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Transmission effect of international grain prices on China's grain prices

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With the rapid development of China's economy, people's living standards and food requirements have also changed. Grain imports have significantly increased to meet the growing demand for food, which has increased the transmission effect between international and domestic grain prices and exposed the nation's food security to greater risk. Therefore, this study aims to investigate the price transmission mechanism and its impact on food security in China. It utilizes data on the spot and futures prices of major international grains from 2013 to 2020, along with an analysis of the corn stockpiling system reform through a quasi-natural experiment. The results indicate that different grain varieties exhibit distinct supply and demand structures, while the degree to which they are affected by international prices varies significantly. Grains with higher levels of marketization and openness are more susceptible to fluctuations in international market prices. This transmission effect is closely related to the total import volume of the agricultural product and its substitutes. The soybean market, the most marketized and open market in China, is influenced by international prices the most significantly. Furthermore, corn prices have become more sensitive to international markets, especially since the reform of the stockpiling system, which has increased marketization. By contrast, as the main staples in China, wheat and rice are less affected by fluctuations in international market prices due to low marketization and openness. This study finds that the transmission mechanism between domestic and foreign grain markets is mainly established through international trade. It provides new empirical evidence for global price transmission theory and promotes international trade theory. In practice, the findings will assist in managing the effects of international grain price fluctuations on the domestic grain market as well as in formulating future policies to more effectively ensure a stable domestic grain supply.

KEYWORDS

grain prices, food security, transmission effect, price support policy, marketization

1 Introduction

China has approximately one-fifth of the world's population but only approximately 8% of its arable land, ranking 126th in terms of per-capita area of arable land (UN, 2019). Grain consumption has increased significantly as the livestock and bioenergy industries have grown rapidly; therefore, making it increasingly difficult to boost the domestic supply of grains to meet the growing demand (Sheng and Song, 2019). In recent years, with the rising cost of domestic grain production and increased openness, growing grain imports have become increasingly important to support China's food security (Luo and Tanaka, 2021). Moreover, since grain prices play a crucial role in guiding grain production and are closely related to price levels across society (Lv et al., 2022), ensuring grain price stability is one of the important aspects of food security (Hua et al., 2022).

Grain prices are an important component of food security since the grain yield may respond to price changes (Haile et al., 2014; Haile et al., 2016; Bonilla-Cedrez et al., 2021), while price stability is closely related to public health (Qaim, 2020), economic growth, and national stability (Adediran et al., 2024). Numerous studies have been conducted to discover the causes of grain price volatility. For the domestic grain market, research demonstrates that grain prices could be influenced by supply shocks (Brümmer et al., 2016; Cafiero et al., 2011), storage activities (Bobenrieth et al., 2013), financial support (Romanus et al., 2020; Osabuohien et al., 2018; Gershon et al., 2020), and financial speculation activities (Brümmer et al., 2016). Moreover, with the increasing international grain trade, the domestic grain market has begun to be influenced by global prices. The literature on grain price transmission is extensive, with many studies employing different models to discover the connections between international markets and examine price correlations from global to local markets (Tanaka and Guo, 2020; Antonakakis and Gabauer, 2017; Durborow et al., 2020; Paul and Karak, 2022; Arnade et al., 2017). Furthermore, studies have investigated the speed of adjustment of grain prices within their corresponding price channels (Drabo, 2017), the price transmission between domestic and international grain markets in both the short and long run (Steel and King, 2004), the probable transmission mechanisms (Hernandez et al., 2011; Balcombe et al., 2007; Zhang and Liu, 2020; Amikuzuno et al., 2013), and the dynamic correlation of price transmission (Gouel, 2013; Gouel, 2016). Additionally, numerous studies suggest that global export restrictions may increase domestic price volatility (Pieters and Swinnen, 2016; Santeramo and Lamonaca, 2019; Guo and Tanaka, 2019; Trostle, 2008), thus driving food insecurity higher. Conversely, an increased self-sufficiency rate has the potential to weaken the level of transmission from international price volatility to domestic markets (Mundlak and Larson, 1992).

International food prices influence China's food market through two primary channels: international trade and the futures market. First, for food varieties with high foreign dependence, international price fluctuations trigger corresponding domestic price changes via imports. For those with lower foreign dependence, international price fluctuations affect domestic prices through consumption and planting substitution mechanisms. Second, the price discovery function of the international food futures market transmits price fluctuations to China's domestic futures market. Through price expectations, these fluctuations impact domestic supply and demand, which in turn affect the spot market, and ultimately domestic food prices. Notably, as China's commodity futures market increasingly integrates with the international market, the influence of the futures market is becoming more pronounced (Sun et al., 2018).

Food price volatility, an important aspect of food security, has been extensively studied. While much of the research on the relationship between international and domestic grain prices focuses on specific grains or the Chinese grain market, the evolution of China's food security strategy has led to significant changes in the production and import levels of various grain types due to policy adjustments. These changes result in various degrees of price transmission across different grains. A review of the existing literature on domestic food prices in China highlights two key issues. First, many studies base their analyses solely on statistical data, lacking internal economic logic and theoretical reasoning. Some studies also overlook endogenous factors in the mutual influence between domestic and international

food prices, leading to biased conclusions. Furthermore, some studies fail to account for the substantial differences in national policies and import controls across different food varieties, leading to generalized findings that fail to reflect the actual situation.

