How Natural Disasters Affect the Evolution of Grain Markets: Evidence from 18th Century China

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Abstract:

Market is the foundation of modern society. However, how did market evolve? Previous research has explored the impacts of spatial distance and transportation conditions on market integration. This paper argues that natural disasters also played a crucial role in the evolution of market integration in China, particularly in the grain market. When natural disasters occur, governments' relief measures and merchants' arbitrage activities will gradually promote interconnectivity among local grain markets. In this paper, China's major grain monthly price dataset from 1746-1795 and the Chinese historical disaster records dataset from 1696-1795 are used to analyze the impact of natural disasters on grain market integration. The empirical results show that natural disasters have a significantly positive effect on the integration of the grain market. The findings continue to hold after controlling the traffic conditions, grain varieties and lag effect. This study proposes a new perspective for understanding the evolution of the grain market.

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JEL Codes: O13, N55

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Abstract

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Key words: Natural Disasters, Market Evolution, Market Integration, Qing Dynasty, Grain Market, China.

JEL classifications: Q13, O13, N55

I. Introduction

Sustained interest in the market and its functions exists among economists because the development of markets and trade has played a key role in economic growth throughout mankind's history (Acemoglu et al., 2005; Keller and Shiue, 2007a). With the growth of markets, new opportunities for the division of labor appear, and new advantages emerge, thereby improving productivity and economic performance (Young, 1928). However, how does a market evolve? Although there is no shortage of theories in the literature regarding how a market is impacted, we propose that natural disasters are an essential factor that has been ignored in previous research.

The purpose of this paper is to test this hypothesis regarding the evolution of markets using regional grain price data and natural disaster data. The evolution of markets is a gradual process that is affected by the natural environment, transport facilities, social institutions and other factors (Ch'üan and Kraus, 1975; Shiue，2002; Park et al., 2002; Anderson and van Wincoop, 2004; Keller and Shiue, 2007b). In this paper, we argue that through governmental disaster relief and merchants' arbitrage trade, market evolution largely attributable to natural disasters, particularly in the early stage of market growth.

Grain trading can be traced to primitive society, and the grain market is one of the oldest markets in mankind's history. Before the industrial revolution, the grain market remained the most important type of market among all product markets, and it continues to be essential in the modern world. The establishment of the initial grain market also provided advantages for the trade of other crops and industrial products.

Thus, in this paper, we focus on the grain market's growth in agricultural society. Crop production is heavily influenced by the natural environment, particularly by weather conditions. Under extreme weather conditions, natural disasters can strike the grain production rapidly and lead to market integration, which is the most important indicator of market growth. However, no existing paper has addressed this important factor of market evolution deeply and extensively.

This article argues that natural disasters impact grain market integration mainly through two channels.

Firstly, the increase in the grain price after natural disasters will stimulate merchants to conduct lucrative cross-regional grain trading. Will et al. (1991) indicate that natural disasters can increase grain production fluctuations and affect the food supply in the short run, thereby causing food prices to rise sharply. Thus, after a natural disaster, the grain price will achieve its peak level. Under extreme weather conditions, natural disasters will reduce the grain supply dramatically, and customers in the local market may be induced to store more. This behavior bids up the grain price, creating a market arbitrage opportunity for merchants to purchase grain from other markets and sell it at the local market.

Secondly, the disaster relief operations of central and local governments after a natural disaster reduce the market transaction costs, thereby promoting the development of food market integration. The *Qing Shilu* records the disaster relief in the Qing dynasty in detail. The disaster relief conducted by the government includes reducing the tax on inter-regional trading, removing domestic import and export bans, implementing campaigns to encourage merchants to transport grain, constructing water conservancy projects and dredging sluggish rivers, effectively deepening the commercial ties between regional markets.

Subject to the availability of data, the empirical research on natural disasters' impacts on market evolution is limited. One interesting finding that is particularly relevant for this paper is that Shiue (2002) investigated the data relating to droughts, floods and grain prices in the Qing dynasty and proposed a positive relationship between regional extreme weather and fluctuations in the local grain prices. However, Shiue's paper did not directly test the impact of natural disasters on grain market integration. Furthermore, Shiue (2002) used data from only 121 prefectures in 10 provinces, whereas we use data from 216 prefectures in 18 provinces in China in this paper. Additionally, unlike Shiue (2002), we distinguish between droughts and floods as different natural disasters.

