

# Research on the Phenomenon That the Increase of Grain Production Did Not Cause the Harvest Paradox in China from 2003 to 2014

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**To cite this article:**

Xu Jianlong, Zhang Xinyue. Research on the Phenomenon That the Increase of Grain Production Did Not Cause the Harvest Paradox in China from 2003 to 2014. *International Journal of Business and Economics Research*. Vol. 7, No. 6, 2018, pp. 218-226.

doi: 10.11648/j.ijber.20180706.16

**Received:** November 8, 2018; **Accepted:** November 30, 2018; **Published:** December 20, 2018

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**Abstract:** The phenomenon that China's increase of grain production didn't cause the Harvest Paradox from 2003 to 2014 occurred in the context of significant increase in domestic residents' income and food demand, as well as loosening price and the market of grain purchase and sales. Research on the phenomenon not only enhances the understanding of the condition and mechanism for the Harvest Paradox, but also maybe offers some little reference values in solving food problems of China. Following the methods of Samuelson and Nordhaus, this paper utilizes the supply and demand theorem to study the phenomenon. The phenomenon was found it didn't cause the loss of farmers' total income that the grain production in China had increased for 11 years from 2003 to 2014, which was inconsistent with the Harvest Paradox in economics. It resulted from non-grain price factors which caused the demand line moved in excess of the supply line. Thus the grain price rose. Grain supply policies taken by Chinese government such as the four subsidies were conducive to the Harvest Paradox. To ensure that farmers' income increase, the demand line should get sharper move towards the upper right via the power of market or government policies.

**Keywords:** Chinese Grain Production, Demand Line's Movement, Occurrence Condition of Harvest Paradox, Supply and Demand Theorem

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## 1. Introduction

Harvest Paradox is a famous paradox in economics. It means that farmers' income decreases when the grain production increases. *Economics* written by Samuelson and Nordhaus is one of the earliest textbooks mentioning this concept. It came from the summary of history experiences and was verified by theory of elasticity. But from 2003 to 2014, Chinese grain production had increased for 11 years. Among these years, farmers' income from grain increased significantly without the occurrence of the Harvest Paradox.

When explaining Harvest Paradox, Samuelson and Nordhaus used the supply and demand theorem. Following their practice, this paper studied the phenomenon that the increase of grain production didn't cause Harvest Paradox in China from 2003 to 2014 with the same theorem. To this end, in the coordinate system with the grain price as the ordinate

and the grain transaction quantity as the abscissa, under the assumption that China's grain demand curve and supply curve are both straight lines, the direction of parallel movement of the two lines and its relative amplitude during this period are studied. The magnitude is to analyze quantitatively the causes of supply and demand that have not occurred in the Harvest Paradox.

As everyone knows, according to the demand function, the factors determining the quantity of grain demand are not only the grain prices index, but also the per capita disposable income of households, the prices index of non-grain food, the preference of consumers for grain, the expectation of consumers for grain price and their income, and the number of consumers. In addition to grain prices index, the main factors determining the grain supply include the prices of agricultural machinery, fertilizers, seeds, labor, taxes and fees, the land-related commodities which are mainly the

prices of non-grain agricultural products, farming, harvesting and management techniques, the expectations of grain prices index and the number of farmers<sup>1</sup>. For the sake of argument, this paper referred to them as non-grain price factors. In the coordinate system with grain price as ordinate and grain turnover as abscissa, non-grain price factors determine the position of demand line and supply line. If they change, the demand line and supply line will move or rotate in parallel.

The concept of grain in this paper is from the statistical yearbook of China, including cereals, beans and potatoes. Firstly, the reason for taking Chinese grain market from 2003 to 2014 as the research object is that the grain policy changed greatly before and after the period, but during this period it was basically stable and unified. In 2004, China's agriculture, especially grain policies, entered a stage of comprehensive transformation. [1] The State Council's "Opinions on Further Deepening the Reform of Grain Circulation System" (No. 17 Document of the State Council in 2004) clearly demanded that the grain purchasing, selling market and price should be fully liberalized, and that the market mechanism should play a fundamental role in the allocation of grain resources. The system of grain circulation market was basically formed. [2] Policies such as minimum purchase price of grain, direct subsidy for growing grain and subsidy for purchasing agricultural machinery and tools were implemented that year<sup>2</sup>. Mainly due to the role of the market mechanism, coupled with the impact of these policies, China's grain production from 2003 to 2014 achieved "eleven consecutive increases". At the same time, however, China's grain market has also seen problems such as higher domestic grain prices than international grain prices, substantial increase in net grain imports, abuse of agricultural resources, partial transfer of policy subsidies to upstream manufacturers and greater impact on downstream processing industries. [3, 4, 5] In view of this, in June 2014, the State Council executive meeting proposed the reform direction of "promoting the minimum purchase price, temporary storage and agricultural subsidy policy to gradually change to the target price system of agricultural products". Secondly, when the grain market in China completely liberalized its purchase, sale and price since 2004, it was basically close to the perfectly competitive market (Lu Wencong, et al. [6], Liao Xiyuan, et al. [7]). It was the rising of grain prices caused by market supply and demand that kept pushing up the lowest purchase price, not the contrary (Hu Feng. [8]). The most important thing is that during this period, the grain market turnover increased year by year and the transaction price rose year by year. Therefore, the annual grain market junction diagram has no inflection point, which is convenient for discussing the parallel movement of demand line and supply line, and does not need to inspect their rotation.

