Ternary Marginal Analysis on China's Agricultural Exports to the United States Market

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Abstract: China-U.S. agricultural trade has the characteristics of China's continuous growth in trade volume with slowing growth and widening deficit. Based on SITC agricultural products data from 1992 to 2016 in UN Comtrade database, extensive margin, price margin and quantity margin of agricultural products exported from China to the United States in different economic periods were calculated, as well as their contribution rates to the growth of agricultural products export share. The research results show that the average extensive margin, price margin and quantity margin are 0.9137, 1.0216 and 0.0312, respectively. It shows that the agricultural products exported from China to the United States cover most tradable agricultural products, and the export price is slightly higher than the average price, while the export quantity accounts for less. The growth sources of China's agricultural exports to the United States are different in each research stage. In general, the growth of agricultural exports mainly comes from intensive margin growth, and the contribution rate of quantity margin is higher than that of price margin.

1. Introduction

As a traditional agricultural country, since its accession to the WTO, China's agricultural trade has grown steadily. In 2018, China's agricultural trade totaled U.S. $216.81 billion, of which U.S. $79.71 billion was exported and U.S. $137.10 billion was imported, resulting in a trade deficit of U.S. $57.38 billion. The United States is China's important agricultural product trade partner, accounting for 20% of the total amount of China's agricultural products trade, and it is China's third largest agricultural export destination countries. In the past three years, due to the intensified trade friction between China and the United States, both the amount of Chinese agricultural products imported from and exported to the United States have declined, which has led to a decline in the total amount of china-U.S. agricultural trade. But on the whole, the trade volume of agricultural products between China and the United States is increasing, and the trade deficit of agricultural products keeps increasing. Is the increase in China's agricultural exports to the United States due to the variety of agricultural exports, the increase in the quantity of agricultural exports, or the increase in the price of agricultural exports? An accurate answer to these questions is of great theoretical and practical significance for clarifying the mechanism for the growth of China's agricultural trade with the United States, better strengthening the agricultural trade cooperation between China and the United States, and promoting the development of agricultural trade.

Existing literatures have conducted in-depth studies on the status quo, structure, development direction and influencing factors of china-U.S. agricultural trade, and obtained rich research results (for example, Luo Xiaofei et al., 2012[1]; Qin Cheng et al., 2018[2]; Yin Xianglai, 2018[3]). On the study of sources of trade growth, Hummels and Klenow (2005) [4] studied the causes of trade growth in large countries, dividing a country's export or import growth into intensive and extensive margins. Based on Hummels' decomposition method, Shi Bingzhan (2011) [5] further decomposed intensive margin into price margin and quantity margin. As for the growth path of China's agricultural product export, Geng Xianhui et al. (2014) [6]found that the intensive margin had a greater impact on the

growth of agricultural product export than the extensive margin, and the growth of China's agricultural product export was mainly caused by the increase in the quantity of agricultural product export or the increase in the price. In addition, the study on the intensive and extensive margin of China's agricultural products exports to specific countries and regions found that the extensive margin of China's agricultural products exports to less developed countries was lower than that of developed countries. On the contrary, the intensive margin of China's agricultural products exports to developed countries was lower than that of less developed countries (for example, Yang Fengmin et al., 2015 [7], 2017 [8], 2018 [9]; Liu Hongze, 2017 [10]; Zheng Yan et al., 2018 [11]; Ding Cunzhen et al., 2019 [12]; Xie Guoe et al., 2017 [13]).

Based on China's agricultural products export to the United States and the world export to America data from 1992 to 2016, using ternary marginal decomposition approach, the ratio of China's agricultural trade volume exported to the United States and the world's agricultural trade volume exported to the United States is decomposed into intensive margin and extensive margin, and then the intensive margin is further decomposed into price margin and quantity margin, thus the export growth of agricultural products is decomposed into extensive margin, quantity margin and price margin. This paper analyzes the influence of intensive margin or extensive margin on the growth of Chinese agricultural products exported to the U.S., and further analyzes the growth rate and contribution rate of extensive margin, quantity margin and price margin in different economic stages.