Through examining the historical materials, we first explain the mechanism of how natural disasters affect market integration theoretically. Thereafter, the monthly grain price dataset and the natural disaster dataset in the Qing dynasty are used to verify this relationship empirically. The contribution of this paper is that we not only provide a framework to explain natural disasters' impacts on market development but also empirically test our hypothesis using historical data.

This paper is organized in the following manner. In section 2, we construct a theoretical framework of how natural disasters affect grain market integration. Data sources and statistical descriptive evidence are described in section 3. In section 4, we present the empirical analysis of our hypothesis. The robust test is addressed in section 5, and the last section includes the discussion and conclusion.

II. The mechanism by which natural disasters affect grain market integration

The key factors that impact the interconnectivity of two markets in different regions are transaction costs and the potential profit created by the price differential. If there is no price differential between two markets, cross-regional transporting is gainless, which causes market isolation. When price differentials exist, merchants compare the price difference to the full cost of moving grain from one market to the other. If the transaction cost is lower than the price differential, motivated by potential profit, merchants will be willing to transport goods from one market to another, leading to interconnectivity between markets. Figure 1 shows the dynamic changes between two markets after natural disasters. In that figure, the price in market A is higher than that in market B, and the price differential is $\triangle P$. The transaction costs between the different regions is TC, which includes tax , transportation cost, return on labor and risk premium. If $\triangle P$ is less than TC, market A is very likely to link to market B. When disasters occur in market A, the grain market price increases from P_{A0} to P_{A1}, and the price differential increases from $\triangle P_0$ to $\triangle P_1$. However, disaster relief measures provided by the central government, such as reductions in the grain circulation taxation, lower the transaction cost from TC_0 to TC_1 and cause an increase in grain transport by merchants, leading to market integration.

Figure 1. The effects of natural disasters on market integration.

Natural disasters and the grain price differentials among regions

In the short run, as agricultural production is seasonal, natural disasters will reduce the grain production in a specific region significantly. Consequently, the grain supply decreases dramatically in the local market, resulting in price growth. During the Qing dynasty, records associated with disasters causing grain price increases are abundant in the local chronicles of most cities and prefectures in China. For instance, disasters occurred in 1707 and 1708 during the reign of Emperor Kangxi of the Qing Dynasty in Zhili Province. The chronicle of Luodian in Jiading of Zhili Province states: "there was a drought in the summer and a flood in the autumn in 1707. Sinister evil existed in this year. The rice price was 2 liang per dan[1]. The heavy rain lasted from lunar April the 10th to lunar May the 15th. An earthquake occurred in Luodian, and the sound carried from the west to the east. There was no wheat in the market that year, and the rice price increased to 2.3 liang per dan." The normal rice price from 1693 to 1772 was lower than 1.2 liang per dan (Bu, 2010), but the rice prices nearly doubled in 1707 and 1708 when natural disasters occurred. Rapidly growing grain prices in regions affected by disasters increase the price differential and potential profit, thereby promoting the interconnectivity of two isolated markets.

Central and local governments' relief operations after natural disasters

During the Ming and Qing Dynasties, because of population growth and the lack of

[1] Liang and dan are the price unit and weight unit, respectively, in the Qing Dynasty.

plowland, the storage of grain in the local prefecture was limited. Additionally, transporting grain to other prefectures was usually forbidden by local governments. Regional protectionism increased the transaction costs between markets and blocked the circulation of grain. *Qing Shilu* records that during the disasters in 1708, the governor of Jiangsu Province submitted memorials to the throne, explaining to Emperor Kangxi that those prefectures in the regions south of the Yangtze River, such as Jiangning, had suffered heavy rain since the summer and that the rice price had subsequently increased dramatically. He requested the emperor to grant him the power to sell the rice that was stored in local counties. He also noted that the population in Jiangsu Province was too large to be supported by the local grain. In the past, Jiangsu Province primarily relied on grain transported from the other provinces (e.g., Hunan, Hubei, and Jiangxi). However, when the flood occurred, local governments in those provinces forbade rice to be transported to Jiangsu Province to ensure grain sufficiency in their own provinces, which caused high grain prices in Jiangsu. He requested that the emperor remove the transportation barriers through central orders to reduce the rice price in Jiangsu. This record demonstrates that when disasters occur and potential profit exists, trade protectionism by the local government may continue to block the circulation of grain. Hence, without coordination from the central government, disasters may not promote market growth. Since China became a highly centralized feudal country during the Qing dynasty, the emperors usually removed the circulation barriers for the whole country's benefit when disasters occurred, which promoted market integration.