In addition, China's grain production also increased in 2015. If the year is added, China's grain production has achieved "twelve consecutive increases". However, due to the Harvest Paradox in that year, this paper did not include this year and the following years into the scope of the study.

Due to the complexity of grain problem, there are many causes for China's grain production increase didn't cause the Harvest Paradox from 2003 to 2014. Instead of explaining many aspects, the paper only focuses on discussing its cause of supply and demand. In doing so, it is not only conducive to understanding the condition and mechanism for the Harvest Paradox, but also maybe offers some little reference values in solving food problem in China.

The entire paper is divided into seven parts. The remaining contents are shown as follows: The second part combs the theoretical context of the Harvest Paradox. The third part uses statistical data to prove that China's increase of grain production violates the Harvest Paradox from 2003 to 2014. The fourth part is the reason analysis, using a schematic graphical model to discuss. The fifth part shows another condition for the occurrence of the Harvest Paradox, and analyzes its implied mechanism. The sixth part is discussion. The final part is the conclusions.

## 2. Theoretical Context and Literature Review

In ancient times, the phenomenon of Harvest Paradox has been observed by ancestors. For example, there are "very expensive of cereal, injure the people; very cheap of cereal, injure the farmers" records in *Han Shu Shi Gou Zhi* written by Ban Gu in the Eastern Han Dynasty of China. Gregory King, a 17th-century British writer, found that farmers as a whole get less income in good years than in bad ones. However, these records described phenomena, did not rise to a theoretical level, with economic principles to explain. Because there was no concept of demand price elasticity at that time.

In economics, Marshall first put forward the concept of demand price elasticity, which refers to the percentage change of demand quantity caused by a specific change in demand price (usually set at 1%) with other conditions unchanged. It can be used to measure the sensitivity of demand quantity to price change. Assuming that the demand function is  $Q^d=f(P^d)$ , where  $Q^d$  represents the quantity of demand and  $P^d$  represents the price of demand, one of the formulas for calculating arc elasticity from the starting point  $E_0(P_0^d, Q_0^d)$  to the end point  $E_1(P_1^d, Q_1^d)$  is given, since the direction of change of  $Q^d$  is opposite to that of change of  $P^d$  and the value of elasticity is positive.

1 According to Michael Parkin: *Microeconomics*, People's Posts and Telecommunications Press in China, 2009, Chinese translation, pages 58, 59 and 62.

2 Together with the grain subsidy policy introduced in 2002 and the comprehensive agricultural subsidy policy introduced in 2006, they are collectively referred to as the four subsidies and the minimum purchase price grain policy.

$$E^d = - \frac{\frac{Q_1^d - Q_0^d}{Q_0^d}}{\frac{P_1^d - P_0^d}{P_0^d}} = - \frac{P_0^d (Q_1^d - Q_0^d)}{Q_0^d (P_1^d - P_0^d)} \quad (1)$$

Marshall, Samuelson and Nordhaus have pointed out that wheat, corn and other grain crops lack elasticity. For these necessities, consumption is slow to respond to price changes. Their judgment has also been confirmed by other scholars' research results. Some results show that the price elasticity of food demand in the USA is 0.12, others indicate 0.21 and others indicate 0.58<sup>3</sup>. Although these results are different<sup>4</sup>, they are all less than 1. In elasticity theory, one of Samuelson's and Nordhaus' contributions is that they are the first to use price elasticity of demand to explain the phenomenon that the Harvest Paradox reduces farmers' incomes on good years.

In the market equilibrium, the total income is the amount paid by the buyer of a commodity and thus obtained by the seller. It can be calculated by multiplying the price of the commodity by the sales volume. Therefore, the total income of the farmer's grain sales  $TR^s = P^d Q^d$ . Its change quantity can be calculated either by difference or by differential. For example, from point  $E_0(P_0^d, Q_0^d)$  to point  $E_1(P_1^d, Q_1^d)$  the difference formula is the following.

$$\begin{aligned} \Delta TR^s &= P_1^d Q_1^d - P_0^d Q_0^d \\ &= Q_0^d (P_1^d - P_0^d) + P_0^d (Q_1^d - Q_0^d) + (P_1^d - P_0^d)(Q_1^d - Q_0^d) \\ &\text{(The last term is small and negligible)} \\ &\approx Q_0^d (P_1^d - P_0^d) \left[ 1 + \frac{P_0^d (Q_1^d - Q_0^d)}{Q_0^d (P_1^d - P_0^d)} \right] \\ &= Q_0^d (P_1^d - P_0^d) (1 - E^d) \end{aligned} \quad (2)$$

Because of the demand price elasticity of grain  $E^d < 1$ ,

$(1 - E^d) > 0$ ,  $Q_0^d > 0$ , when  $P_1^d - P_0^d < 0$  which means

the grain price drops, according to formula (2),  $\Delta TR^s < 0$ . Samuelson and Nordhaus cited data from the US Bureau of Labor Statistics and pointed out that the continued decline in the relative prices of basic agricultural products (such as wheat, corn, soybeans, etc.) has become a major factor affecting the US agricultural economy. In the past few decades, the price of agricultural products has fallen at a rate of 2% per year relative to the general price level.<sup>5</sup> [9] Among them, the grain price has also generally shown such changes. This discovery has made people understand that the decline in grain prices relative to CPI is a long-term phenomenon and the Harvest Paradox is a long-term law, in other words, "there is a long-term relative decline in agriculture". The circumstances are basically the same not only in the United States, but also in other developed countries. The conclusion of Lu Feng and Xie Ya' research is that the actual grain price in the world market in 2007 was about 2/3 lower than that in 1957, [10] which suggests that the decline in grain prices relative to CPI may be a common phenomenon and the Harvest Paradox may be a common problem in all countries.