2. Overview of China-U.S. agricultural trade

2.1 Trade scale increased with fluctuating

Since China joined the WTO, the trade volume of agricultural products between China and the U.S. has been on the rise. Bilateral trade in agricultural products reached 38.058 billion U.S. dollars in 2016, up from 5.843 billion U.S. dollars in 2002. The average annual growth rate of China-U.S. agricultural trade over the past 15 years was 14.32%. As can be seen from Table 1, during the 10 years from 2002 to 2012, the total trade volume of agricultural products between China and the United States increased steadily with a large increase. Between 2012 and 2016, the average annual growth rate of total trade declined and the growth rate slowed down. In 2013, 2015 and 2016, there was even negative growth.

Table 1 Import and Export Volume of Agricultural Products from China to the United States

Unit: $100 million

Year	Total Trade	Import	Export	Deficit	Year	Total Trade	Import	Export	Deficit
2002	58.43	38.12	16.71	24.41	2010	305.29	243.46	61.83	181.63
2003	86.51	65.07	21.44	43.63	2011	384.28	311.86	72.42	239.44
2004	120.58	96.15	24.43	71.72	2012	438.24	360.96	77.28	283.68
2005	122.48	91.19	31.29	59.90	2013	422.12	344.18	77.94	266.24
2006	144.91	103.32	41.59	61.73	2014	444.44	365.22	79.22	286.00
2007	177.08	127.96	49.12	78.84	2015	392.46	313.86	78.60	235.26
2008	246.24	189.78	56.46	133.32	2016	380.58	302.00	78.58	223.42
2009	228.68	177.97	50.71	127.26					

Source: the UN Comtrade database

To be specific, the reasons for the decline in China-U.S. trade in agricultural products are as follows. First, the prices of agricultural products in the international market are low, and China's agricultural imports tend to diversify. Second, China's economy has entered a "new normal" situation. As the supply-side structural reform continues to advance, China is less dependent on the U.S. market. Finally, affected by the trade friction between China and the United States, the export restrictions of the United States on Chinese products increased significantly, and the economic and trade relations between China and the United States were relatively tense.

2.2 Trade deficit continued to widen

In addition, the trade volume of Chinese agricultural products exported to the United States has been in deficit for a long time. The trade deficit increased from 2.441 billion U.S. dollars in 2002 to 22.342 billion U.S. dollars in 2016 with an average annual growth rate of 17.13 percent. This is mainly due to China's large population and its growing demand for agricultural products, while the intensive degree of U.S. agricultural products and its large output have resulted in a large number of Chinese imports of U.S. agricultural products and an increasing deficit year by year.

3. Methods and data

3.1 Ternary marginal decomposition method

In terms of the trade growth of China's agricultural products exported to the U.S. market, intensive margin refers to the increase in the total agricultural products exported to the U.S. due to the increase in the quantity or price of agricultural products within the range of the agricultural products exported from China to the U.S..

The extensive margin measures the growth in agricultural exports as a result of the increase in the variety of agricultural products that China exports to the United States. Based on the decomposition method proposed by Shi Bingzhan (2011) [5], this paper breaks down the share of China's agricultural trade volume exported to the United States in the total agricultural trade volume exported to the United States into the product of intensive margin and extensive margin. The calculation formula of intensive margin and extensive margin is as follows:

$$\text{Intensive margin: } IM_{CU} = \frac{\sum_{i \in I_{CU}} P_{CU} Q_{CU}}{\sum_{i \in I_{CU}} P_{WU} Q_{WU}} \tag{1}$$

$$\text{Extensive margin: } EM_{CU} = \frac{\sum_{i \in I_{CU}} P_{WU} Q_{WU}}{\sum_{i \in I_{WU}} P_{WU} Q_{WU}} \tag{2}$$

Where i represents a certain type of agricultural products, I_{CU} and I_{WU} respectively represents two sets of agricultural products exported to the United States by China and other countries in the world, P_{CU} and Q_{CU} respectively represents the price and quantity of agricultural products exported to the United States by China, while P_{WU} and Q_{WU} represents the price and quantity of agricultural products exported to the United States by other countries in the world.