During the reign of Emperor Qianlong, disaster relief from the central government typically reduced transaction costs and improved market growth. Zhang (2007) summarizes the disaster relief provided by the government during the reign of Emperor Qianlong in detail. First, the government ceased taxing the circulation of grain. In Qianlong 3rd Year (1739), a flood occurred in Jiangsu Province and Anhui Province. Emperor Qianlong ordered tax exemptions for ships that transported rice and soybeans to ports. In the same year, the central government proposed an executive order that exempted all taxes in the provinces in which disasters occurred; according to this order, the tax could be exempted in emergencies before the central government allowed the general exemption. This practice later became an established convention. Second, the export and import ban on the sea would be removed when a disaster occurred. During Emperor Qianlong's reign, exporting and importing grain by sea was forbidden, and all grain was transported over land. Anyone who transported grain by sea privately would be punished. However, to resolve the grain shortage problem in the coastal provinces (such as Zhili Province and Zhejiang Province) when they suffered disasters, Qianlong removed the ban on transporting grain by sea in certain areas because ocean shipping could reduce the transport time and cost. Furthermore, the central government also forbade local officials from hindering merchants from buying grain. Qianlong believed that the shortage of grain in the regions that suffered disasters could be remedied only if grain was circulated (Zhang, 2007).

Furthermore, through policies, Emperor Qianlong provided guidance to facilitate grain transport and demanded that local governments run campaigns to encourage merchants to transport grain. For example, when Hubei and Anhui experienced a disaster in 1785, the governor, Li Shijie, helped the merchants establish a market to buy grain. In this case, Emperor Qianlong believed that the establishment of the market was a good idea. Furthermore, Emperor Qianlong allowed the local government to lend money to those merchants to buy grain without interest to induce more merchants to transport grain.

In addition, the government built water conservancy projects and dredged the sluggish rivers to provide infrastructure and services for the grain market, thereby promoting interconnectivity. Emperor Shunzhi in the Qing dynasty believed that the eastern provinces were the most important regions for fiscal levies; however, droughts and floods placed people in distressed situations. He ordered the local government to dredge the sluggish rivers and build dams. In 1748, Ali Gun, the governor of Shandong Province, reported that "the rivers in Jinan, Dongchang, Yanzhou, Yizhou and Taian were used for transportation…… In recent years, because of the unusual continuous heavy rain, there was no extra space for water, which caused flooding in those areas. Now, the Yihe River and the Lanhe River have started to be dredged, and the work-relief attracts many people ……" We can conclude that this disaster relief also ensured the transfer capacity of the river, which was regarded as the most efficient means by which to transport grain.

Although both the impact of disasters and the reactions of the central government are short term, they act to remove market barriers in a dramatic fashion and connect markets, which have long-term effects on market integration. These long-term effects occur by two different means. Firstly, temporary disaster relief policies may persist after a natural disaster (Zhang, 2007). Thus, the transfer cost can remain low for a long time. Secondly, those merchants who transport grain to another new market for the first time may generate high costs. Nevertheless, when the connection between the two markets is built, the merchants will become familiar with the environment, and the costs of subsequent transfers will decrease.