People may wonder since the increase in grain production will bring about a reduction in farmers' income, why should farmers adopt new varieties, introduce new technologies, work hard, and carefully manage crops to increase grain production? Mankiw believed that the answer to this question involves the nature of how competitive market works. Since each farmer is a negligible part of the grain market, he sees grain prices as established. Under the circumstances, a single farmer will believe that his income will rise only if he produces and sells more grain. However, when the vast majority of farmers work in this way, the grain supply will increase, the price will decrease, and everyone's situation will generally deteriorate. Mankiw further pointed out that agricultural technological advancement may be a bad thing for farmers because it makes farmers gradually unnecessary, but it is definitely a good thing for consumers who can buy grain at lower prices. Similarly, policies aimed at reducing the supply of agricultural products can increase the income of farmers, but at the expense of the interests of consumers. Because grain demand lacks price elasticity, increased supply will cause a decrease in income, which in turn encourages farmers to leave agriculture. [11] This view has made people understand that the government's Minimum Purchase Price Policy and restrictions on the expansion of farming area are just expedient measures, which can only meet the needs of the moment and cannot solve the problem of farmers' poverty permanently.

There are also some doubts about the Harvest Paradox. For example, Zhao Shoujun and some else think that since the birth of agriculture, the Harvest Paradox has occurred so many times, but even after people observed this phenomenon, farmers' efforts to pursue high yields have never stopped.

3 Source: Ahsan Mansur and John Whalley, "Numerical Specification of Applied General Equilibrium Models: Estimation, Calibration and Date," in Scarf and Shoven eds., *Applied General Equilibrium Analysis* (New York: Cambridge University Press, 1984), p. 109; Hendrik S. Houthakker and Lester D. Taylor, *Consumer Demand in the United States: Analysis and Projections* (Cambridge: Harvard University Press, 1970). Quoted from Michael Parkin: *Microeconomics*, People's Posts and Telecommunications Press in China, 2009, Chinese translation, p. 83; Joseph Stiglitz: *Economics* (volume 1), China Renmin University Press, 2000, Chinese translation, p. 91.

4 This may be caused by the difference in the degree of rejection of non-grain price factors when calculating the price elasticity of demand for grain. It may also indicate that the price elasticity of demand for grain is different from time to time.

5 Note that 2% is the average annual decline rate, which is almost not smaller than the average annual growth rate of the US GDP. Refer to Paul Samuelson, William Nordhaus: *Microeconomics*, People's Posts and Telecommunications Press in China, 2012, Chinese translation, p. 67.

They hold that Economics only analyzes the static results of this phenomenon at some historical point of time, but it does not examine the dynamic evolution of this phenomenon in the long history. [12] On how to solve the Harvest Paradox problem, Jiang Xusheng correctly pointed out that it is not the best policy to formulate protection prices. Only expanding demand at the same time is the fundamental way. [13]

This paper uses actual statistics from 2003 to 2014 of China's grain market to verify the western Harvest Paradox. After discovering the contradiction between the two, it does not simply negate the Harvest Paradox, but strives to tap its implicit content and clearly proposes another necessary condition that causes it to happen, understanding it from a theoretical point of view. Therefore, the topic has certain theoretical significance. There may be three contributions: First, the paper is the first special study to the phenomenon that China's grain production increase has not caused the Harvest Paradox during this period, and tries to explain the reasons; second, it quantitatively demonstrated the relative position of China's grain demand line has moved more than the supply line during this period.; third, it proposes and demonstrates that the grain supply policies such as the four subsidies and the minimum purchase price policy implemented by the Chinese government are conducive to the occurrence of the Harvest Paradox.

### 3. Situation That China's Increase of Grain Production Violates the Harvest Paradox from 2003 to 2014

In order to explain the problem more concisely, this paper only examines the changes in China's grain output and its total income. In China's various yearbooks, there are three main grain price indices: the retail price index, the production price index and the consumer price index. Referring to the method in the book *Feeding the World – An Economic History of Agriculture (1800-2000)*, [14] this paper selects the production price index. The price index from *China Yearbook of Agricultural Price Survey* is nominal, it did not be eliminated the influence of inflation and cannot reflect the real situation objectively. So, the link relative ratio of grain production price index to CPI as well as corresponding fixed base index in China was measured, and use the product of the grain production fixed base index and the production price fixed base index relative to CPI to calculate the fixed base index of farmers' total income. The grain output indices, production price indices and farmers' total income index of China from 2003 to 2014 are shown in Table 1.

