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Study on the influencing factors of wheat import trade in China

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중국 밀 수입무역의 영향요인 연구

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Abstract Wheat is one of the three major food crops in China, and wheat production plays an important role in people's lives and industrial development. China is the world's largest consumer of products and also a leading wheat trading country. However, the production of low-quality wheat in some regions, large trade deficit, and excessive concentration of import sources have troubled the development of China's wheat industry. In this study, the import trade pattern of wheat was studied, and the gravity model of trade and Poisson pseudo-maximum likelihood (PPML) estimator were used to conduct an empirical analysis on the factors influencing wheat import trade. From 2010 to 2020, China gradually formed an import pattern mainly involving Australia and Canada and supplemented by the United States, France, and Kazakhstan. Mexico, Argentina, and other countries gradually withdrew from trading wheat with China. Among the factors affecting China's wheat import trade, China's per capita GDP and total imports, geographical distance, current GDP of exported countries, and last year's wheat output have a significant impact. In addition, climate factors also had a significant impact on China's wheat imports.

요 약 밀은 중국의 3대 주요 식량 작물 중 하나로, 밀 생산은 사람들의 삶과 산업 발전에 중요한 역할을 했다. 또한, 중국은 세계 최대 밀 소비국가일 뿐만 아니라 세계 최대 밀 무역 국가이다. 일부 지역의 밀 생산 질이 낮고 무역적자가 커 수입원이 지나치게 집중된 것도 중국 밀 산업의 발전을 가로막고 있다. 밀의 수입 무역 패턴을 연구하고 분석하고자 국제무역의 중력 모델(Gravity model of trade)을 선택하고, PPML분석(Poisson pseudo-maximum likelihood) 추정량을 사용하여 밀 수입 무역의 영향 요인에 대한 경험적 분석을 수행하였다. 2010년부터 2020년까지, 중국은 점차 호주와 캐나다를 중심으로 한 수입 관계를 형성했고 미국, 프랑스, 카자흐스탄이 추가되었다. 멕시코, 아르헨티나, 그리고 다른 나라들은 중국과의 밀 무역에서 점차 철수했다. 중국 밀 수입 무역에 영향을 미치는 요인 가운데 중국의 1인당 국내총생산(GDP)과 총수입량, 지리적 거리, 수출국의 현재 국내총생산(GDP), 지난해 밀 생산량 등이 중국 밀 수입에 큰 영향을 미치고 있다. 게다가, 기후 요인 또한 중국의 밀 수입에 중요한 영향을 미친다.

Keywords : China's Wheat Trade, Import Trade Pattern, Influencing Factors of Wheat Import Trade, Gravity Model of Trade, Poisson Pseudo-Maximum Likelihood

1. Introduction

China is a major producer and consumer of wheat in the world as well as a major wheat importer. For a long time, China has been a net importer of wheat in most years with very little export volume. As China attaches importance to grain production in recent years, the production

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and quality of wheat have improved year by year. Fig. 1 showed the change of total production, total consumption, per capita production, and per captia consumption by calculating from Brick Agricultural Database and World Bank. As seen from the trend chart, total production of China's wheat had fluctuated greatly since the year of 1992. The change in wheat production could be roughly divided into four stages: (1) From 1992 to 2003, the overall trend of wheat production was on the rise, increasing to 123,289,000 tonnes in 1997; (2) From 1997 to 2003, the wheat production in China decreased to 86,488,000 tonnes in 2003, with an obvious downward trend; (3) Total production of wheat rose sharply between 2003 and 2006; (4) From 2006 to 2020, China's total wheat production continued to increase steadily although it suddenly declined in 2018, but began to rise again in 2019. The specific algorithm of total wheat consumption is as follows: China's wheat consumption = initial stocks + domestic production + wheat imports - wheat exports - ending stocks. The consumption of wheat had generally increased since the 1990s. From 1992 to 1997, the consumption of wheat increased gradually. From 1998 to 2005, the consumption of wheat decreased gradually. From 2005 to 2011, wheat consumption gradually increased. After 2011, wheat consumption fluctuated until 2020, when it jumped to 165,000,000 tonnes.