To address these gaps, this paper draws on successful research methodologies and differentiates food varieties based on their levels of marketization and openness. It analyzes the impact of international food prices on domestic prices and uses the instrumental variable method for robustness tests to improve the reliability of the results. Additionally, by utilizing the quasi-natural experiment of China's domestic corn market reform, this paper explores how domestic food prices of the same variety are influenced by the international market under varying levels of marketization and openness. The paper also identifies the primary channels and factors influencing the transmission of international food price fluctuations to the domestic market. This research contributes to a deeper understanding of China's food security strategy and the mechanisms behind domestic food prices. Moreover, understanding the price linkage mechanism between China's domestic and international markets holds significant practical value for other countries, particularly in mitigating domestic food price volatility and stabilizing food supplies.

2 Strategic evolution of food security in China

For many years, China has adhered to the food security policy of ensuring basic self-sufficiency of grain and absolute security of staple foods. In 2020, China's per capita grain share reached 470 kg, an increase of 14% compared to 414 kg in 1996 and 126% compared to 209 kg in 1949.¹ One of the main measures to achieve these achievements is to protect farmers' enthusiasm for grain cultivation while promoting their employment and income growth. During certain periods, specific prices, and for particular grain varieties in designated regions, China has successively implemented minimum purchase price policy acquisitions, such as temporary purchase and storage.² Since 2004 and 2006, minimum purchase price policies have been implemented for wheat and rice, respectively,³ and temporary purchase and storage policies were implemented for corn from 2008 to 2015.⁴

1 Data taken from the National Bureau of Statistics of China.

2 Source: "White Paper on Food Security in China," 2019.

3 Taking 2020 as an example, the national standard third-class wheat and rice produced in 2020 are standard products. The minimum purchase prices for wheat, midlate indica rice, and japonica rice announced by the state are 2.24 yuan/kg, 2.54 yuan/kg, and 2.6 yuan/kg, respectively. The grade difference between adjacent grades was controlled by 0.04 yuan/kg. That is, when the market price of standard products is lower than the minimum purchase price specified by the state, the state will purchase grain at the minimum purchase price to ensure that the market price operates above the minimum purchase price, thereby ensuring farmers' income from grain cultivation.

4 Taking 2015 as an example, the listed purchase price of temporarily stored corn by the state (national standard third-class quality standard) is 1 yuan/kg, and the price difference between adjacent grades is controlled by 0.04 yuan/kg. That is, when the market price of standard products is lower than the listed purchase price specified by the state, the state initiates temporary collection

TABLE 1 Variable descriptions.

Variables	Data sources	Meanings	Monthly Data			Quarterly data		
			Sample	Mean	Sta. Dev	Sample	Mean	Sta. Dev
<i>IUScorn</i>	CNGOIC	Logarithm of the CIF price of American corn to Chinese ports	96	5.39	0.16	32	5.39	0.16
<i>ISRW</i>	CNGOIC	Logarithm of the CIF price of American wheat to Chinese ports	96	5.56	0.14	32	5.56	0.14
<i>IVrice</i>	CNGOIC	Logarithm of the CIF price of Vietnamese rice with a 5% tax break	96	5.97	0.10	32	5.97	0.10
<i>IUSSoyb</i>	CNGOIC	Logarithm of the CIF price of American soybeans to Chinese ports	96	6.09	0.15	32	6.09	0.14
<i>IDalcorn</i>	CNGOIC	Logarithm of Dalian's domestic corn closing price	96	5.74	0.18	32	5.74	0.18
<i>IZwheat</i>	CNGOIC	Logarithm of Zhengzhou's wheat purchase price	96	5.93	0.08	32	5.93	0.08
<i>IJarice</i>	CNGOIC	Logarithm of Jiamusi's rice purchase price	96	6.46	0.09	32	6.46	0.09
<i>IHasoyb</i>	CNGOIC	Logarithm of Harbin's soybean purchase price	96	6.44	0.14	32	6.44	0.14
<i>feeding</i>	China Customs	Logarithm of feed grain imports (10,000 tons)	96	5.24	0.44	32	6.35	0.41
<i>ICornim</i>	China Customs	Logarithm of corn imports (10,000 tons)	96	2.86	1.53	32	4.33	1.01
<i>ladies</i>	NBSC	Logarithm of the monthly average of the annual disaster area	96	5.26	0.17	32	6.36	0.17
<i>IAucoa</i>	IMF	Logarithm of the Australian steam coal monthly average price	96	4.37	0.24	32	4.37	0.24
<i>IUsoil</i>	NYMEX	Log of NYMEX crude oil futures monthly average price	96	4.10	0.40	32	4.11	0.39
<i>Cref</i>		Corn reform (0 before 2016, 1 after 2016)	96	0.63	0.49	32	0.63	0.49

(Continued)

TABLE 1 (Continued)

Variables	Data sources	Meanings	Monthly Data			Quarterly data		
			Sample	Mean	Sta. Dev	Sample	Mean	Sta. Dev
<i>CreflU</i>		Interaction between corn reform and log of American corn price	96	3.32	2.59	32	3.32	2.62
<i>corn</i>		Difference between domestic and foreign corn prices	96	0.35	0.15	32	0.35	0.15
<i>IM2</i>	NBSC	Logarithm of the money supply M2 (\$100 billion)	96	5.45	0.19			
<i>rese</i>	NBSC	Logarithm of foreign exchange reserves (\$10 billion)	96	5.81	0.09			
<i>lConf</i>	NBSC	Logarithm of the consumer confidence index (100 in May 2003)	96	4.72	0.08			
<i>lingual</i>	NBSC	Logarithm of industrial added value (100 in 2010)	96	5.14	0.19			
<i>gdp</i>	NBSC	Logarithm of quarterly GDP (100 billion yuan)				32	5.186	0.225
<i>laggdp</i>	NBSC	Logarithm of GDP per capita (10,000 yuan)				32	0.257	0.214