**Table 1.** China's grain output index, production price index and farmers' total income index from 2003 to 2014.

Years	output			nominal production price index	CPI	production price index relative to CPI		total income index
	Absolute quantity (Ten thousand tons)	Annual growth rate (%)	Fixed base index (Year 2003 =100)	Chain index (Last year =100)	Chain index (Last year =100)	Chain index (Last year =100)	Fixed base index (Year 2003 =100)	Fixed base index (Year 2003 =100)
2003	43069.5	—	100.0	—	—	—	100.0	100.0
2004	46946.9	9.0	109.0	126.2	103.9	121.5	121.5	132.4
2005	48402.2	3.1	112.4	99.1	101.8	97.3	118.2	132.9
2006	49804.2	2.9	115.6	102.0	101.5	100.5	118.8	137.3
2007	50160.3	0.7	116.5	110.3	104.8	105.2	125.0	145.6
2008	52870.9	5.4	122.8	109.6	105.9	103.5	129.4	158.9
2009	53082.1	0.4	123.2	103.7	99.3	104.4	135.1	166.4
2010	54647.7	2.9	126.9	113.3	103.3	109.7	148.2	188.1
2011	57120.8	4.5	132.6	109.0	105.4	103.4	153.2	203.1
2012	58958.0	3.2	136.9	104.8	102.6	102.1	156.4	214.1
2013	60193.8	2.1	139.8	103.6	102.6	101.0	158.0	220.9
2014	60702.6	0.8	140.9	102.6	102.0	100.6	158.9	223.9

Note: The link relative ratio of production price index relative to CPI= The link relative ratio of nominal production price index/ The link relative ratio of CPI. Sources: The Output comes from page 453 in China Statistical Yearbook 2013 and page 385 in China Statistical Yearbook 2017. The link relative ratio of CPI comes from page 131 in China Statistical Yearbook 2017. The link relative ratio of nominal production price index comes from page 17 in China Yearbook of Agricultural Price Survey 2017.

It can be seen from Table 1 that in 2003-2014, China's grain output index increased year by year for 11 consecutive years. Overall, the total grain production fixed base index increased by 123.9% after the inflation factor was removed, which was contrary to the Harvest Paradox. And in the annual view, only one year (i.e. 2005) in the 11 years, the production price index relative to CPI decreased, but even in this year, the total income of farmers still rose for the reason that the increase in grain output (3.1%) exceeded the decline in the production price index relative to CPI (2.7%). Therefore, in the 11 years,

regardless of whether the production price index was rising or falling, the total income of farmers was always rising. This phenomenon violates the Harvest Paradox.

### 4. Reasons Analysis

Why did China's grain output increase not lead to the Harvest Paradox in 2003-2014? It is the reason that the position of the demand line moves to the upper right direction more than the supply line position to the lower right direction.

The explanatory model is shown in Figure 1.

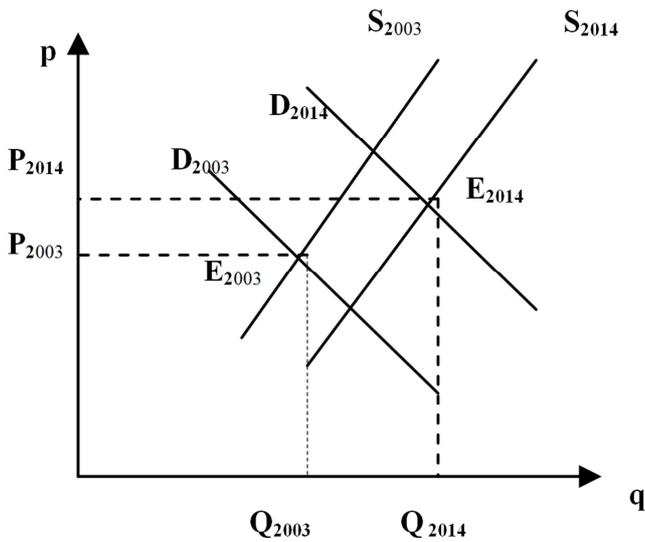


Figure 1. Changes in the equilibrium point E of China's grain market from 2003 to 2014.

In Figure 1, assume that the demand line is shifted from  $Q_{2003}^d$  in 2003 to  $Q_{2014}^d$  in 2014 by the upper right direction. The functions are  $Q_{2003}^d = -aP_{2003}^d + b_{2003}$ ,  $Q_{2014}^d = -aP_{2014}^d + b_{2014}$  respectively, and its translation distance is  $b_{2014} - b_{2003}$ . While the supply line is shifted from  $Q_{2003}^s$  to the lower right to  $Q_{2014}^s$ . The functions are  $Q_{2003}^s = cP_{2003}^s + f_{2003}$ ,  $Q_{2014}^s = cP_{2014}^s + f_{2014}$  respectively, and its translation distance is  $f_{2014} - f_{2003}$ . Besides, the translation distance of the demand line is greater than the translation distance of the supply line because  $a > 0, c > 0, b_{2014} > b_{2003}, f_{2014} > f_{2003}$ , and that is  $b_{2014} - b_{2003} > f_{2014} - f_{2003}$ . According to the equilibrium conditions of supply and demand:  $Q_t^d = Q_t^s = Q_t$ ,  $P_t^d = P_t^s = P_t$ ,  $t=2003$  or  $2014$ , then  $P_{2003} = \frac{b_{2003} - f_{2003}}{a + c}$ ,  $P_{2014} = \frac{b_{2014} - f_{2014}}{a + c}$ ;

$$Q_{2003} = \frac{af_{2003} + cb_{2003}}{a + c}, \quad Q_{2014} = \frac{af_{2014} + cb_{2014}}{a + c}$$

$$Q_{2014} - Q_{2003} = \frac{a(f_{2014} - f_{2003}) + c(b_{2014} - b_{2003})}{a + c} > 0, \quad Q_{2014} > Q_{2003};$$

$$\therefore P_{2014} - P_{2003} = \frac{(b_{2014} - b_{2003}) - (f_{2014} - f_{2003})}{a + c} > 0, \quad \therefore P_{2014} > P_{2003}$$

the total income of the grain is  $P_{2014} \times Q_{2014} > P_{2003} \times Q_{2003}$ , so the Harvest Paradox will certainly not happen.