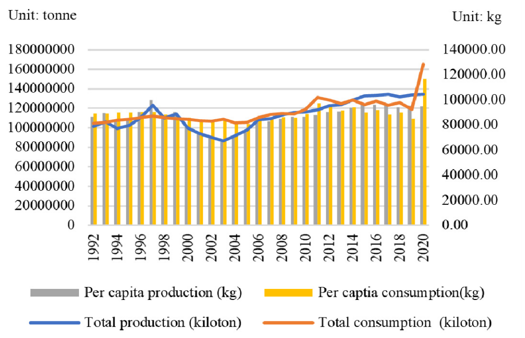

Fig. 1. Changes in production and consumption for wheat from 1992 to 2020.

However, China's volume of wheat imports have increased in recent years. This is because that residents' food demand structure changed and high-quality wheat supply was insufficient with the improvement of the national income level. Imported wheat accounted for about 2~3% of China's total wheat consumption of late years. The import of wheat was mainly high-end high-quality which was used to adjust the surplus and shortage of varieties and met the increasing diversified consumer demand of residents. Fig. 2 displayed the data of wheat consumption structure which was calculated base on Brick Agricultural Databases. China's wheat consumption mainly includes flour, wheat bran, industrial consumption, seed consumption, and wastage. The consumption of wheat flour, which excludes the consumption of wheat industrial processing, showed a declining trend in general, with a sharp drop to 46.36% in 2020. Bran consumption fluctuated until it dropped to 16.18 percent in 2020. Feed consumption fluctuated irregularly, but showed an overall upward trend with an extra high proportion in three years (13.73% in 2011, 11.29% in 2012, and 27.27% in 2020). The proportion of planting consumption also exhibited a downward trend from 6.89% in 1991 to 3.03% in 2020, indicating the improvement of wheat planting production efficiency. The proportion of wheat loss increased from 0.79% in 1991 to 1.94% in 2019. By 2020, it had dropped sharply to 1.21%.

Fig. 3 demonstrated proportion of flour consumption structure from 2013 to 2019 (Ma, 2020) [1]. Flour consumption is on the decline, but consumption of catering and baking continues to increase. In particular, wheat for baking consumption tends to be high gluten wheat which planted in China is insufficient for market.

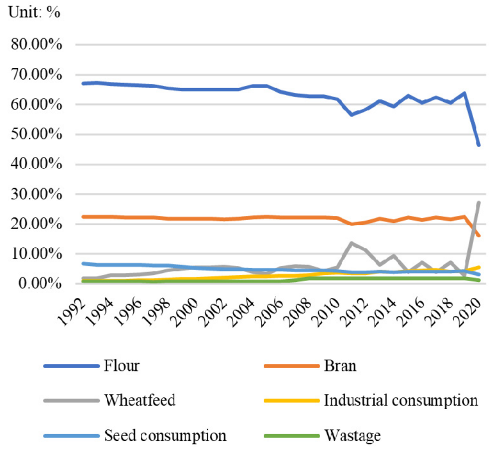

Fig. 2. Changes in the proportion of wheat consumption structure from 1992 to 2020.

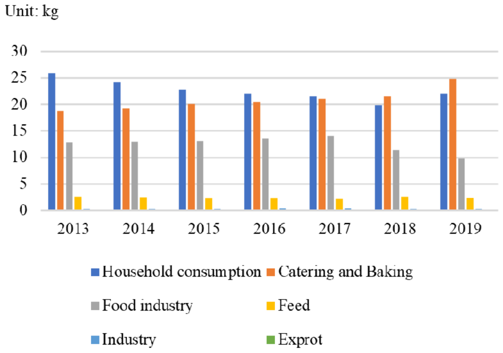

Fig. 3. Changes in the proportion of flour consumption structure from 2013 to 2019

In terms of total trade volume China's wheat imports showed a growing trend amid fluctuations. In 2019, China's wheat imports totaled 3,200,000 tonnes, up 11.43% from 2018. However, in 2020, China imported a record 8,380,000 tonnes of wheat up 140.2% from the previous year and equivalent to 87% of the annual quota of 9,640,000 tonnes. There are 88 countries exporting wheat in the world. However, more than 90% of China's wheat imports are concentrated in Canada, Australia, France, Kazakhstan, and the United States, with the concentrated distribution of channels and limited import sources. Canada has always been China's largest wheat importer due to its low price, high quality, and obvious advantages. However, because of the close relationship between Canada and the United States, Canada's internal affairs have been greatly influenced by the United States and there will be a high risk if China imports wheat excessively from the Canadian market.

Under the current international trade pattern, it is of great significance to analyze the rationality of China's wheat import structure and influencing factors of import to stabilize China's food market and ensure food security.

