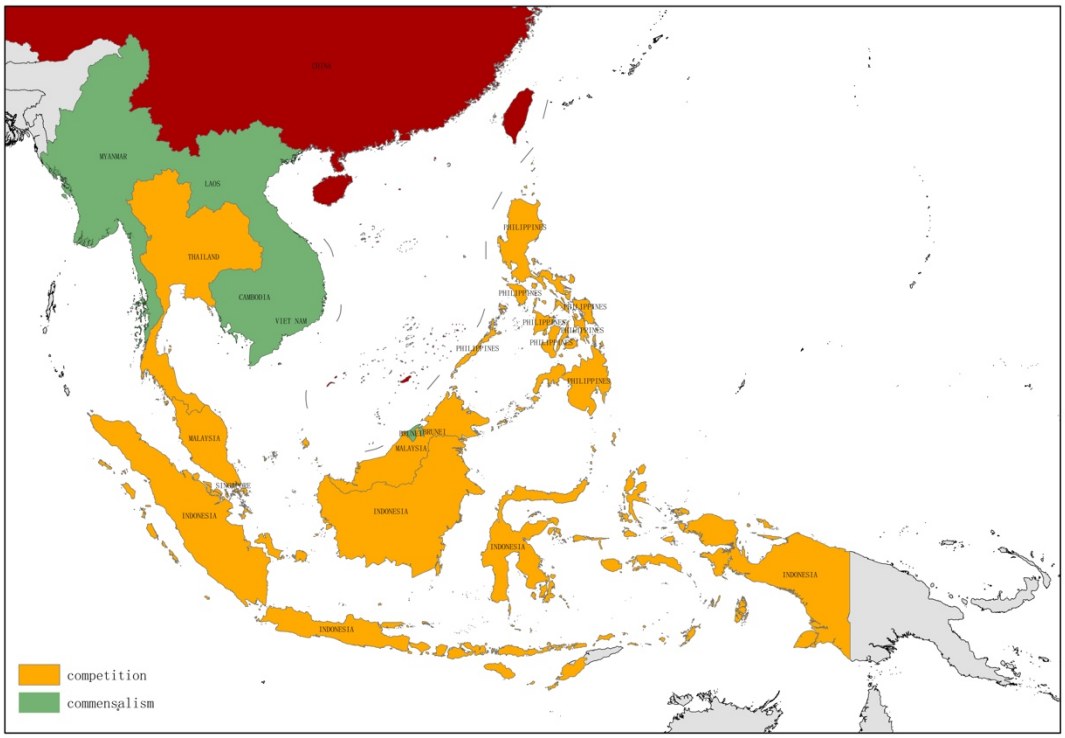

Figure3 Bilateral trade relations between China and ten ASEAN countries

Conclusion

1. Summary

China and ASEAN have very close economic and trade ties and are important trading partners for each other, so this paper studies the bilateral trade competition and cooperation between China and neighboring countries from the perspective of ecological population competition[46]. The research finds that the current bilateral trade relations between PRC and the ten ASEAN nations still need to be further developed. China is in a competitive relationship with most ASEAN countries and is likely to have trade frictions. According to different classifications: First, according to the Lotka-Volterra ecological population competition model, China has a strong competitive relationship with Singapore, Malaysia, Thailand, Indonesia, and the Philippines, which are the top five countries in economic development. There are many competitive industries, and the possibility of trade friction is the largest.[19] Secondly, according to the Lotka Volterra ecological population competition model, the bilateral trade relations between Cambodia, Laos, Myanmar, Brunei and Vietnam and China are biased, which is likely to cause trade friction. China has a greater profit in bilateral trade with Cambodia, Laos and Myanmar, while it has a smaller profit in bilateral trade with Brunei and Vietnam.

In general, the trade relationship between PRC and ASEAN is in line with the Lotka Volterra ecological population competition model, which belongs to the symbiotic relationship. The main types of competition and cooperation relationship are competition relationship and profit biased relationship. The main reason for the competition relationship is that Southeast Asian countries have more labor force and natural resources, which makes PRC and ASEAN countries have great similarities in the export trade structure and the export structure tends to be consistent, In the export market, they are also concentrated in developed nations such as the United States and Japan, with great market overlap.[27,45] The reasons leading to the partial profit relationship are more complex. Due to the great difference between the structure of export products of some ASEAN countries and China, the effect of external factors such as the policies of various countries and the international situation, the benefits obtained by both sides in the trade process are different.[30]

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At present, ASEAN, as an important trade partner of China and an important emerging economy nationwide[24], should pay more attention to bilateral trade relations with ASEAN. Although from the perspective of ecological population competition, trade competition between PRC and ASEAN is inevitable, but this trade competition is not necessarily detrimental to the development of China ASEAN Free Trade Area, By contraries, it rises the positive production influence of the free trade area, further brings trade creation influence to member nations, and drives the growth of bilateral trade. If the major countries of China and ASEAN can give full play to their comparative advantages to carry out production division and cooperation and actively adjust and upgrade their own industrial structures, the two sides may still continue to maintain competitiveness and achieve common prosperity in the future international competition, and China and ASEAN will certainly grow together in benign competition, work together to build a China ASEAN community of shared future.[17]