The key assumption in Figure 1 is that the demand line translation distance is greater than the supply line. In theory, it is because the influence of the non-grain price factor that determines the position of the demand line exceeds the supply line. From 2003 to 2014, most of these non-grain price factors have changed, and some are even very significant. There are some main non-grain price factors affecting demand: (1) The per capita real disposable income of urban households increased by 154.7%, and the actual net income per capita of rural households increased by 155.7%; (2) The nominal grain consumer price index rose by 102.7%, which was lower than the 122.6% of grain, and this shows that the overall decline in grain prices relative to grain prices; (3) The proportion of per capita grain expenditure of urban and rural residents in consumer spending has declined slightly<sup>6</sup>; (4) Consumers generally expect grain prices to rise and income to increase; (5)

The number of consumers<sup>7</sup> increased by 5.8%. In terms of the magnitude of the change, except for the fourth type of factors, the first category is the largest, reaching three digits; the second category is larger, which is two digits; the third and fifth categories are smaller and remain basically unchanged. In terms of the impact of change<sup>8</sup>, the first and fifth categories will move the demand line position to the upper right direction under the condition that other factors remain unchanged, and the second and third categories will move the demand line position to the lower left direction. The impact of category 4 is uncertain.

And there are some main non-grain price factors affecting supply: (6) The nominal price index of agricultural production materials increased by 89.3%, the average total cost of three types of grain (rice, wheat, corn) increased by 183.4%, and the labor cost increased by 499.3%<sup>9</sup>. (7) The nominal production price index of agricultural products increased by 109.2%, slightly lower than 120.0% of grain, indicating that the prices of other agricultural products decreased slightly relative to grain prices; (8) The unit yield of cereals increased by 20.9%, and the planting area of grain crops increased by 8.6%<sup>10</sup>. (9) Farmers

6 Taking 2003 as the base year, the per capita grain consumption index of urban and rural residents in 2014 was 146.2, and the grain consumption price index was 103.1. The product of the two was divided by 100 to 301.8, which was the per capita grain expenditure index of urban and rural residents in that year; The urban and rural per capita consumption expenditure index is the sum of the respective population proportions and the corresponding per capita consumption (or cash consumption) expenditure. The calculated result is 11567.9 yuan, and its fixed base index is 304.9. The ratio of 301.8 to 304.9 is 0.99. Therefore, this conclusion can be drawn.

7 According to the calculation of the total population of China at end of year.

8 According to Michael Parkin, *Microeconomics*, People's Posts and Telecommunications Press in China, 2009, Chinese translation, pp. 58-59.

9 According to the data of *National Agricultural Products Cost-benefit Data Collection in China*, page 4 of 2008 volume and 2015 volume.

10 Mainly caused by scientific and technological progress and structural adjustment.

generally expect grain prices to rise; (10) The number of farmers growing grain decreased by 37.1%<sup>11</sup>. In terms of the magnitude of the change, the first category is the largest except for the fourth category; the third and fifth categories are smaller, and the second category is relatively unchanged. In terms of the impact of change<sup>12</sup>, the first and fifth categories will move the supply line position to the upper left direction under the condition that other factors remain unchanged, and the second type basically does not affected. The third and fourth categories move the supply line position to the lower right direction.

Due to the limitations of data and methods, it is difficult to calculate the respective impacts of the above-mentioned 10 categories of non-grain price factors on the positional changes of these two lines. Their combined impacts on the movement range of the grain demand line and the supply line position are more important. The number of transactions in China's grain market was calculated by the algorithm that the amount of transactions in China's grain market equals the sum of imports and domestic production in 2003 and 2014. On this basis, their respective growth rates were calculated also during this period. Detailed data is shown in Table 2.

**Table 2.** Number of transactions in China's grain market in 2003 and 2014  
Unit: 10,000 tons.

	Import	Domestic Production	transactions
2003	2282.0	43069.5	45351.5
2014	7796.0	60702.6	68498.6
Growth rate (%)	241.6	40.9	51.0

Note: According to the usual practice, the grain size of import and export is grain and grain flour and soybean, which are not completely consistent with the production grain.

Source: Imports are from table 18-8 of Volume 2004, p.369 of Volume 2015 in *China Statistical Yearbook*.

Referring to Jeffrey M. Perloff's point of view, [15] the number of demand is considered to be the amount of grain actually purchased by the consumer, and the quantity supplied is the amount of grain actually sold by the farmers. Thus, the volume of grain market transactions in Table 2 is both the quantity of grain demand and the quantity of grain supplied. According to the demand function and the supply function, the change in the quantity of grain demand and the quantity of supply<sup>13</sup> are the result of the impact combination of changes in grain price and changes in non-grain prices. From 2003 to 2014, China's grain demand volume increased by 51.0%. How many of these are caused by changes in non-grain price factors, namely the movement of demand lines? The supply volume has also increased by 51.0%. How many of these are caused by changes in non-grain price factors, that is, the movement of supply lines? Both can be obtained by eliminating the impact of changes in grain prices. As can be seen from Table 1, the grain production price index relative to CPI increased by 58.9% during this period. According to the demand theorem, it

should reduce the demand for grain; according to the supply theorem, it should increase the supply of grain. Therefore, in order to eliminate the impact of changes in the grain price, the relative position of the demand line should move more than 51.0% in the upper right direction, and the relative position of the supply line should move less than 51.0% in the lower right direction. This shows that the assumptions in Figure 1 are consistent with the actual changes in China's grain market.