In 2012, China proposed a new food security concept, namely “ensuring basic self-sufficiency of grain and absolute security of staple foods,” to ensure complete self-sufficiency of domestic rations such as wheat and rice. The majority of grains, such as corn, rely on domestic production, and imports are adjusted based on surplus and shortage. Under the guidance of this strategy, the minimum purchase price policy for domestic wheat and rice continues to be implemented, whereas the temporary purchase and storage of corn was canceled in 2015. To ensure domestic self-sufficiency, a quota system is adopted for imports. Since 2013, the soybean market has implemented producer subsidy policies with no quota restrictions on imports. A series of policy measures were introduced to ensure self-sufficiency in domestic grain consumption and a high grain self-sufficiency rate. Due to the limited arable land and water resources in China, soybean production is relatively low. This has led to a market supply and demand pattern in which the domestic production of wheat and

rice is greater than the levels of consumption, a small amount of corn is imported, and the majority of soybeans are imported.

As an important aspect of achieving China’s strategic goal of national food security, grain price stability is essential for local grain production, national economic growth, and social stability. Therefore, it is crucial to accurately grasp the linkage between domestic and international grain prices and to discover the extent of international price transmission of different grain varieties. In this study, grain varieties with different degrees of marketization and openness are distinguished using spot market price data of domestic and foreign corn, soybean, wheat, and rice from 2013 to 2020 to analyze the heterogeneity of the price transmission of different grain varieties. Taking the reform of the corn stockpiling policy in China as a quasi-natural experiment, the level of international price transmission is tested, and the results are found to support the argument that the level of price transmission may be subject to changes in the degrees of marketization and openness. Although numerous studies have investigated the factors that influence agricultural prices and international price transmission, only a few have attempted to find the potential drivers behind price transmissions, especially those considering different grain varieties separately. Thus, the major contributions of this study are its assessment of the different price transmission levels of different grain varieties, discovery of the potential determinants of

and storage to ensure that the market price operates above the minimum purchase price, thereby ensuring farmers’ income from grain cultivation, with a similar effect to the minimum purchase price.

international price volatility passing through to the domestic market, and provision of empirical evidence supporting the role of marketization and openness as significant drivers of price transmission between domestic and international markets.

3 Materials and methods

This study examines the transmission effects of international grain prices on the prices of four major domestic staple foods in different strategic goals and policy environments under the strategic context of China's new food security concept. First, the study determines the main control variables that affect domestic grain prices based on the results of historical research; then, it provides a theoretical basis for constructing econometric models that affect domestic grain prices. Moreover, through a quasi-natural experiment of a certain variety of marketization reforms, the study investigates the channel and transmission mechanism of international grain prices' effects on domestic grain prices.

3.1 Theoretical basis

Based on neoclassical trade theory, differences in factor endowments among countries create comparative advantages, leading to the international division of labor and trade, which facilitates the transmission of international prices. With trade liberalization, when a country exports products for which it has a comparative advantage, the price of the product will gradually increase. Without considering factors such as transportation costs and trade barriers, international trade ultimately leads to the convergence of prices between countries, effectively equalizing commodity prices. Therefore, if factors such as transportation costs and tariff barriers are not considered, as long as a price difference exists between domestic and international grain prices, then price transmission will occur until domestic and international grain prices are consistent. The transmission effect of international food prices depends on the degree of openness of the domestic market, which could be recognized as the degree of participation in the international market. The higher the degree of participation, the stronger the transmission effect of international food prices. According to the inference of commodity price equalization in neoclassical trade theory, as the import scale gradually expands, the transmission effect of international grain prices on domestic grain prices will also gradually increase, as shown in Equation 1.

The price of grain x in the domestic and foreign markets during period t is assumed to be $p_{x,t}^i, p_{x,t}^o$ respectively, where the foreign market is defined as a global market outside of China, while the transaction cost of transporting grain from the international market to the domestic market is assumed to be C . Therefore, according to the "law of one price,"⁵ the price of grain x in the two regional markets should satisfy the following equation:

$$p_{x,t}^i = p_{x,t}^o + C \quad (1)$$

Next, the following two scenarios are considered:

- (1) According to neoclassical trade theory, if there is complete free trade in grain x between domestic and foreign markets, such as non-tax, quota, and other restrictions, and the circulation conditions are convenient and the quantity is large, then the transaction cost C of unit grain x can be significantly reduced or even close to zero. Then, the price of domestic and foreign grain x will converge—that is, $p_{x,t}^i = p_{x,t}^o$.
- (2) Since food security is the foundation of national security, fluctuations in food prices can easily create economic problems. To maintain a balance between food supply and demand in the domestic market, many countries and regions implement policy interventions, such as domestic price support policies and international trade policies. If there is no free trade in grain between the domestic and foreign markets, such as the absence of trade contacts, then the existence of restrictive measures (e.g., import quota permits and high tariff barriers) may cause the transaction cost C to approach infinity, and domestic and foreign prices will be independent of each other without any transmission effect.