The gravity model of trade is often used in the research and application of international agricultural trade. Zhang et al. (2020) used the expanded gravity model to analyze China's agricultural export potential to BRICS countries from the perspective of trade facilitation [2]. Liu (2019) based on the gravity model, the trade potential of China's import of Brazilian soybeans were analyzed [3]. Zhang et al. (2020) used the stochastic frontier gravity model to divide variables into basic variables and trade inefficiencies and conducted regression analysis at the same time to study the influencing factors of China's soybean import trade [4]. Peng et al. (2021) empirically studied the wheat trade between China and the United States, Canada, Australia, Russia, and Kazakhstan based on the trade gravity model [5].

Although some scholars had studied the influencing factors of China's wheat import trade, the linear model is used to analyze the results. In addition, there are gaps in the research on the impact of climate factors on import trade. Therefore, in this study, the import trade pattern of wheat was studied and analyzed, and the gravity model of trade was selected and Poisson pseudo-maximum likelihood (PPML) estimator was used to conduct an empirical analysis of the influencing factors of wheat import value so as to provide effective suggestions for the stability and security of China's wheat market.

2. Current situation of China's wheat import

2.1 China's total wheat imports

China's wheat trade volume and trade volume showed wavy changes and the total import of wheat far exceeded the total export of wheat. During the period from 1992 to 1996, China's wheat supply was in short supply and a large amount of wheat imports were needed. From 1996 to 2003, China was able to be self-sufficient in wheat. During this period the import volume fell sharply. In 2003, China imported only 424,000 tonnes of wheat, while exports increased again during the same period. In the context of decreasing domestic grain supply, the import volume increased significantly to 7,232,883 tonnes in 2004, and the import volume also exceeded 1.5 billion US dollars. At the same time, the state strongly made policies to support food production and the domestic grain supply relationship has significantly improved. Since 2005, China's wheat imports had been sharply reduced again. until 2008, China's wheat imports were only 43,100 tonnes. With the onset of the global financial crisis in 2008, agricultural prices fell sharply, while low temperatures and rainfall hit China's wheat crop in 2009, leading to a shortage of high-quality wheat in the country. Since the second half of 2010, global wheat production had decreased and China's wheat imports continued to rise. In 2012, China imported 3,688,617 tonnes of wheat. Wheat prices fell in 2013 as weather recovered in many wheat exporting countries and global grain production hit a new high. At the same time, China's wheat imports reached 5,506,712 tonnes in 2013 due to the decline in yield and quality caused by climate. Global wheat production remained stable from 2014 to 2017. In 2016, China's domestic wheat was affected by weather, which reduced the quality of wheat. At the same time, global wheat prices continued to decline, so China increased the import of wheat in 2017. Wheat imports had been increasing since 2018. China actually produced surplus wheat, but still need to imports it. China has already facing a food security problem with poor quality grain production after years of increased production.

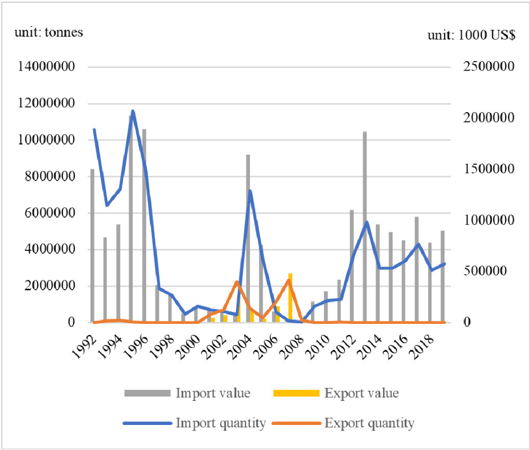

Fig. 4. China's total wheat imports

2.2 China's wheat import trade structure

The top four countries of china's wheat import between 1992 and 2020 were shown in Table 1 ~ Table 3. It could be seen that China's main source of wheat imports had undergone a total of three stages of change. The first phase was the year 1992-1999. As shown in Table 1, during this period, China's wheat import pattern was "Canada, the United States, Australia and France", forming a pattern dominated by Canada, supplemented by the United States and Australia, with France, Argentina, and Turkey as major importers of other wheat sources.

Table 1. Main source countries of China's wheat imports from 1992 to 1999.