Obviously, the product of intensive margin and extensive margin is equal to the proportion of China's agricultural exports to the United States and the world's agricultural exports to the United States.

$$IM_{CU} \times EM_{CU} = \frac{\sum_{i \in I_{CU}} P_{CU} Q_{CU}}{\sum_{i \in I_{WU}} P_{WU} Q_{WU}} \tag{3}$$

Furthermore, the intensive margin can be decomposed into the product of the quantity margin and the price margin.

$$IM_{CU} = PM_{CU} \times QM_{CU} \tag{4}$$

Where, the calculation formulas of price margin and quantity margin are as follows:

$$PM_{CU} = \prod_{i \in I_{CU}} \left[\frac{P_{CUi}}{P_{WUi}} \right]^{w_{CUi}} \tag{5}$$

$$QM_{CU} = \prod_{i \in I_{CU}} \left[\frac{Q_{CUi}}{Q_{WUi}} \right]^{w_{CUi}} \tag{6}$$

The weight w_{CUi} in the above formula is calculated by the following formula:

$$w_{CUi} = \frac{\frac{S_{CUi} - S_{WUi}}{\ln S_{CUi} - \ln S_{WUi}}}{\sum_{i \in I_{CU}} \frac{S_{CUi} - S_{WUi}}{\ln S_{CUi} - \ln S_{WUi}}} \tag{7}$$

Among the categories of agricultural products exported by China to the United States, S_{CUi} represents the proportion of the exports of category i agricultural products to the United States accounted for the total agricultural products exported by China to the United States. S_{WUi} indicates that within the category of China's agricultural products exports to the United States, the proportion of the exports of category i agricultural products to the United States in the total agricultural products exports to the United States of the world is as follows:

$$S_{CUi} = \frac{P_{CUi} Q_{CUi}}{\sum_{i \in I_{CU}} P_{CUi} Q_{CUi}} \tag{8}$$

$$S_{WUi} = \frac{P_{WUi} Q_{WUi}}{\sum_{i \in I_{CU}} P_{WUi} Q_{WUi}} \tag{9}$$

Therefore, the market share of China's agricultural products exported to the United States can be divided into the product of three marginal factors, namely, the extensive margin, the price margin and the quantity margin:

$$EX_{CU} = EM_{CU} \times IM_{CU} = EM_{CU} \times PM_{CU} \times QM_{CU} \tag{10}$$

3.2 Sample selection and data sources

The data are from the UN trade database. According to the classification standard of international trade classification (SITC), and referring to the research of Zhang Yue (2016) [14] on the definition of the scope of agricultural products in agricultural products trade, agricultural products in this paper are divided into seven categories: bulk agricultural products, livestock products, aquatic products, horticultural products, beverages and tobacco, forest products and other agricultural products.

Stata15.0 software was used to sort and process the above data and calculate the intensive margin, extensive margin, price margin and quantity margin of China's agricultural products exported to the U.S. market from 1992 to 2016. The results are shown in Table 2.

4. Ternary marginal analysis of China's agricultural products export to the U.S. market

4.1 Extensive margin analysis

It can be seen from Table 2 that the extensive margin value of agricultural products exported from China to the United States is relatively large, with the average extensive margin value from 1992 to 2016 being 0.9137. This indicates that China's agricultural products exported to the United States account for a high proportion of the world's agricultural products exported to the United States. In other words, China's agricultural products exported to the United States basically cover the agricultural products exported to the United States by other countries in the world.