Based on these scenarios, under the assumption of free trade, the larger the scale of grain imports, the stronger the transmission effect of international grain prices. By contrast, the smaller the scale of grain imports, the weaker the transmission effect of international grain prices. Furthermore, the higher the degree of market openness, the more significant the impact of international prices on domestic prices. Moreover, policy interventions significantly affect the transmission effect of domestic and foreign grain prices. The more policy intervention there is, the less the price is affected by the international market. Additionally, the higher the degree of marketization, the greater the international market's effect on domestic grain prices. In China, the domestic and foreign trade situations of the four major grain varieties are different, with the soybean market being close to Scenario 1, while the domestic and international soybean markets are completely free to trade. In contrast, the wheat and rice markets are close to Scenario 2, with the domestic wheat and rice markets in China being relatively closed. The corn market lies between the two scenarios.

3.2 Other factors that affect domestic food prices in China

The previous subsection introduced the theoretical basis for the impact of international food prices on domestic food prices. Domestic grain prices are affected by many other factors, mainly in terms of domestic supply and demand. In terms of demand, economic growth, population size, and living consumption level are the main factors that affect food consumption. Therefore, macroeconomic indicators that reflect demand are added to this study's model as control variables. On the supply side, energy prices can increase the cost of and affect grain production, and they have a certain effect on grain prices. Moreover, although grain inventory is another important factor that affects grain supply (Minot, 2011), relevant data are difficult to obtain. Some

⁵ In 1953, Milton Friedman proposed that when trade is open and the transaction cost is zero, the price of the same goods expressed in the same currency is the same regardless of where they are sold.

scholars use China's inventory data published by the United States Department of Agriculture, which do not accurately reflect the actual situation and may affect the test results. Thus, this indicator is excluded from the study.

Based on the results of previous studies, important variables that affect domestic grain prices are determined. Taking the prices of domestic grains as explained variables and relevant factors as explanatory variables, the determining equation for domestic grain prices is as follows:

$$P_x^i = f(P_x^o, Macro, P^{Energy}, Supply) \quad (2)$$

In Equation (2), where P_x^i represents the domestic price of grain x , and P_x^o represents the international price of grain x . Macro refers to macroeconomic variables, including industrial added value, the consumer confidence index, M2, foreign exchange reserves, GDP, and GDP per capita; P^{Energy} represents the price of energy, such as steam coal and crude oil; and $Supply$ is a variable that affects supply, specifically the area of crops affected by disasters in this study.

3.3 Measurement model

The following measurement model is constructed for this study:

$$\ln P_{x,t}^i = \beta_0 + \beta_1 \ln P_{x,t}^o + \sum \delta_i \pi_{i,t} + \varepsilon_t \quad (3)$$

In Equation (3), where $\ln P_{x,t}^i$ represents domestic prices of grain varieties x (corn, soybean, wheat, and rice) in period t ; $P_{x,t}^o$ represents international spot prices of grain varieties x (corn, soybean, wheat, and rice) in period t ; $\pi_{i,t}$ indicates other factors that may affect grain prices; β_0 , β_1 , and δ_i are the parameters to be estimated; and ε_t is the random disturbance term.

3.4 Data description

The explained variable of domestic grain price $\ln P_{x,t}^i$ includes the domestic prices of corn, soybean, wheat, and rice, which are expressed as $\ln D_{corn}$, $\ln D_{soy}$, $\ln D_{wheat}$, and $\ln D_{rice}$, respectively. The domestic prices of corn, soybean, wheat, and rice are, respectively, represented by the purchase prices in Dalian, Harbin, Zhengzhou, and Jiamusi, which are the benchmark delivery locations for these grains; thus, the prices there are highly representative. Daily price data are obtained from the National Grain and Oil Information Center (CNGOIC), monthly data are the monthly average purchase prices, and quarterly data are the quarterly average purchase prices.

The core explanatory variable is the international grain spot price $\ln P_{x,t}^o$. The spot prices of international corn, soybean, wheat, and rice are expressed as $\ln U_{Scorn}$, $\ln U_{Ssoy}$, $\ln U_{SRW}$, and $\ln U_{rice}$, respectively. Since the United States is a major exporter of corn, soybean, and wheat and a major source of imports to China, the CIF prices of American corn, soybean, and soft red winter wheat (varieties traded in CBOT wheat futures) are selected as the international spot prices. Moreover, considering that Vietnam is a major exporter of rice and the major source of rice imports to China, the CIF price of Vietnamese

rice is selected as the international spot price of rice. These data are derived from the CNGOIC database.

The control variables are mainly macroeconomic indicators, such as industrial added value⁶ and the consumer confidence index,⁷ M2 and foreign exchange reserves, and GDP and GDP per capita, which are expressed as $\ln I$ and $\ln C$, $\ln M2$ and $\ln re$, and $\ln gdp$ and $\ln gdp$, respectively. Energy prices include steam coal and crude oil prices, which are expressed as $\ln A$ and $\ln U$, respectively, and other supply factors such as disaster-affected area variables of crops are expressed as $\ln d$. Relevant data are obtained from the National Bureau of Statistics of China (NBSC).