III. Data sources and statistical description

The data of food price

In accordance with Shiue (2002) and Keller and Shiue (2007b), this paper also selects the grain price data from the Qing dynasty as the data source due to the availability of these data over a long period. Specifically, the grain price data used here originate from *Gongzhong Liangjia Dan*[2], which contains the specific prices of 40 different types of crops in more than 20 provinces from 1736 to 1911. Some of the data are missing, and the prices in the late Qing dynasty are not accurate, as the reporting system did not work well during that time period. Thus, we use the price data in the early stage of the Qing dynasty, as the records from that period are reliable. Specifically, the grain price data of 216 prefectures from 18 provinces, including Anhui, Jiangsu, Zhejiang, Jiangxi, Hunan, Hubei, Guizhou, Fujian, Guangdong, Guangxi, Sichuan, Yunnan, Zhili, Shanxi, Shaanxi, Henan, Shandong and Gansu Provinces, from 1746 to 1795 during the reign

[2] Every province was requested to report the main crop prices in every prefecture to the emperor every month beginning in 1736, and these original records are called Lingjia Qingdan. These records are housed in the First Historical Archives of China in Beijing and the Palace Museum in Taipei. The lowest and highest prices of the main crop in the prefectures are listed. The price unit is liang, and the weight unit is dan. We use the average of the lowest and highest price as the crop price.

of Emperor Qianlong are used. As rice and wheat were the most important grains in the market, as noted by Shiue and Keller (2004), we focus on the prices of wheat and rice. To decrease the error caused by missing observations, we select rice price data from lunar February and August and wheat price data from calendar March and October[3]. In this work, the wheat market includes 161 prefectures, and the rice market involves 119 prefectures. The average prices of wheat and rice are 1.31 liang per dan and 1.41 liang per dan, respectively (Table 1).

Table 1. Descriptive statistics of the wheat and rice markets from 1746 to 1795.

The data of historical natural disasters

The main disasters that affect agricultural production are floods and droughts (Liu, Chen, 2000; Wang et al., 2007). Li (1993) and Min (2001) demonstrated that the most frequent disasters were floods and droughts, which represented 69.4% of all the disasters in the early and middle Qing dynasty. Thus, we use floods and droughts to estimate the disaster frequency in 216 prefectures during the Qing dynasty.

The natural disaster data we use in this paper are derived from the *Atlas of Droughts and Floods Distribution* in China over the Last 500 Years and its extended data, which are processed by the Chinese Academy of Meteorological Sciences. This data set contains the meteorological records of floods and droughts from 120

[3] Our wheat price data are derived from the Qingdai Liangjia Ziliao Ku, which has been transferred from lunar dates to solar calendar dates. The rice price is derived from Shiue and Keller's paper, "Markets in China and Europe on the Eve of the Industrial Revolution", which uses lunar dates. Those two datasets are both from Gongzhong Liangjia Dan. By checking the calendar, we find that, some of the dates in solar calendar March and lunar February overlap and that some of the dates in solar calendar October and lunar August overlap during 1746 and 1795. Because there are missing variables in the original data, we use Time Series Regression with Autoregressive Integrated Moving Average (ARIMA) Noise, Missing Observations and Outliers (TRAMO) to supplement the data.

observation spots from 1470 to 2000 in China. These records use a 5-degree scale, as follows: 1 indicates that a severe flood occurred in that year, 2 indicates that a flood occurred in that year but was not severe, 3 indicates that no disaster occurred in that year, 4 indicates that a drought occurred in that year but was not severe, and 5 indicates that a severe drought occurred in that year.

Calculating the historical frequency of disasters in every prefecture in China is extremely challenging because the natural disaster data we use covers only 120 observation spots. Shiue (2002) and Keller and Shuie (2007b) follow the simplest approach, which is that if an observation spot is in the prefecture, the degree of natural disaster recorded at that observation spot is assumed to reflect the natural disaster situation of the whole prefecture. If no observation spot is located in the prefecture, the adjacent observation spot is used instead. However, due to the large area of individual prefectures in the Qing dynasty, this approach may cause inaccuracy. In meteorology, the Ordinary Kriging approach is a popular means of calculating the parameters of an unknown spot based on known spots. In this paper, we use the Ordinary Kriging approach to interpolate the disaster degree in every county from the 120 observation spots every year. In this method, the disaster degree becomes a floating number and is no longer one of the original 5-level integer numbers. The distribution of meteorological data in every county is constant for the 120 observation spots, and we restore the data as 5-level data through the Ordinary Kriging approach. By adding the degree of floods and droughts, the historical disaster frequency at the county level in every year is obtained. Furthermore, after matching the prefectures with current counties, the prefecture-level meteorological data can be defined as the mean data of the counties contained in each prefecture.