During this period, the four subsidies and the minimum purchase price of grain supply policies implemented by the Chinese government have significant effects. Using the supply and demand theorem, they all have an impact on the equilibrium quantity including production and equilibrium price mainly through the effect on non-grain price factors. For example, the implementation of the four subsidies has reduced the price of inputs for grain and agriculture, and promoted the cultivation of crops, harvesting and management technologies and even labor productivity. The implementation of the minimum purchase price policy has alleviated the concerns of farmers on the decline in grain prices. And this enhances the farm's expectations of the rising grain prices<sup>14</sup> and help crops planting area increased. Through these changes in non-grain prices, these two policies move the supply line position to the lower right, resulting in an equilibrium quantity including increased production and a balanced price reduction<sup>15</sup>. The results are included in the above two paragraphs. However, due to the demand factors including the impact of demand policies, the grain price has risen, and thus the increase has exceeded the reduction caused by these two supply policies. Therefore, the overall result is that the equilibrium quantity includes the output increase, the balanced grain prices rise, and the total income of farmers has certainly increased. This is also an important reason why the per capita net income of rural households in China has increased more than the per capita disposable income of urban households and the income gap between urban and rural residents has narrowed. But does this mean that the Harvest Paradox in the West is not convinced by China? In order to clarify this issue, it is necessary to explore the conditions for the occurrence of the Harvest Paradox.

## 5. Another Condition for the Occurrence of the Harvest Paradox

What is the condition for the Harvest Paradox? Samuelson and Nordhaus believe that the answer lies in the lack of price elasticity of demand for agricultural products<sup>16</sup>. The

14 This is an important reason why the Chinese government has chosen to announce the minimum purchase price policy before the preparation of the crops. In fact, the minimum purchase price policy will only play its role in promoting the increase of grain and farmers' income before it is announced before the preparation of the cropping season, and it will be enhanced as long as it is released before the preparation, but whether it is implemented or not, it will have the effect of enhancing the expected and even rising grain prices of grain farmers.

15 See Joseph Stiglitz: *Economics (Volume 1)*, China Renmin University Press, 2000, Chinese translation, pp. 77-78.

16 This paper also assumes that China's grain demand elasticity is less than 1 from

11 Assume a reduction in the same number of employment as the primary industry.

12 According to Michael Parkin, *Microeconomics*, People's Posts and Telecommunications Press in China, 2009, Chinese translation, p. 62.

13 This paper follows the concept of supply and demand in microeconomics, paying attention to the difference between supply and demand.

phenomenon that the Harvest Paradox was not affected by the increase in China's grain production from 2003 to 2014 shows that this answer does not apply to all situations. It implies other conditions which require us to understand and comprehend. Zhou Jian has clearly pointed out that another necessary condition for the occurrence of the Harvest Paradox is that the position of the supply line moves significantly, and the position of the demand line remains basically unchanged. [16] In other words, it must be ensured that the original equilibrium point  $E_0$  and the new equilibrium point  $E_1$  are on the same demand line, as shown in Figure 2. Only in this case, the demand price arc elasticity of the line segment  $E_0E_1$  can be calculated according to the formula (1), so that the formula (2) can be used, that is, the demand price arc elasticity of the  $E_0E_1$  is used to calculate the variation  $\Delta TR^s$  of the grain total income sold by farmers. Otherwise, the position of the demand line moves significantly. As shown in Figure 1, the two equilibrium points are not on the same demand line, and the demand price arc elasticity of the line segment  $E_{2003}E_{2014}$  cannot be calculated. In this case, the formula (2) cannot be used to calculate the change  $\Delta TR^s$  of the grain total income sold by farmers. Therefore, you can see that whether it is a domestic or foreign textbook or a research article, when you talk about the content of the Harvest Paradox, its graphic style is generally shown in Figure 2.

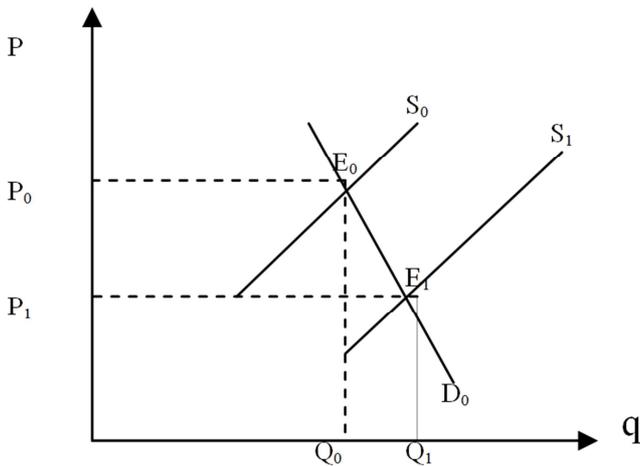


Figure 2. Another condition for the Harvest Paradox.

It is this highly simplified model that has led many people to think that as long as the price elasticity of demand for grain is less than 1, it will ensure that the increase in grain production will lead to a decline in grain prices and Harvest Paradox. However, changes in China's grain market from 2003 to 2014 indicate that this understanding is not perfect. In fact, Figure 2 is just an abstract theoretical model that captures the main contradictions, reflects the nature of the problem, and helps people understand the profound truth. However, if people ignore the implied conditions and do not understand the use of it to explain the real world, it is also prone to

2003 to 2014. Due to space limitations, this prove of hypothesis may discussed in another article.

errors<sup>17</sup>.