The macroeconomic indicators are added to the model as control variables, which are mainly used to reflect the macroeconomic situation and test the robustness of the model by replacing each other. The industrial added value and consumer confidence index are taken from monthly data released by the NBSC. M2 and foreign exchange reserves are monthly data obtained from the People's Bank of China. GDP is taken from quarterly data published by the NBSC. The calculation of GDP per capita assumes that the total population will grow steadily throughout the year. The population at the end of each quarter is then estimated, and quarterly GDP is divided by the quarter-end population to obtain the GDP per capita.

Furthermore, energy prices have a certain impact on the prices of agricultural products. Steam coal and crude oil are the two main sources of energy in China, and this study uses them alternately as control variables to test the model's robustness. The monthly price of Australian steam coal, published by the International Monetary Fund, is adopted for the price of steam coal, while the NYMEX crude oil futures price in New York is used for crude oil prices. Monthly and quarterly data are obtained by calculating monthly and quarterly averages, respectively.

Moreover, changes in grain supply and inventory also affect grain prices, and this study selects the affected area with a strong correlation with output changes as the control variable. As the relevant data for the affected area are annual data published by the NBSC, monthly and quarterly averages are calculated according to the needs of the measurement model. The meanings of each variable, data sources, the number of samples, and descriptive statistics are presented in Table 1.

6 Industrial value added (IVA) refers to the final output of industrial production activities expressed in monetary terms within a reporting period by industrial enterprises. It represents the balance of the total output of all production activities of industrial enterprises after deducting the value of material products and services consumed or transferred during the production process. IVA reflects the newly added value in the production process of industrial enterprises.

7 The Consumer Confidence Index (CCI) is a leading indicator obtained through sample surveys and weighted average calculations, typically represented as a percentage with a value range between 0 and 200. It comprehensively reflects consumers' evaluations of the current economic situation and their subjective perceptions of future economic prospects, income levels, income expectations, and consumption psychology. The CCI plays a significant role in monitoring economic cycle changes and predicting economic trends and consumption tendencies.

TABLE 2 Regression results using monthly data.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Corn	Corn	Soybean	Soybean	Wheat	Wheat	Rice	Rice
International corn price (IUScorn)	0.496*** (0.0543)	0.400*** (0.0489)						
International soybean price (IUSoyb)			0.764*** (0.0754)	0.589*** (0.0713)				
International wheat price (ISRW)					−0.0656 (0.0514)	−0.0617 (0.0433)		
International rice price (IVrice)							0.00121 (0.0735)	−0.0856 (0.0689)
Industrial added value (linduad)	0.0482 (0.0470)		0.00497 (0.0576)		−0.0651* (0.0387)		−0.0115 (0.0529)	
Crude oil price (IUsoil)	−0.152*** (0.0244)		−0.198*** (0.0275)		0.0516*** (0.0189)		−0.0567** (0.0223)	
Consumer confidence index (lConf)		−0.333 (0.208)		−0.693*** (0.248)		−0.0471 (0.149)		−0.952*** (0.203)
Coal price (lAucoa)		−0.128*** (0.0345)		−0.101** (0.0453)		0.125*** (0.0251)		0.126*** (0.0370)
Annual disaster area (ladis)	−0.293*** (0.0590)	−0.294*** (0.0598)	0.0698 (0.0698)	0.101 (0.0739)	0.0161 (0.0499)	0.0131 (0.0450)	0.0536 (0.0641)	0.0927 (0.0595)
Money supply (IM2)	−0.00873 (0.0661)	0.182 (0.110)	0.157* (0.0815)	0.488*** (0.128)	−0.0417 (0.0541)	−0.0523 (0.0745)	−0.241*** (0.0767)	0.249** (0.108)
Foreign exchange reserves (lrese)	2.138*** (0.106)	1.785*** (0.112)	0.963*** (0.131)	0.601*** (0.149)	0.407*** (0.0990)	0.644*** (0.0963)	0.263** (0.127)	0.329** (0.125)
Constant	−7.375*** (0.802)	−4.094*** (0.878)	−4.233*** (0.981)	−0.115 (1.170)	4.203*** (0.619)	2.426*** (0.648)	6.252*** (0.841)	7.153*** (0.922)
N	96	96	96	96	96	96	96	96
R ²	0.911	0.913	0.770	0.745	0.671	0.746	0.505	0.574

***, **, and * indicate that the estimated results are significant at the 0.01, 0.05, and 0.1 levels; figures in brackets are standard errors.

4 Empirical results

4.1 Benchmark test

First, monthly data are used to conduct an ordinary least square regression according to the measurement Equation (3), the results of which are presented in Table 2. The econometric model mainly examines the impact of international food prices on domestic food prices. From columns (1) and (2) of Table 2, one can see that international corn prices significantly affect domestic corn prices. By replacing the industrial added value and the monthly average price of crude oil with the consumer confidence index and the monthly average price of Australian steam coal, respectively, the coefficient of the international corn price variable is still significant at the 1% level, and the results are relatively robust. The coefficients are 0.496 and 0.4, respectively, which can be interpreted as follows: A 1% increase in the international corn price will cause a 0.4–0.496% increase in the

domestic corn price. Columns (3) and (4) provide the regression results before and after the explanatory and core explanatory variables are replaced with soybean prices. The conclusion is consistent with that derived for corn: International soybean prices significantly affect domestic soybean prices. In addition, the coefficients of international soybean prices reach 0.764 and 0.589, respectively, which are much higher than those of international corn prices. Moreover, columns (5) to (8) present the regression results for wheat and rice, respectively. They show that the impact of international prices on the domestic market is non-significant, and the results remain valid after some control variables are changed.