Figure 2 shows the distribution of natural disasters in China from 1746-1795. We divide the prefectures into 3 levels: slight, normal and severe. Figure 2 illustrates that the disaster frequency in the east regions was higher than that in the west. The disaster frequency in the western provinces, such as Gansu, Sichuan, Guizhou and Yunnan, was low. In contrast, the prefectures that experienced serious disasters were mainly distributed in Shanxi, Shandong, Jiangsu, Jiangxi and Fujian Provinces.

Figure 2. Natural disasters in China (1746-1795).

The data of distances and rivers

Previous research has demonstrated that traffic affects market integration significantly. Thus, we control both geographical distance and traffic in this paper. The distance data originate from *The China Historical Geographic Information System* (CHGIS), which provides the latitudes and longitudes of all the central cities in the prefectures and counties during the Qing dynasty. The average distance separating all 216 prefectures used in this paper is 992.16 kilometers, and the standard distribution is 486.87 (Table 2).

In early modern society, transport technology was non-mechanized, and the river was the most reliable means of transporting grain. Our data relating to the main river situation are basically based on Deng (1994), which estimates the quantities of grain transported by the Yangzi River, Xijiang River, Hanjiang River, Minjiang River, Huaihe River, Yellow River, Haihe River, Luanhe River and Grand Canal from Beijing to Hangzhou, which were greater 100 thousand dan in every year during the Qing dynasty. In our paper, the Yangzi River, Yellow River, Huaihe River, Xijiang River and Grand Canal are selected as our main transport rivers, as their grain transport quantities are more than 1 million dan. Using the river paths and the map of the Qing dynasty in 1820 derived from the Set of Chinese Historical Maps, we consider that the river flows through the prefectures when the main branch of the river overlaps with the region. The 6 rivers we used flow through 80 prefectures and most of the provinces, except Fujian Province.

Overall, compared with Shiue (2002) and Keller and Shiue (2007b), we increase the number of samples from 10 southern provinces to 18 provinces and the number of prefectures from 121 to 216. Furthermore, we use a more scientific means to manipulate the data relating to natural disasters to ensure the accuracy of our results.

Table 2. Statistical description of the key variables.

IV. Empirical analysis

The measure of market integration

Market integration is regarded as one of the most important indicators for estimating market growth (Sexton et al., 1991; Chen and Knez,1995; Bekaert and Harvey,2003). Thus, market integration can be measured by the price correlation coefficient between two markets in different regions; the specific calculation formula is as follows:

$$PC_{ij} = \frac{\sum_{t=t_0}^{tn}(P_{it}-\overline{P_i})(P_{jt}-\overline{P_j})}{\sqrt{\sum_{t=t_0}^{tn}(P_{it}-\overline{P_i})^2 \sum_{t=t_0}^{tn}(P_{jt}-\overline{P_j})^2}} \quad (1)$$

In (1), PC_{ij} represents the price correlation coefficient of market i and market j. P_{it} and P_{jt} denote the prices of prefecture i and prefecture j, respectively, at time t. $\overline{P_i}$ and $\overline{P_j}$ denote the average prices of prefecture i and prefecture j, respectively, from $t_0$to t_n. In this article, $t_0 = 1746, and\ t_n = 1795.$ First, we pair one prefecture with another prefecture in both the rice and wheat markets, and then, we calculate the price correlation coefficient between each pair of prefectures The number of price correlation coefficient observations in the rice markets of 119 prefectures in February and August is 7021, whereas that in the wheat markets in March and October is 12880. Thus, there are 39802 observations in total. In Table 2, the first line shows the statistical description of the long-term price correlation coefficients of 216 prefectures in 18 provinces in the Qing dynasty during 1746-1795. The mean value of the price correlation coefficient of prefectures is 0.21, the minimum is -0.71, and the maximum is 0.96.

The relationship between natural disasters and market integration

After the long-term price correlation coefficients between any two prefectures during 1746-1795 was calculated, we constructed a model of the market integration of a prefecture relative to all others to represent the whole market integration situation of market i. The specific formula is as follows:

$$PC_i = \frac{\sum_{j \neq i}^{N} PC_{\mathrm{ij}}}{N-1} \qquad (2)$$

In (2), PC_i represents the average value of the grain price correlation between prefecture i and all other prefectures. PC_{ij} represents the grain long-term price correlation coefficient between prefecture i and prefecture j, as introduced previously.