Farmers are producers and suppliers of grain. Their grain supply line  $S$  reflects the relationship between the supply price  $P^s$  of the grain and the quantity  $Q^s$  supplied by the farmers under the premise that the non-grain price factors remain unchanged. The total income of the farmer's grain sales  $TR^s = P^s Q^s$ , which is supply price  $P^s$  multiplied by supply quantity  $Q^s$ . That is, the abscissa  $Q^s$  is multiplied by the ordinate  $P^s$  on each point of the supply line, according to the footnote 2 on this page<sup>18</sup>, the amount of change  $\Delta TR^s$  is only directly related to the supply price elasticity  $E^s$ ; while the residents are grain consumers, their grain demand line  $D$  reflects the correspondence between the demand price  $P^d$  and the demand quantity  $Q^d$  of the grain under the premise of non-grain price factors. The total expenditure  $TE^d$  of the consumer's purchase of grain is equal to  $P^d Q^d$ , the demand price  $P^d$  of the grain multiplied by its demand quantity  $Q^d$ , that is, the product of the abscissa  $Q^d$  and the ordinate  $P^d$  of each point on the demand line, the amount of change should be recorded as  $\Delta TE^d$  to show the difference, with reference to formula (2), which is directly related to the demand price elasticity  $E^d$ . Only when the supply and demand in the grain market are balanced, as shown in  $E_0$  and  $E_1$  in Figure 2, because  $P^s = P^d$ ,  $Q^s = Q^d$ , that is,  $TR^s = P^s Q^s = P^d Q^d = TE^d$ . In this case, if the position of the demand line does not change, the position of the supply line changes significantly, that is, the two equilibrium points  $E_0$  and  $E_1$  are on the same demand line. Then, from the equilibrium point  $E_0$  to  $E_1$ , the change in the total income of the farmers selling grain is equal to the change in the total expenditure of the grain purchased by the residents, that is,  $\Delta TR^s = \Delta TE^d = \Delta(P^d Q^d)$ . Therefore, the amount of change in the total income of the farmers  $\Delta TR^s$  is related to the demand price elasticity  $E^d$ , and can be measured by the formula (2), so the Harvest Paradox is generated.

Although in Figure 1, the demand price elasticity of the equilibrium points  $E_{2003}$  on the grain demand line  $D_{2003}$  and  $E_{2014}$  on the grain demand line  $D_{2014}$  are still less than 1, but the two equilibrium points  $E_{2003}$  and  $E_{2014}$  are not on the same demand line. Therefore, the change of total income of farmers selling grain  $\Delta TR^s$  cannot be measured by the demand price elasticity  $E^d$  and the formula (2). Marshall's concept of demand price elasticity refers to the percentage change in the quantity of demand caused by a specific change in demand price (usually set to 1%) under the condition that other influencing factors remain unchanged. However, in the real world, other influencing factors are almost impossible to remain unchanged.

17 Such mistakes are common in newspapers, such as a paper by Sun Xiaosu [17] published in the "Journal of Lanzhou Business School".

18 assuming that the supply function is  $Q^s=f(P^s)$ , where  $Q^s$  represents the supply quantity and  $P^s$  represents the supply price, one of the calculation formulas of the supply price arc elasticity from point  $E_0(P_0^s, Q_0^s)$  to point  $E_1(P_1^s, Q_1^s)$  is  $E^s = \frac{P_0^s(Q_1^s - Q_0^s)}{Q_0^s(P_1^s - P_0^s)}$ , the change amount of the total income  $\Delta TR^s = P_1^s Q_1^s - P_0^s Q_0^s = Q_0^s(P_1^s - P_0^s) + P_0^s(Q_1^s - Q_0^s) + (P_1^s - P_0^s)(Q_1^s - Q_0^s) \approx Q_0^s(P_1^s - P_0^s)(1 + E^s)$ . It can be seen that the value of  $E^s$  is always greater than 0. So as long as  $\Delta P^s$  is greater than 0, there must be  $\Delta TR^s > 0$ , which means that the total income and the supply price change direction are always consistent, regardless of whether  $E^s$  is greater than 1. Please note the difference between it and formula (2).

In terms of the effects of grain supply policies such as the four subsidies and the minimum purchase price implemented by the Chinese government during this period, it has increased the movement of the supply line to the lower right, which has little effect on the demand line position, and thus will not stop the Harvest Paradox. And it will increase its probability of occurrence<sup>19</sup>. At this time, if the comprehensive impact of non-grain price factors on grain demand is small or even zero, the Harvest Paradox will inevitably occur. The above situation is shown in Figure 2. Not only that, but we also believe that in the real environment of non-grain price factors such as residents' income, related commodity prices, consumer preference for food, food price expectations and number of people, keeping the demand line position unchanged is another condition. The requirements are too strict, and can be relaxed as: the movement amplitude of the demand line position in the upper right direction is significantly smaller<sup>20</sup> than that of the supply line position in the lower right direction, and can be neglected. In this way, the applicability of the harvest paradox is even stronger.

From this point of view, China's grain production from 2003 to 2014 has not caused occurrence of the Harvest Paradox, not because China's grain market is special, but because the demand line has moved, and further, the fundamental reason is its movement in the upper right direction. The movement of the supply line in the lower right direction is exceeded. If this happens in other countries, the result will be the same. For example, this happened in US agriculture in 2007<sup>21</sup>.