According to the empirical results, domestic soybean and corn prices are significantly affected by international market prices, and the price transmission of soybeans is more significant. Furthermore, wheat and rice prices are not significantly affected by international market prices. The results clearly show that the price transmission differs between domestic and international grain markets of different grain

TABLE 3 Regression results using quarterly data.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Corn	Corn	Soybean	Soybean	Wheat	Wheat	Rice	Rice
International corn price (IUScorn)	0.629** (0.237)	0.574*** (0.145)						
International soybean price (IUSoyb)			0.926*** (0.161)	0.658*** (0.127)				
International wheat price (ISRW)					−0.0140 (0.0889)	0.0635 (0.0691)		
International rice price (IVrice)							0.0255 (0.128)	−0.00338 (0.129)
GDP (lgdp)	−0.338** (0.165)		−0.100 (0.103)		−0.153** (0.0592)		−0.225** (0.0829)	
Crude oil price (IUsol)	−0.119 (0.106)		−0.227*** (0.0608)		0.0616* (0.0359)		−0.0441 (0.0408)	
Average GDP (lagdp)		−0.298** (0.140)		−0.0204 (0.101)		−0.177*** (0.0591)		−0.188** (0.0793)
Coal price (IAucoa)		−0.315*** (0.0803)		−0.251*** (0.0594)		0.0753** (0.0345)		0.00532 (0.0509)
Annual disaster area (ladis)	0.155 (0.204)	0.0399 (0.156)	0.194 (0.124)	0.0789 (0.118)	0.0906 (0.0736)	0.144** (0.0685)	0.147 (0.1000)	0.137 (0.101)
Constant	3.610 (2.494)	3.844*** (1.378)	1.026 (1.518)	3.036*** (1.040)	5.975*** (0.910)	4.383*** (0.640)	6.719*** (1.177)	5.633*** (1.077)
N	32	32	32	32	32	32	32	32
R ²	0.567	0.712	0.691	0.718	0.671	0.688	0.487	0.459

varieties. This may be explained by the fact that the higher the degrees of marketization and openness to domestic grain, the more significantly domestic grain prices are affected by international grain prices.

4.2 Sensitivity test

To further demonstrate the reliability of the conclusions, quarterly data are used to conduct a sensitivity test. Among the macro indicators, since GDP more accurately reflects the overall macroeconomic environment, industrial added value, the consumer confidence index Conf, money supply M2, and foreign exchange reserves are replaced with monthly GDP and monthly GDP per capita data in the quarterly data regression. The regression results are presented in Table 3.

In columns (1)–(4), the regression results for corn and soybean indicate that domestic soybean and corn market prices are significantly affected by international grain prices. The robustness of the results is also tested. Moreover, the coefficient of the international soybean price is significantly higher than that of corn, which indicates that the international soybean price has a greater influence on the domestic soybean price than the price transmission of corn. In the regression results

for wheat and rice in columns (5)–(8), the impact of international rice and wheat prices on domestic market prices is still non-significant. This is entirely consistent with the conclusions of the monthly data regression, which further confirms them.

5 Analysis of a quasi-natural experiment on marketization's influence

The results in the previous section demonstrate that the domestic corn and soybean prices are significantly affected by international prices, while the price transmission of soybean prices is more significant. Domestic wheat and rice prices are not significantly affected by international prices. This may be explained as follows: The higher the degree of marketization and openness of domestic grain, the more significant the price transmission effect. As different grain varieties have different levels of marketization and openness, many differences exist across other aspects, such as import source countries, production entities, and demand, which may interfere with the results. Thus, for further demonstration, the reform of the corn stockpiling policy in China is used as a quasi-natural experiment.

5.1 Introduction to the reform of temporary corn purchase and storage

To protect farmers’ interests and encourage grain production, while addressing problems such as difficult corn sales and declining income in northeast China, the Chinese government implemented a temporary purchase and storage policy in the main domestic corn-producing areas (three provinces and one district in northeast China) from 2008 to 2015. Before the corn harvest is listed in October each year, a temporary purchase and storage price are announced. If the price is lower than this level, the government starts to purchase corn to prevent the price from falling further and increase farmers’ income. Following the implementation of this policy, the market price fluctuated around the price of the temporary purchase and storage announced by the state, which distorts the market pricing mechanism and reduces marketization. However, it also leads to the failure of the market price to regulate market resources, which results in a series of problems, such as a mismatch between supply and demand in the domestic corn market and low resource use efficiency. Therefore, China reformed the corn storage system in 2016 and canceled the temporary purchase and storage price mechanism. Since then, the state has not purchased corn at the set price, and the price of corn has been entirely set by supply and demand in the market. The degree of corn marketization has significantly improved. Thus, the reform

provides a quasi-natural experiment that can be used to verify the relationship between the marketization degree and price transmission level.

5.2 Verification of marketization

By setting the dummy variable Cref for the level of marketization before and after the reform (before 2016 = 0, after 2016 = 1), we construct the interactive term CrefIU (the product of Cref and IUScorn) for the marketization reform and international corn spot price. Then, two regression analyzes are conducted using monthly and quarterly data, respectively. The results are presented in Table 4.