PC_i measures the general grain market integration of prefecture i. In this paper, we select the rice price in lunar February and August and the wheat price in March and October. We first calculate the long-term price correlation of the four months separately and then compute the degree of the general market integration. Furthermore, natural disaster data are used to calculate the disaster frequency from 1746 to 1795 for every prefecture. Figure 3 shows that the long-term natural disaster frequency correlated positively with market integration in both the rice market and the wheat market, indicating that a natural disaster in the region would promote grain market growth.

Figure 3. Scatter plot of the relationship between grain market integration and natural disaster frequency in the prefectures of the Qing dynasty.

Although Figure 3 illustrates a positive correlation between natural disasters and grain market integration, other variables, such as distance and traffic, may also affect market integration. Thus, we control these other variables to verify the relation in the next section.

Regression model

The most compelling contribution of this paper is that we propose a new hypothesis suggesting that natural disasters determine market integration. The dependent variable in this paper is the price correlation coefficient between two prefectures, and the key independent variable is the sum of the natural disaster frequency of these two prefectures between 1746 and 1795. The distance between two prefectures is controlled in the regression. The basic regression model is shown below.

$$PC_{ij} = \beta_0 + \beta_1 \cdot Disaster_{ij} + \beta_2 \cdot Distance_{ij} + \beta_3 \cdot Disaster_{aij} \cdot Distance_{ij} + \mu_{ij} \qquad (3)$$

In formula (3), PC_{ij} is the price correlation coefficient between prefecture i and j; $Distance_{ij}$ is the distance between prefecture i and j. $Disaster_{ij}$ is the sum of the frequency of floods and droughts between two prefectures during 1746-1795, and μ_{ij} is the stochastic disturbance term.

Table 3 shows the results. In R1, we take only nature disaster as the independent variable, and β_1 is highly statistically significant. After controlling the effect of distance in R2, natural disasters remain pronounced. However, distance negatively affects market integration, which is consistent with Parsley and Wei (2001). Furthermore, we add the interaction term of natural disasters and distance into the regression. The interaction term is also negative, which indicates that the influence of a disaster on grain market integration decreases as the distance increases.

Table 3. Natural disasters and grain market integration: Regression model.

V. Robustness Test

In addition to natural disasters and the distance between prefectures, other factors, such as traffic and institutions, may also influence market integration. Thus, we control the traffic and crop types in this section.

The traffic factor

Traffic conditions are a key factor impacting market integration. Because the railway was not available prior to modern society, the transporting paths are constrained by the natural geographical environment. River transport is always regarded as an efficient means of transporting bulk stock, such as grain and cotton. The cost of river transport is much lower than that of land transport, and grain was usually transported by shipping during the early period of the Qing dynasty. In this paper, we consider the river conditions using the regression model described below.

$$PC_{ij} = \beta_0 + \beta_1 \cdot Disaster_{ij} + \beta_2 \cdot Distance_{ij} + \beta_3 \cdot River_{ij}$$
$$+\beta_4 \cdot Disaster_{ij} \cdot Distance_{ij} + \beta_5 \cdot Disaster_{ij} \cdot River_{ij} + \mu_{ij} \quad (4)$$

In formula (4), $River_{ij}$ is a dummy variable. If the main rivers (Yangzi River, Yellow River, Haihe River, Huaihe River, Xijiang River and Grand Canal from Beijing to Hangzhou) flow through prefecture i and prefecture j at the same time, then $River_{ij}$=1; otherwise, $River_{ij}$=0. The results are reported in R1 and R2 in Table 4. After controlling traffic, natural disasters remain a significant predictor of the likelihood of market integration, which is consistent with the basic regression. The river positively influences market integration at the 1% level.

Table 4. Natural disasters and grain market integration (Controlling the influences of traffic and crop type).

The regression result considering the crop types

Using the data on the rice and wheat markets, we analyzed the impact of natural disasters on grain market integration. However, whether this impact will differ between crop types remains to be addressed.