Year	Country	Ratio	Country	Ratio	Country	Ratio	Country	Ratio
1992	CAN	56.36%	USA	29.75%	FRA	11.32%	AUS	2.39%
1993	CAN	49.39%	USA	36.50%	AUS	10.82%	ARG	1.41%
1994	CAN	49.37%	USA	29.27%	AUS	20.98%	TUR	0.37%
1995	CAN	42.88%	USA	33.51%	AUS	3.74%	ARG	2.09%
1996	CAN	42.52%	AUS	28.60%	USA	26.59%	FRA	2.28%
1997	CAN	70.04%	AUS	14.39%	ARG	1.18%	USA	11.17%
1998	CAN	64.55%	USA	20.78%	AUS	14.30%	ZA1	0.36%
1999	USA	34.44%	CAN	24.44%	AUS	24.05%	FRA	17.05%

ARG: Argentina; AUS: Australia; CAN: Canada; FRA: France; TUR: Turkey; USA: United State of America; ZA1: African country.

The second phase is the year 2000-2009. As shown in Table 2, at this stage, Australia's wheat export share to China increased, while the proportion of China's wheat import from Canada decreased, and the United States, Australia, and Canada alternately occupied the dominant position. In addition, China had started importing wheat from Mexico, but Mexico accounted for an extremely small proportion of trade of China's wheat. Other sources of imports were France and Britain. Argentina pulled out of wheat imports to China.

Table 2. Main source countries of China's wheat imports from 2000 to 2009.

Year	Country	Ratio	Country	Ratio	Country	Ratio	Country	Ratio
2000	CAN	70.41%	USA	18.69%	AUS	10.90%	MEX	0.00%
2001	CAN	58.23%	USA	34.51%	AUS	6.23%	UK	1.03%
2002	CAN	62.41%	USA	27.47%	AUS	10.12%	MEX	0.00%
2003	USA	51.19%	CAN	47.10%	AUS	1.70%	MEX	0.00%
2004	USA	39.52%	CAN	36.96%	AUS	22.18%	FRA	1.34%
2005	CAN	44.45%	AUS	26.34%	FRA	15.61%	USA	13.60%
2006	AUS	51.39%	USA	31.01%	CAN	17.60%	MEX	0.00%
2007	CAN	51.41%	USA	22.67%	AUS	25.92%	Others	0.00%
2008	AUS	96.77%	USA	3.23%	PAK	0.00%	MEX	0.00%
2009	USA	44.45%	AUS	36.05%	CAN	15.26%	UK	4.24%

AUS: Australia; CAN: Canada; FRA: France; MEX: Mexico; PAK: Pakistan; TUR: Turkey; UK: United Kindom; USA: United State of America; ZA1: African country.

The third phase is the year 2010-2020. As shown in Table 3, during this period, China gradually formed a wheat import structure dominated by Australia and Canada, followed by the United States and France. In addition, Kazakhstan had become China's fourth-largest source of wheat imports due to its competitive advantage in wheat. In 2018, the import share reached the highest at 12.78%.

Table 3. Main source countries of China's wheat imports from 2010 to 2020.

Year	Country	Ratio	Country	Ratio	Country	Ratio	Country	Ratio
2010	AUS	61.86%	CAN	25.16%	USA	10.14%	KAZ	2.83%
2011	AUS	46.89%	USA	37.60%	CAN	15.26%	KAZ	0.25%
2012	AUS	60.36%	USA	21.20%	CAN	14.01%	KAZ	4.00%
2013	USA	67.72%	CAN	17.69%	AUS	11.27%	FRA	1.87%
2014	AUS	46.63%	USA	29.49%	CAN	14.79%	KAZ	7.31%
2015	AUS	40.69%	CAN	35.18%	USA	20.88%	KAZ	3.12%
2016	AUS	40.43%	CAN	26.88%	USA	25.97%	KAZ	6.71%
2017	AUS	40.70%	USA	37.75%	CAN	15.24%	KAZ	5.47%
2018	CAN	53.52%	AUS	17.16%	USA	14.47%	KAZ	12.78%
2019	CAN	54.90%	FRA	14.46%	KAZ	10.01%	USA	7.48%
2020	CAN	28.97%	FRA	27.82%	USA	20.55%	AUS	15.91%

AUS: Australia; CAN: Canada; FRA: France; KAZ: Kazakhstan; USA: United State of America.