6 Results

In Table 4, columns (1) and (2) present the results of the regression using monthly regression data, while columns (3) and (4) present the results using quarterly data. They show that the CIF price of international corn is significant at the 1% level and that the interactive variables of marketization reform and international corn price are also significant, which indicates that the price transmission of corn is highly correlated with the degree of corn marketization. However, the regression results using both monthly and quarterly data indicate that

TABLE 4 Validation of marketization’s impact.

	Monthly data		Quarterly data	
	(1)	(2)	(3)	(4)
	lDalcorn	lDalcorn	lDalcorn	lDalcorn
International corn price (IUScorn)	0.400*** (0.0489)	0.385*** (0.0485)	0.573*** (0.144)	0.366*** (0.118)
Interaction of corn reform and the log of American corn price (CrefIU)		−0.0154** (0.00723)		−0.0565*** (0.0123)
GDP (lgdp)			−0.288** (0.134)	0.0828 (0.129)
Money supply (lm2)	0.182 (0.110)	0.289** (0.119)		
Foreign exchange reserves (lrese)	1.785*** (0.112)	1.496*** (0.175)		
Consumer confidence index (lconf)	−0.333 (0.208)	−0.404* (0.206)		
Annual disaster area (ladis)	−0.294*** (0.0598)	−0.273*** (0.0595)	0.0331 (0.158)	−0.175 (0.127)
Coal price (lAucoa)	−0.128*** (0.0345)	−0.112*** (0.0347)	−0.316*** (0.0801)	−0.216*** (0.0644)
Constant	−4.094*** (0.878)	−2.708** (1.080)	5.321** (1.938)	5.583*** (1.466)
N	96	96	32	32
R ²	0.913	0.918	0.713	0.842

TABLE 5 Further validation of marketization's influence.

	Monthly data		Quarterly data	
	(1)	(2)	(3)	(4)
	Corn	Corn	Corn	Corn
Corn imports (lCornim)	−0.00983		0.000000461	
	(0.00691)		(0.0236)	
Feed grain imports (lfeedim)		0.0793***		0.179***
		(0.0271)		(0.0557)
GDP (lgdp)			−0.0925	−0.0581
			(0.140)	(0.119)
Money supply (lm2)	0.871***	0.634***		
	(0.156)	(0.167)		
Foreign exchange reserves (lrese)	1.429***	1.193***		
	(0.181)	(0.176)		
Consumer confidence index (lConf)	−1.324***	−1.013***		
	(0.309)	(0.321)		
Annual disaster area (ladis)	−0.0972*	−0.0827	−0.368***	−0.216**
	(0.0559)	(0.0538)	(0.0931)	(0.0898)
Coal price (lAucoa)	−0.0666	−0.114	0.0932	−0.00755
	(0.0927)	(0.0914)	(0.183)	(0.155)
Constant	−5.645***	−4.708***	1.391	0.220
	(1.478)	(1.375)	(1.343)	(1.133)
N	96	96	32	32
R ²	0.667	0.690	0.425	0.584

the interaction coefficient between the market-oriented reform and the international corn spot price is significantly negative, which is contrary to the expected results. That is, there is an abnormal situation where the effect of international corn prices on domestic corn prices decreases after the market-oriented reform.

6.1 Further verification of marketization's influence

To further verify marketization's influence, it is necessary to further examine the relationship between domestic and foreign price linkages and the import volume of feed grain and corn. The larger the difference between domestic and international corn prices, the higher the profit from feed grain imports, which would lead to stronger import motivation, thereby promoting the narrowing of the price difference. Thus, the impact of the international price on the domestic grain market is directly reflected in the change in the price difference. If the price difference for corn changes with the import volume of feed grain rather than corn's import volume, then this would indicate that the domestic corn price is affected by the international market and is related to the total import volume of corn and its substitutes. This further verifies that the “anti-openness” after the reform of the collection and storage system has caused the reduced impact of international corn prices on domestic corn prices. Thus, another regression analysis is performed between the index of the price

difference of domestic and foreign corn (the logarithm of the domestic corn price minus the logarithm of the international corn price) and the import volume of feed grain and corn, respectively. The results are presented in Table 5.

7 Conclusion

Neoclassical trade theory holds that when countries engage in international trade based on their comparative advantages, international prices will have a transmission effect on the domestic prices of importing countries through changes in import volume. This study uses monthly and quarterly price data of the four major staple foods at home in China and abroad from 2013 to 2020. By controlling for factors such as macro, policy, and energy prices that affect domestic and international grain prices, the study empirically analyzes the impact of international grain prices on domestic grain prices. Furthermore, lagged futures prices are used as a tool to test the robustness of the conclusions. Moreover, China's reform of the corn storage system is used as a quasi-natural experiment to further analyze the effects of international grain prices on domestic grain prices under different levels of marketization and openness.

Past research found that international grain prices significantly affect domestic grain prices in China through trade routes (Bren d'Amour et al., 2016). International soybean and corn prices have

significant economic impacts on domestic prices in China. The international price elasticity of domestic soybean and corn prices is approximately 0.7 and 0.4, respectively. However, international wheat and rice prices have no significant impact on domestic prices in China. As a result, there are no significant differences in how domestic prices of various grains respond to international prices (Marchand et al., 2016), primarily depending on the degrees of openness and marketization of China's domestic grain market. The greater the degree of domestic grain openness, the greater the impact of international grain prices on its prices. The larger the import volume, the more significant the impact of international prices on domestic prices in the importing country.