In 1996, the extensive margin value fell to the lowest value of 0.6059, with a growth rate of -34.21%, mainly due to the significant reduction in the variety of agricultural and livestock products because of the impact of the Asian financial crisis. The extensive margin value increased rapidly in 1996-1997 and 2009-2011 respectively, mainly because the trade types of aquatic products and

forest products increased significantly in this stage. Among them, the extensive margin value increased from 0.6059 in 1996 to 0.9362 in 1997, with a growth rate of 54.51%, indicating that the types of agricultural products increased significantly during the year, which had a significant impact on the growth of the trade volume of agricultural products exported to the U.S. market.

Table 2 Extensive margin, intensive margin, price margin and quantity margin value

Year	Extensive margin	Intensive margin	Price margin	Quantity margin	Year	Extensive margin	Intensive margin	Price margin	Quantity margin
1992	0.8169	0.0163	0.8427	0.0193	2005	0.9187	0.0343	0.8671	0.0395
1993	0.8868	0.0139	0.8168	0.017	2006	0.9383	0.0413	0.8828	0.0468
1994	0.9147	0.0134	0.743	0.018	2007	0.9496	0.0427	1.0251	0.0417
1995	0.9209	0.0145	0.9783	0.0148	2008	0.9310	0.0388	1.1245	0.0345
1996	0.6059	0.0213	1.1274	0.0189	2009	0.9518	0.0441	1.181	0.0373
1997	0.9362	0.0145	1.0875	0.0133	2010	0.9487	0.046	1.3075	0.0352
1998	0.9201	0.0153	1.089	0.014	2011	0.9522	0.0463	1.3675	0.0338
1999	0.8965	0.0156	0.966	0.0161	2012	0.9434	0.057	1.2308	0.0463
2000	0.9214	0.0155	0.8588	0.018	2013	0.9448	0.056	1.2031	0.0466
2001	0.9081	0.0208	0.8532	0.0244	2014	0.9361	0.0615	1.1243	0.0547
2002	0.9223	0.0254	0.8077	0.0315	2015	0.9538	0.0514	1.2253	0.0419
2003	0.9432	0.0297	0.7223	0.0411	2016	0.9602	0.0500	1.3038	0.0384
2004	0.9213	0.0290	0.8049	0.0360	mean	0.9137	0.0326	1.0216	0.0312

After 2000, the extensive margin value basically remained stable at above 0.9, indicating that the types of agricultural products exported from China to the United States were basically fixed, and the export structure of agricultural products was generally stable.

4.2 Intensive margin analysis

From 1992 to 2016, the intensive margin value of China's agricultural exports to the United States fluctuated between 0.01 and 0.05, with an average value of 0.0326. Although the intensive margin value was small, it showed an obvious increase year by year.

The price margin of China's agricultural trade with the United States increased from 0.8427 in 1992 to 1.3038 in 2016, with an annual average of 1.0216 and an annual growth rate of 1.84%. It is worth noting that the price margin of agricultural products after 2007 is all greater than 1, which indicates that the price of agricultural products exported from China to the U.S. is higher than the average price of agricultural products exported from other countries to the U.S.

The quantity margin of agricultural products exported from China to the United States fluctuates between 0.01 and 0.05, with an annual average value of 0.0312. Although the value is small, the growth rate continues. It can be seen that the intensive marginal growth of China's agricultural products exports to the United States is derived from the marginal growth of both price and quantity.