2. Limitations and Prospects

（1）Limitations

This paper studies and discusses the bilateral trade relations between PRC and the ten ASEAN nations based on the Lotka-Volterra ecological population competition model. Due to my limited knowledge in theoretical basis, I inevitably have omissions in many aspects, and there are still deficiencies in the treatment and research of some problems. In addition, the actual problems are complex, so there is still a lot of research work to be further carried out. First of all. the Lotka-Volterra model is the most basic population model in this paper. Although the impact of trade competition coefficient and mutual benefit coefficient between countries is considered, the impact of trade relations between major countries outside the region and ASEAN on China ASEAN trade relations is not considered, nor is the impact of political, security and other fields between PRC and ASEAN on trade relations considered. In the study of PRC and ASEAN nations, due to the lack of a small part of basic data, some of the parameters are estimated, and there are some errors. The detailed study of various coefficients in the model will be the key to ensure the accuracy of the model, and also the focus of the next research.

（2）Prospects

At the existing research level, both theoretical and practical research is full of high research value. In this paper, the Lotka-Volterra ecological population competition model is introduced to research the bilateral trade relations between PRC and the ten ASEAN nations, and a good fitting effect is obtained, which proves that the model can be used in the study of international trade relations and is a beneficial attempt of international trade relations. At present, scholars have expanded the model of two competitors to three or more competitors. In the future research, the introduction of Lotka-Volterra model will provide a more convenient method for the analysis of global trade relations, and its validation effect needs to be further tested.

3. Policy Suggestion

Although the construction of China ASEAN Free Trade Area has been improved, the main factors hindering the development of bilateral trade are the level of ports and transportation infrastructure, customs efficiency, technical barriers to trade and other non-tariff trade barriers[18]. In addition, ASEAN countries generally lag behind in the modernization of port, highway and customs management, and are eager to change the status quo. Therefore, China should strengthen cooperation in port, highway and other infrastructure construction, give full play to its own infrastructure construction capacity and financial advantages, and help the 10 ASEAN countries improve their infrastructure level, enhance bilateral trade efficiency, and thus reduce trade costs[23].

At present, the competition in bilateral trade between PRC and ASEAN is mainly because of the concentration of exports, the similarity of export products and industrial structure, and China's comparative advantage and competitiveness in labor-intensive products[35,36]. Therefore, China should make great efforts to improve the technical added value level of export products, so as to improve the position of its own industry in the international industrial chain. First of all, China should strengthen innovation, constantly invest in R&D high-tech industry, optimize the R&D investment structure, and constantly strengthen and develop its own core technology[32]. Secondly, China should pay attention to the important position of enterprises in R&D innovation and give

some enterprises financial or policy support. Finally, China should also attach importance to the intellectual property rights and actively help solve the problem of insufficient research and development motivation of companies[44].

According to the structure and technical level of different countries and regions in the China ASEAN Free Trade Area, seek cooperation fields and carry out economic and trade cooperation. To be specific, Laos, Vietnam, Myanmar, Cambodia and other countries are rich in resources, but their industrial base is weak and their technology level is low[42]. We should strengthen cooperation with them in the field of resource development and industrial production. Due to the shortage of foreign exchange in the above countries, various payment methods should be adopted and flexible. Thailand, Singapore, Brunei and other countries, with relatively developed light industry, strong economic strength and good payment conditions, should strengthen cooperation in resource exploration and production of means of production, strengthen bilateral trade, give play to their comparative advantages and expand trade scale from the perspective of industry complementarity[37].

We should promote regional economic and trade cooperation with non-governmental organizations, especially enterprises as the main body. Taking enterprises as the main body to promote regional economic and trade cooperation is a practical way with low cost, good benefits, quick results, conflict avoidance. Diversified and multi-directional cooperation among enterprises, with less market risk, is easy to achieve economic benefits, which is conducive to accelerating economic and trade cooperation[41]. At the same time, with the expansion of market access and the reduction of tariff and non-tariff barriers, a large number of SMEs will be impacted. Although the China ASEAN Free Trade Area allows the protection of sensitive products, it is difficult for SMEs to safeguard their interests in the "special product protection" because of their economic weakness when the country formulates protection objects[47]. Therefore, various policies and financial support in line with WTO rules should be adopted to help SMEs improve their competitiveness.

Author Contributions: Conceptualization, W.R. and X.Y.; methodology, W.R.; software, S.W.; writing—original draft preparation, W.R. and X.Y.; writing—review and editing, W.R., X.Y. and S.W.; visualization, T.Z.; supervision, X.Y.; project administration, X.Y.; funding acquisition, X.Y. All authors have read and agreed to the published version of the manuscript.

Funding: This research was supported by the Project of Social Science Foundation of Jiangsu Province (No. 22TQC005).

Data Availability Statement: The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest: The authors declare no conflict of interest.

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