Additionally, domestic prices in the importing country are more susceptible to the impact of international grain prices, which leads to an increased risk of domestic economic fluctuations (Seekell et al., 2017; García-Germán et al., 2016; Ceballos et al., 2017), and the degree of transmission of international grain prices to domestic markets varies. The higher the degree of marketization of domestic grain, the more significant the impact of international grain prices on domestic prices. Furthermore, the more government intervention there is in domestic grain prices, the smaller the impact of international grain prices on domestic grain prices. Specifically, the soybean market exhibits the highest degrees of openness and marketization as well as the largest import volume, and it is also the market most affected by the international market. In addition, the price of domestic corn is significantly affected by the international market, while wheat and rice are the main staples for which the domestic market guarantees 100% self-sufficiency, and the degrees of marketization and openness are relatively low. The prices of domestic staples are not significantly affected by international price changes. A past quasi-natural experimental study on the reform of the corn storage system found that the transmission mechanism between domestic and foreign grain markets is mainly established through international trade; the larger the import volume, the more significant the impact of the international market on China's domestic grain prices. Furthermore, the import volume is not limited to the specific grain variety itself, as that of related substitutes also significantly affects the linkage degree between domestic and foreign grain prices. Specifically, the larger the import volume of related grains and their substitutes, the greater the impact of international grain prices.

In the context of global economic integration, food is a crucial commodity in international trade. This study provides new empirical evidence for global price transmission theory and promotes international trade theory. In practice, its findings will assist in coping with the impacts of international grain price fluctuations on the domestic grain market as well as in formulating future policies to more effectively ensure a stable domestic grain supply. As an important component of the price index, grain prices are of great significance to a country for stabilizing prices, controlling inflation, and maintaining macroeconomic stability. Due to the involvement of multiple markets, currencies, and transportation modes in the international grain price data, this study's data collection and processing are difficult to perform, which may affect the accuracy and reliability of its results. Furthermore, the transmission of international grain prices to domestic grain prices experiences a time lag, which also increases the complexity and uncertainty of the research. Moreover, governments around the world attach great importance to their domestic grain

market; therefore, the country's regulatory policies significantly affect prices, and policy factors may conceal or distort the true impacts of international grain prices on domestic grain prices.

The subsistence of a nation's population fundamentally depends on a stable and secure food supply. This paper provides an in-depth exploration of the complex relationship between domestic and international food prices. Such research is of paramount practical significance for any country striving to mitigate the volatility of domestic food prices and ensure the stability of its food supply chain. By leveraging the findings of this study, countries can take proactive measures to safeguard their food supply and maintain price stability in the following ways.

First, it is necessary to strengthen our food production capacity. At the production level, a comprehensive integration of various regulatory instruments is essential for enhancing domestic food production and reducing excessive dependence on international markets. The research indicates that the correlation between domestic and international prices is relatively weak for food varieties with low foreign reliance. Therefore, reducing import dependence is crucial. This can be achieved by improving resource integration, fostering collaborative innovation ecosystems, and establishing an efficient modern agricultural research framework.

Moreover, it is crucial to drive technological advancements in agriculture. Initiatives such as improved seed programs, sustainable plant protection methods, precision fertilization techniques, and water-saving irrigation practices should be actively promoted. These efforts will not only support the stable development of the agricultural sector but also play a key role in ensuring national food security. Expanding the coverage of agricultural insurance can also enhance farmers' resilience to risks, thus stimulating their motivation to engage in grain cultivation.

Second, it is necessary to optimize food trade patterns. In the realm of food trade, optimizing the structure of food imports is crucial. Actively participating in multilateral food trade can effectively diversify the risks associated with international market fluctuations. The funding of this research suggests that international food price fluctuations have both direct and indirect effects on the domestic agricultural market, primarily through import trade channels and market expectations.

To mitigate these effects, countries should fully leverage international resources to narrow the domestic food supply-demand gap and pursue a strategy of "moderate imports." In addition to strengthening existing trade channels, efforts should be made to identify and develop new food trade partners. This strategy will help reduce risks arising from the concentration of food imports in a few countries. By broadening food security channels, countries can better guard against the impact of global trade policy uncertainties, geopolitical tensions, and other external factors on the domestic food market.

Third, it is necessary to establish an early warning and prevention mechanism. A comprehensive system for monitoring international food price risks should be developed, supported by enhanced tracking of international economic policies and food price trends. Research indicates that international food price fluctuations can significantly affect the domestic market, with simultaneous price fluctuations in multiple food categories exacerbating the risks.

Therefore, it is necessary to closely monitor international food trade trends, accurately predict the fluctuation patterns of international food prices, and establish a robust early warning and

emergency response mechanism. By scientifically evaluating the impact of major global events on international food trade and the domestic market, countries can implement timely and targeted policies to prevent substantial losses from sudden and sharp fluctuations in international food prices.

In future studies, data sources could be further enriched and policy factors could be incorporated into research frameworks to analyze the differences in the impact of international grain prices on domestic grain prices under different policy environments, as well as to more accurately analyze the transmission path and mechanism of international grain prices on domestic grain prices. Given the differences in food market systems and policy environments between emerging markets and developed countries, future research should focus on the effects of these differences on the food price transmission mechanism.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

CMQ: Conceptualization, Data curation, Formal analysis, Investigation, Resources, Writing – original draft, Writing – review &

editing. CM: Formal analysis, Funding acquisition, Methodology, Writing – review & editing. SY: Data curation, Formal analysis, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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