3. Materials and Methods

3.1 Gravity model of trade

The idea and concept of gravity model originated from the law of universal gravitation proposed by Newton in physics: the mutual gravitation between two objects is proportional to the mass size of two objects, and the distance between two objects is inversely proportional to as early as in the early 1950s, Isard&Peck (1954) and Beckerman (1956) intuitively found that the more geographically close countries are, the larger the scale of trade flows will be is generally believed that Tinbergen (1962) and Poyhonen (1963) were the first to use a gravity model to study international trade [6-9]. They independently used the gravity model to study bilateral trade flows and obtained the same result: the scale of bilateral trade of two countries is directly proportional to their economic aggregate and inversely proportional to the distance between the two countries. Lineman (1966) added the population variable into the gravity model and believed that the trade scale between two countries was also related to population, and the number of population was positively correlated with the trade scale [10]. Berstrand (1989) went further and replaced the population index with per capita income [11]. Due to the high availability and reliability of the data required by the gravity model, the gravity model of trade has been widely used and has become the main empirical research tool of international trade flow.

Starting in the late 1970s, economists began to find the theoretical basis for a gravity model of trade. Anderson (1979) took the lead in deriving the gravity equation under the assumption of product difference [12]. Bergstrand (1985, 1989) theoretically discussed the determinants of bilateral trade by using the trade gravity model under the framework of the simple monopolistic competition model [11,13]. Flam and Helpman (1987) revised the gravity model in the framework of differential products with economies of scale [14]. Deardorff (1998) synthesized these theoretical derivations and argued that gravity models embody many of the characteristics of models and can be derived from standard trade theory [15]. Anderson and Wincoop (2001) derived a gravity model with strong operability on the basis of the invariant substitution elastic expenditure system [16]. These theories not only provided theoretical support for the trade gravity model but also helped to explain various problems. And differences in the empirical application results made the trade gravity model gradually get rid of the long-standing doubt of lack of theoretical basis.

The original gravity model is:

Where, F_{ij} represents volume of trade from country i to country j; M_i, M_j represent GDP of country i and country j respectively; D_{ij} represents the distance between two countries; η_{ij} represents the error term where the expectation is equal to 1.

Take the logarithm of both sides of Formula 1 to obtain the logarithm model:

$$\ln(F_{ij}) = \beta_0 + \beta_1 \ln(M_i) + \beta_2 \ln(M_j) - \beta_3 \ln(D_{ij}) + \varepsilon_{ij} \tag{2}$$

3.2 Poisson pseudo-maximum likelihood (PPML) estimator

There are two main problems with this approach of formula (2). It clearly cannot be use when trade flow equals to zero. And as Silva et al. (2006) believed estimation of a log-linearized equations by OLS may result in significant deviations if researchers consider the parameters of the real model to be nonlinear [17]. As an alternative, Poisson pseudo-maximum likelihood (PPML) estimator based on the Poisson model was used for estimation:

$$F_{ij} = \exp[\beta_0 + \beta_1 \ln(M_i) + \beta_2 \ln(M_j) - \beta_3 \ln(D_{ij})]\eta_{ij} \tag{3}$$

There were pieces of evidence that showed that a large portion of the international trade matrix consists of zero trade. Haveman and Hummels (2004) finded that about one-third of the bilateral trade matrix was missing [18]. Helpman et al. (2008) finded that about half of the country pairs in their sample did not trade with each other at all [19]. What happens if bilateral trade between countries is zero and we estimate them using a conventional Log-linear model? Taking logarithms of such observations effectively drops them from the sample as log(0) is undefined. Dropping these observations causes a reduction of observations. Which also causes loss of information. Moreover, using truncated samples in logarithms may yield misleading results. The solution to the zero trade problem could be sought in the PPML estimator. Silva et al. (2006) suggested that PPML could be a solution to the problem tzero trade [17]. They also highlighted that the PPML estimator is a robust approach in the presence of heteroskedasticity. This method also could be applied on the levels of trade thus estimating directly the non-linear form of the gravity model and avoiding dropping zero trade. The dependent variable is the traded value not log, whereas, the explanatory variables are still in log forms.

Since some values of trade volume in the data was equal to 0, PPML estimators were used in this paper. Model (4) was established based on the gravity model of trade, introducing variables of the t-1 year of Chinese wheat production, t-1 year of importing countries wheat production, Chinese total wheat import volume, the coastal states of importing countries, exchange rate, average temperature, and precipitation of importing countries.

$$\begin{aligned} value_{ijt} = & \beta_0 + \beta_1 \ln gdp_{it} + \beta_2 \ln gdp_{jt} \\ & + \beta_3 \ln D_{ij} + \beta_4 \ln q_{jt-1} + \beta_5 \ln m_{it} \\ & + \beta_6 tem_{jt} + \beta_7 rain_{jt} + \varepsilon_{ijt} \end{aligned} \quad (4)$$