## 6. Discussion

Does the phenomenon that China's grain production increase did not lead to a Harvest Paradox from 2003 to 2014 indicate that the Harvest Paradox is wrong? This conclusion may not be reached. Because many countries have experienced increasing agricultural production and grain prices, such as the United States in 2007 and Japan in 1981–1984. However, from the long-term situation after the "World War II" in these countries, the grain price relative to CPI is declining, and the Harvest Paradox is correct. Therefore, the proportion of their agricultural added value is decreasing, and the agricultural labor force is shifting outwards. China will certainly do the same. This may indicate that although the Harvest Paradox is not an inevitable law, it has a long-term

19 In contrast, the Chinese government's policy of expanding grain demand will increase the movement of the grain demand curve in the upper right direction, but has little effect on the supply curve position, so prevent the occurrence of Harvest Paradox. From 2003 to 2014, an important reason why China's grain market did not have Harvest Paradox was that demand policy played a greater role than supply policy.

20 That is, the decrease in the equilibrium price can be exceeded by the decrease in the equilibrium quantity. See Wang Xiangchun, *Microeconomics*, Dongbei University of Finance and Economics Press, 2002, pp. 154–155.

21 According to the data of *International Statistical Yearbook in China*, 2013 volume, the year 2005 is the base year, the US agricultural production index was 98.1 in 2006, the price index of CPI agricultural product is 95.6; in 2007, the two indices were 101.9 and 114.0.

trend. Thus, the issues that need to be discussed are:

First, due to the existence of the Harvest Paradox, "Good years and big harvests (large Q) have reduced farmers' incomes (low PQ)", [18] "Is the good news of agriculture bad news for farmers?" [19] This means that the problem of increasing agricultural production and the problem of increasing farmers' income are often antagonistic. It inspires us that it is difficult to solve the problem of increasing agricultural production and increasing farmers' incomes by relying solely on supply policies. The win-win situation in China's grain production increase and farmer's income increase from 2003 to 2014 is the result of supply and demand factors including policies which happened coincidentally.

Second, regarding China's four grain subsidy policies, they have undoubtedly played a key role in increasing grain production, increasing grain labor productivity, stabilizing grain prices, curbing inflation, and safeguarding consumer welfare, especially in reducing agriculture expenditures. However, they don't ensure an increase in the total income of agriculture. Even worse is, they also often lead to Harvest Paradox and the decline in the total income of farmers. That is to say, these policies are definitely good policies to promote grain production and safeguard consumer welfare. But it is not necessarily to improve the efficiency of growing grain and increase the income of farmers. Compared with the grain supply line, when there is a small change in the position of the demand line, that is, when the Harvest Paradox occurs, it may not be; if there is a big change in the demand line position, such as the situation in China from 2003 to 2014, it may be good. To ensure increase of farmers' total grain income, the government should adopt policies to move the demand line to the upper right.

## 7. Conclusions

In summary, from 2003 to 2014, for the Chinese grain market, the research conclusions can be summarized as follows.

First, the Harvest Paradox put forward by Samuelson and Nordhaus is not correct, whether it is from the overall perspective or the annual survey; the consequences of Mankiw's point of view - encouraging people to leave agriculture, which is consistent with the actual situation. The view that the increase in grain production will bring about a decline in grain prices and the inevitable occurrence of the Harvest Paradox [17] cannot withstand the facts.

Second, the price elasticity of grain demand is less than 1 is not a necessary and sufficient condition for the occurrence of the Harvest Paradox, but a necessary condition. Another necessary condition is that the amplitude of the demand line position moving to the upper right direction is significantly smaller or even negligible compared to the movement amplitude of the supply line position in the lower right direction. That is to say, compared with the change in the comprehensive impact of the non-grain price factors that determine the location of the grain supply line, the change in the comprehensive impact of the non-grain price factors that

determine the position of the grain demand line is significantly smaller. Only when the two necessary conditions are in place at the same time can the Harvest Paradox be ensured.

Third, the grain supply policies such as the four subsidies and the minimum purchase price implemented by the Chinese government have increased the movement range of the supply line to the lower right, which has little effect on the demand line position, and is actually conducive to the occurrence of the Harvest Paradox. However, due to the demand factors in the same period, including the greater impact of demand policy on grain demand, the reality cannot be achieved.

Fourth, the main reason for the increase in farmers' income from grain production is the price increase of grain. The fundamental reason for the price increase of grain is the comprehensive impact of non-grain price factors that determine the demand for grain and the location of the supply line. It is closely related to the expansion of grain demand policies adopted by the Chinese government in the same period, such as raising residents' income and improving income distribution. However, it has little to do with grain supply policies such as four subsidies policy, and the correlation with the minimum purchase price grain supply policy may not be significant<sup>22</sup>.

If the viewpoint of this paper is correct, after negating the conclusion that the Harvest Paradox is an inevitable law, the question that needs further study is its scientific nature. That is, is the harvest paradox a long-term trend phenomenon or a short-term probability phenomenon? This problem has been clarified, which helps scholars to consider whether to incorporate it into the theory of elasticity, or to propose targeted policies for the simultaneous increase of agricultural production and the increase of farmers' income. To this end, more historical data on agricultural conditions in the United States should be collected and using it as an example to study this issue. In doing so, the persuasive power may be stronger.

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22 With respect to the impact of the minimum purchase price policy on the income of farmers and grain production should be combined with the effect of reducing the income due to the Harvest Paradox and the increase in income due to actual purchases. During this period, the Chinese government used the lowest purchase price to purchase the most grain in 2006, with a purchase volume of 4,900,000 tons, accounting for 10.0% of the total domestic grain production that year; in 2014, the purchase volume dropped significantly.