4.3 Analysis on the contribution of agricultural products export growth

In general, the growth of China's agricultural exports to the United States has both intensive and extensive marginal effects. Due to the large span of the research interval, the sources of agricultural product export growth may be different in different periods. In order to analyze the contribution of the extensive margin, price margin and quantity margin in different stages to the growth of agricultural product export market share, the growth rate of China's agricultural product export market share to the United States is decomposed into the sum of the extensive marginal growth rate, price marginal growth rate and quantity marginal growth rate, namely:

$$g_{EX} = g_{EM} + g_{PM} + g_{QM} \tag{11}$$

Where, $g_{EX}, g_{EM}, g_{PM}, g_{QM}$ respectively represent the growth rate of China's market share of agricultural products exported to the United States, the extensive marginal growth rate, the price marginal growth rate and the quantity marginal growth rate. These growth rates can be calculated by

subtracting the natural logarithms of the market share, extensive margin, price margin and quantity margin of the reporting period from the natural logarithms of the respective base periods. The formula for calculating the contribution of extensive margin, price margin and quantity margin to market share growth is as follows:

$$per_{EM} = g_{EM} \Big/ g_{EX} \text{ , } per_{PM} = g_{PM} \Big/ g_{EX} \text{ , } per_{QM} = g_{QM} \Big/ g_{EX} \tag{12}$$

Selecting year 1995 (American entry into the WTO), 2001 (China's accession to the WTO), 2008 (the global financial crisis) and 2012 as four time node, the sample years from 1992 to 2016 were divided into five time stages and then the growth rate of market share, extensive margin, intensive margin, price margin and quantity margin and the growth contribution rate of each margin in each period are calculated as shown in Table 3.

Table 3 Ternary margin growth rate and contribution rate

Period	Market share growth rate	Margin growth rate				Margin contribution rate			
		Extensive margin	Intensive margin	Price margin	Quantity margin	Extensive margin	Intensive margin	Price margin	Quantity margin
1992~1995	0.0036	0.1198	-0.1163	0.1492	-0.2655	33.6407	-32.6407	41.8858	-74.5264
1996~2001	0.3814	0.4046	-0.0233	-0.2787	0.2554	1.0610	-0.0610	-0.7307	0.6697
2002~2008	0.4313	0.0094	0.4219	0.3309	0.0910	0.0218	0.9782	0.7673	0.2109
2009~2012	0.2486	-0.0089	0.2575	0.0413	0.2161	-0.0357	1.0357	0.1662	0.8695
2013~2016	-0.0970	0.0162	-0.1132	0.0804	-0.1935	-0.1667	1.1667	-0.8287	1.9954
1992~2016	1.2860	0.1616	1.1244	0.4364	0.6880	0.1257	0.8743	0.3394	0.5350

As can be seen from Table 3, before the U.S. joined the WTO, the share of China's agricultural products exported to the U.S. showed a slow growth, while the quantity of agricultural products showed a negative growth. The growth rates of the extensive margin and the price margin were 0.1198 and 0.1492, respectively. During this period, the growth of China's agricultural exports to the United States was mainly caused by the increase of agricultural exports categories and the rise of agricultural prices, whose respective contribution rates were 33.6407 and 41.8858, respectively. This indicates that the export types of agricultural products increased and the prices also increased, but the quantity of agricultural products decreased.

China's share of agricultural exports to the U.S. increased slightly between 1996 and 2001. Among them, the price margin growth rate is -0.2787, which is mainly due to the fact that the United States entered the WTO and gradually reduced the trade barrier of agricultural products as promised, but many preferential policies are only for WTO members, so it will have a certain impact on the export price of China's agricultural products, and the export price of agricultural products will decline. The types and quantities of Chinese agricultural products exported to the U.S. increased, with contribution rate being 1.0610 and 0.6697 respectively.

From China's accession to the WTO in 2001 to the eve of the global financial crisis, China's accession to the WTO had a certain impact on China's agricultural exports to the United States, with the highest price margin growth rate among the three margins being 0.3922, and the highest contribution rate being 0.7673.The growth rate of the extensive margin and the quantity margin were 0.0094 and 0.0910 respectively, with the contribution rate being 0.0218 and 0.2109 respectively. During this period, the growth of China's agricultural exports to the United States was mainly driven by price growth, and the trade types and quantities of agricultural products also increased slightly.