Where,

i denotes the country that imports wheat, China, in the case of this study;

j denotes exported countries that export wheat to China;

β_0 is the constant term;

$value_{ijt}$ denotes China's wheat import value from country j, in US$ in period t;

$\ln gdp_{it}$ denotes the natural logarithm of Chinese GDP, in US$, in period v;

$\ln gdp_{jt}$ denotes the natural logarithm of exported countries' GDP, in US$, in period t;

$\ln D_{ij}$ denotes the natural logarithm of the geographical distance between the capital of China and the capital of the exported countries in kilometers;

$\ln q_{jt-1}$ denotes the natural logarithm of wheat production in exported countries in 10000 tons, in period $t-1$;

$\ln m_{it}$ denotes the natural logarithm of quantity of imported wheat, in 10000 tons, in period t;

tem_{jt} denotes the average temperature in the exported countries, in period t;

$rain_{jt}$ denotes the average rainfall in exported countries, in period t;

ε_{ijt} is term for error.

3.3 Data Sources

All data used in the study referred to 11 major sources of wheat imports to China - Argentina, Australia, Canada, France, Kazakhstan, Mexico, Pakistan, Russian Federation, Turkey, United States and United Kingdom - between the period 1992-2020. Table 4 showed the meanings of variables, expected symbols, and data sources. The wheat import amount of China to country j in year t were based on the UN Comtrade indicators. The GDP were based on the World Bank Indicators. The distance between China and the main destinations of exported countries referred to distances (in kilometers) between the respective geographic center of these countries obtained from the Distance calculator website that calculated the distance with the Haversine formula. Data of wheat production were obtained from the United Nations FAOSTAT database. Average annual temperature and rainfall data were obtained from the World Bank database.

Table 4. Variable meaning, expected symbol, and data sources.

Variables		Meaning	symbol	Data sources
Dependent variable	$value_{ijt}$	China's wheat import value ($)		UN Comtrade
Independent variables	$\ln gdp_{it}$	China's GDP per capita ($)	-	World Bank
	$\ln gdp_{jt}$	Exported countries' GDP per capita ($)	+	World Bank
	$\ln D_{ij}$	Geographical distance (km)	-	Distance caculator
	$\ln q_{jt-1}$	Exported countries' wheat production (10^4 t)	+	FAOSTAT
	$\ln m_{it}$	Quantity of imported wheat (10^4 t)	+	FAOSTAT
	tem_{jt}	Average temperature (°C)	-	World Bank
	$rain_{jt}$	Average rainfall (mm)	-	World Bank

GDP per capita were used as a proxy for country i's ability to demand imported wheat and country j's ability to supply exported wheat. As per capita GDP increases, exporters are expected to be better able to invest in infrastructure and become more productive and more export-oriented. The variable of GDP per capita in wheat exported countries ($\ln gdp_{jt}$) was expected to have a positive coefficient. While, higher per capita GDP means more purchasing power for imported countries. If per capita GDP higher, the ability to purchase wheat will increase. However, China is a net wheat importer which means China's wheat imports increased, its net export volume decreased, and China's GDP fell. Therefore, The variable of GDP per capita in China ($\ln gdp_{it}$) was expected to have a negative coefficient. The greater the geographical distance ($\ln D_{ij}$) between the exported countries and China, the higher the transportation costs and the less wheat will be imported. So the distance coefficient is predicted to be negative. The more wheat an exported country produces last year ($\ln q_{jt-1}$), the more competitive its wheat prices become. Hence, the production coefficient is predicted to be positive. The more quantity of wheat China imports ($\ln m_{it}$), the more demand China has for imported wheat, which has a positive impact on the import value. The sector most vulnerable to climate risk is agriculture. Increased flooding and droughts could reduce crop production and thus wheat exports. The variables of average temperature (tem_{jt}) and rainfall ($rain_{it}$) in the exported countries would be expected to have negative coefficients.

4. Results and Analysis

4.1 Descriptive Statistics analysis

The descriptive statistics used in the analysis were displayed in Table 5. The average of China's wheat import value was 6,970,000$ which ranged from 0 to 1,260,000,000$. On average, the natural logarithm of China's GDP was about 7.73 which ranged from 5.90 to 9.26. The mean of natural logarithm of exported countries' GDP was 9.33 with the maximum and minimum approximately 6.06 and 11.13 separately. The average of natural logarithm of distance was 8.87 with the minimum value at 7.99 and a minimum value at 9.85. The mean

Table 5. Summary statistics of variables used in gravity model of trade.