From 2009 to 2012, despite the impact of the global financial crisis, the bilateral agricultural

export trade between China and the United States seems not to have been affected much, and the total agricultural trade volume still keeps increasing year by year.

The quantity margin growth rate was 0.2161 and the extensive margin growth rate was negative, indicating that the trade category of agricultural products in this period declined slightly and the marginal price increased slightly. The main driving force of China's agricultural trade growth in this period was the quantity margin, which contributing 0.8695.

From 2013 to 2016, the share of China's agricultural exports to the United States steadily declined, with the quantity margin growth rate being -0.1935, and the extensive and price margin growth rate being 0.0162 and 0.0804, respectively. The fluctuation of agricultural exports at this stage was mainly caused by the decrease in the quantity of agricultural exports.

From 1992 to 2016, the contribution of quantity margin, price margin and extensive margin to the share increase of China's agricultural exports to the U.S. was 0.5350, 0.3394 and 0.1257 respectively. Although the sources of market share growth of China's agricultural products exported to the United States are different in each stage. In general, the growth of agricultural products exports mainly comes from intensive marginal growth, and the contribution rate of quantity margin growth is higher than that of the price margin growth.

5. Conclusion

Based on the data of agricultural trade between China and the United States from 1992 to 2016, the general situation and current situation of agricultural trade between China and the United States were analyzed. China's agricultural exports to the United States show sustained growth in the volume of agricultural products, but the growth rate has slowed down significantly in recent years.

Using the method of ternary marginal analysis, the extensive margin and intensive margin of Chinese agricultural products exported to the U.S. market from 1992 to 2016 were calculated, and the intensive margin was further decomposed into price margin and quantity margin. The extensive margin increased more slowly, with an average value of 0.9137, that is, Chinese agricultural products exported to the United States basically covered the vast majority of the world's tradable agricultural products. And that value has been stable above 0.9 since 2000, indicating that China's agricultural products exported to the United States are basically stable. The intensive margin value fluctuates between 0.01 and 0.07, and the annual average value is 0.0326. Although the intensive margin value is small, it shows an obvious increase year by year. The increase of intensive margin benefits from both the increase of price margin and quantity margin. Among them, the price margin increases in a small range in fluctuation, with an annual average value of 1.0216. Since 2007, the price margin has been greater than 1, that is, the average price of agricultural products exported from China to the United States is higher than that from other countries in the world. The quantity margin fluctuates between 0.01 and 0.06, and the annual average value is 0.0312.

Considering that the contribution of the extensive margin, price margin and quantity margin to the growth of agricultural product export share in different economic stages is different, the research intervals from 1992 to 2016 are divided into five periods, that is, from 1992 to 1995, from 1996 to 2001, from 2002 to 2008, from 2009 to 2012 and from 2013 to 2016. The results show that before the United States joined the WTO, the share of China's agricultural products exported to the United States grew slowly, while the quantity of agricultural products grew negatively. During the period from 1996 to 2001, the export share of agricultural products increased slightly, among which, the export prices of agricultural products decreased significantly, and the types and quantities of agricultural products increased. From 2002 to 2008, the export growth of agricultural products was mainly driven by prices, and the types and quantities of agricultural products also increased slightly. From 2009 to 2012, the trade share of agricultural products increased year by year, with a large quantity margin increase, a slight decline in the trade category of agricultural products, and a slight increase in the price margin. The main driving force for the growth of agricultural products trade was the increase in the export volume of agricultural products, with a contribution rate of 0.8695.From 2013 to 2016, the share of China's agricultural exports to the United States declined steadily, and the slowdown in agricultural exports was mainly due to the decrease in the quantity of agricultural

exports. Over the entire study period from 1992 to 2016, China's share of agricultural exports to the United States increased. Although the sources of market share growth of China's agricultural products exported to the United States are different in different stages, the main sources of agricultural products export growth are intensive margin growth. Among them, the contribution rate of quantity margin growth is higher than that of price margin growth.

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