Variable	N	Mean	Std. Dev	Min	Max
$value_{ijt}$	319	6,970,0000	168,000,000	0	1,260,000,000
$\ln gdp_{it}$	319	7.73	1.10	5.90	9.26
$\ln gdp_{jt}$	319	9.33	1.30	6.06	11.13
$\ln D_{ij}$	319	8.87	0.57	7.99	9.85
$\ln q_{jt-1}$	319	16.79	0.77	14.66	18.27
$\ln m_{it}$	319	14.45	1.39	10.37	16.27
tem_{jt}	319	10.94	8.69	-5.38	22.88
$rain_{jt}$	319	612.03	260.99	190.75	1389.81

value of the natural logarithm of wheat production in exported countries was 16.79 between 14.66 and 18.27. The average value of the natural logarithm of quantity of imported wheat was 14.45. The mean of imported countries' average temperature and average rainfull were 10.94℃ and 612.03mm separately.

4.2 Results of Poisson pseudo-maximum likelihood (PPML)

The panel correlation coefficients for the concerned variables were shown in Table 6. Farrar and Gauber (1967) referred that the value of correlation between independent variables should be limited to 0.8 or 0.9 to avoid multicollinearity problem [20]. Mela and Kopalle (2002) indicated that the value of bivariate correlations between the independent variables higher than 0.75 (|r| 〉 0.75) would lead to a collinearity problem [21]. On the other hand, Mason (2013) pointed that the value of bivariate correlations between independent variables above 0.7 could lead to collinearity problem [22]. Since the values of the correlation coefficients were all less than the absolute value of 0.6, and the value of dependent variable had many 0 values, the nonlinear PPML estimator was used for research with no consider the multicollinearity.

Table 6. Test of correlation coefficients.

	$\ln gdp_{it}$	$\ln gdp_{jt}$	$\ln D_{ij}$	$\ln q_{jt-1}$	$\ln m_{it}$	tem_{jt}	$rain_{jt}$
$\ln gdp_{it}$	1						
$\ln gdp_{jt}$	0.3155	1					
$\ln D_{ij}$	0	0.5092	1				
$\ln q_{jt-1}$	0.1007	0.2872	-0.2552	1			
$\ln m_{it}$	-0.051	-0.0353	0	-0.0081	1		
tem_{jt}	0.0323	-0.189	0.2716	-0.4806	-0.0037	1	
$rain_{jt}$	0.0061	0.5624	0.5032	-0.0649	0	0.0228	1

STATA 16.0 was used to estimate the gravity model of wheat import with the PPML estimator. The results for estimations showed the coefficient estimates for affecting factors of China wheat import trade in Table 7.

Table 7. Results of the gravity model with PPML estimator.

	1992-2020	1992-1999	2000-2009	2010-2020
Variables	(1)	(2)	(3)	(4)
$\ln gdp_{it}$	-0.410***	0.564**	-0.971**	-0.0487
	(0.0914)	(0.249)	(0.441)	(0.833)
$\ln gdp_{jt}$	1.999***	2.919***	3.122***	1.792***
	(0.183)	(0.275)	(0.424)	(0.232)
$\ln D_{ij}$	-0.481**	-0.121	-2.047**	-0.404
	(0.242)	(0.553)	(0.941)	(0.381)
$\ln q_{jt-1}$	0.581***	0.543***	-0.124	0.799***
	(0.155)	(0.193)	(0.253)	(0.310)
$\ln m_{it}$	1.068***	1.170***	1.056***	0.943***
	(0.0924)	(0.109)	(0.104)	(0.362)
tem_{jt}	-0.0251***	-0.0448***	-0.0203**	-0.00937
	(0.00734)	(0.00849)	(0.00793)	(0.0103)
$rain_{jt}$	-0.00449***	-0.00613***	-0.00627***	-0.00368***
	(0.000618)	(0.000909)	(0.000974)	(0.000938)
Cons	-26.36***	-38.18***	-34.95***	-29.17***
	(4.181)	(4.174)	(11.57)	(6.650)
Observations	319	88	110	121
R-squared	0.673	0.940	0.879	0.534

Robust standard errors in parentheses
*** p〈0.01, ** p〈0.05, * p〈0.1

For the variable of China's per capita GDP, in the year 1992–2020 and 2000-2009, the impact of it on China's wheat import were significant at the statistical level of 1% and 5%, respectively. The coefficient sign was negative as expected. As China's GDP per capita rises, China invests more in domestic wheat planting technology, leading to higher wheat productivity and higher yields of high-quality wheat, leading to lower wheat imports. Between the years 1992-1999, the impact of it on China's wheat import is significant at the statistical level of 5%. But the sign is positive because that with the increase of GDP, China's wheat supply was in short supply and a large amount of wheat imports were needed. In the year 2010–2020, although the result is not significant, the symbol is negative in line with expectations.

The economic growth of wheat exported countries is an important factor affecting China's wheat import trade to this country. The estimated GDP coefficient of this country is positive and significant at the statistical level of 1%, which is consistent with the expectation.

For China's wheat import from other countries, geographical distance has a negative impact on wheat import. Under the condition of controlling the influence of other factors, the longer the distance from China, the higher the transportation cost, and greater transportation risks will export less wheat to China. The coefficient of geographical distance between 1992-2020 and 2000-2009 is statistically significant at 5%. Although the coefficient of geographical distance between 1992-1999 and 2010-2020 is not significant, the coefficient signs are in line with expectations.

In addition to the 2000-2009 results, last year's wheat production of exported countries has a positive effect on China's wheat imports, and it is significant at the 1% level, in line with the expected direction. It indicates that the exported countries is more likely to export wheat to China if its grain production in one year is high enough to meet the food demand of its citizens in the next year. In the period of 2000-2009, the coefficient is negative and not significant. The reason is that China's wheat imports fell between 2006 and 2009. In 2005, food production in major food-producing countries was significantly affected by extreme weather events. By 2006, global cereal production had fallen by 2.1%. In 2007, soaring oil prices increased the cost of fertilizers and other food production factors. As international food prices rise to unprecedented levels, countries are scrambling to fend off potential food shortages and price shocks. Some food-exported countries imposed export restrictions, while some major food-imported countries began buying grain regardless of the cost to maintain domestic supplies. And the global economic crisis of 2008 and 2009 undermined food security in many countries.

There is a positive relationship between China's wheat import volume and import value, and it is significant at the confidence level of 1%, which is consistent with the expectation.

For climate-related variables, the average temperature and average precipitation of wheat exported countries have a negative relationship with wheat import. Extreme weather events such as floods, high temperatures, and droughts can reduce crop yields. On top of that, according to a 2011 National Academy of Sciences report, for every 1 degree Celsius increase in global temperature, overall crop yields fall by 5 to 15 percent. Many commodity crops, such as corn, soybeans, wheat, rice, cotton, and oats, do not grow well above certain temperature thresholds. In addition, crops will be affected by reduced water and groundwater supplies, increased pests and weeds, and fire risks.

5. Conclusion

Based on a descriptive statistical analysis of relevant data of China's wheat import from 1992 to 2020, this study conducted an empirical analysis of the factors affecting wheat import by constructing a gravity model and using the PPML Estimator. The main conclusions are summarized as follows:

(1) From 2010 to 2020, China gradually formed an import pattern dominated by Australia and Canada, supplemented by the United States, France, and Kazakhstan. Mexico, Argentina, and other countries gradually withdrew from wheat trade with China.

(2) Among the factors affecting China's wheat

import trade, China's per capita GDP and total imports, geographical distance, current GDP of exported countries, and last year's wheat output have a significant impact on China's wheat import. In addition, climate factors also have a significant impact on China's wheat imports.

China's main sources of wheat imports continue to come from traditional wheat exporters Australia, the United States, and Canada. China's wheat imports are highly dependent on these three countries, which greatly reduces the market security of China's wheat imports. To improve this situation, China should firstly further optimize the wheat import structure from a strategic height. The government needs to strengthen the production orientation and regional distribution of new varieties. They also should give prominence to advantageous producing areas and key areas, optimize the mix of wheat varieties and quality, and develop high-quality wheat. China can take full advantage of its economic cooperation with countries along the Belt and Road and further expand its cooperation with the wheat trade of Turkey, Israel, Kazakhstan, the Russian Federation, and other countries located on the Silk Road. The geographical distance between these countries and China is relatively close, and the GDP of these countries also shows an overall upward trend in recent years. The production and economy of these countries are in good condition, and there is a great space for development. In addition, China should pay close attention to the climatic conditions of exported countries, timely predict the source of wheat imported by China, and estimate China's wheat imports to ensure sufficient wheat supply. Make good use of domestic and foreign wheat markets in a balanced way to ensure China's food security.

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