The planting and storing conditions of rice and wheat are very different, leading to different market behaviors when natural disasters occur and differences in market integration. R3 and R4 in Table 4 report the results. In addition to the traffic factor, we also add a crop type dummy variable to the model. The result of impact of natural disasters on market integration remain robust. The degree of market integration is higher for the rice market than for the wheat market. In R4, we add additional interaction items, and the crop type dummy is significantly positive, indicating that the rice market is more affected by natural disasters than the wheat market. This finding may be attributed to the different planting conditions, as rice is more reliant on the natural environment than wheat, and thus, natural disasters have a stronger influence on rice.

Figure 4. The line chart relating grain market integration and natural disasters in the Qing dynasty.

The regression result from a dynamic perspective

Natural disasters promote grain transport-based commerce, population movement and infrastructure construction. However, the impact may be lagged. In this section, we verify the impact of natural disasters on market integration from a dynamic perspective. First, the data of natural disasters during 1695-1746 are used instead those from 1746-1795. Table 5 reports the results. From this table, we can observe that natural disasters affect the market growth significantly positively, and the results remain robust after controlling other variables.

Table 5. Natural disasters and grain market integration: Hysteresis effect.

Furthermore, we divide the period of 1746-1795 into 5 periods (10 years each) to verify the relationship. After calculating the price correlation between two prefectures for each period, we compute the average degree of market integration for each prefecture and the average degree of natural disaster for every prefecture. The dynamic trend is depicted in Figure 4, which indicates that the market integration is exactly consistent with the natural disaster frequency. For further study, we regress all the samples in the 5 periods while controlling the period dummy. R1, R2 and R3 are the regressions with the current period natural disasters as the key variable, whereas R4, R5 and R6 are the regressions with the lagged period natural disasters as the key variable. In all the regressions, the coefficient of natural disasters is significant and positive, leading to the conclusion that natural disasters promote market growth.

Figure 4. The line chart of grain market integration and natural disasters in the Qing dynasty.

Table 6. Natural disasters and market integration: The result of segmented regression.

VI. Conclusion

Market evolution is an essential problem in economics. As the primary extreme weather conditions, natural disasters have played an important role in market evolution, but previous research has not elucidated this relationship strictly and scientifically. In this paper, we first analyze the mechanism by which natural disasters promote grain market integration. Then, using the grain price data of 216 prefectures in 18 provinces, a practical analysis is conducted, proving that natural disasters can significantly positively affect grain market integration. Furthermore, the results remain robust in different models. This paper provides a new perspective for understanding market evolution.

Although this paper demonstrates that natural disasters can promote grain market evolution, we do not agree with the mechanical nature determination theory. Instead, this paper agrees with the opinion of Arnold Toynbee (1972), a great historian: "In Man, the decisive factor---the factor that tips the balance either success or towards failure---is not race, and it is not skill either, it is the spirit in which man responds to the challenge of the sum total of nature that has become man's environment as a result of man's own appearance in the universe". Thus, natural disasters induce disaster relief, which promotes grain market growth.

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Table 1. Descriptive statistics of the wheat and rice markets from 1746 to 1795.

Crop type	Province	Number of prefectures	Number of observations	Average grain price(Liang/Dan)	Deviation of grain price
Wheat	Anhui	13	1300	1.17	0.20
	Gansu	11	1100	1.05	0.36
	Henan	9	900	1.31	0.32
	Hubei	9	900	1.04	0.22
	Hunan	9	900	1.07	0.17
	Jiangsu	11	1100	1.29	0.22
	Jiangxi	13	1300	1.26	0.16
	Shandong	9	900	1.50	0.29
	Shannxi	12	1200	1.26	0.40
	Shanxi	18	1800	1.90	0.40
	Sichuan	11	1100	1.00	0.37
	Yunnan	21	2100	1.29	0.44
	Zhejiang	10	1000	1.26	0.20
	Zhili	5	500	1.84	0.39
Total of wheat provinces		161	16100	1.31	0.42
Rice	Anhui	13	1300	1.57	0.27
	Fujian	11	1100	1.71	0.25
	Guangdong	13	1300	1.51	0.28
	Guangxi	12	1200	1.12	0.16
	Guizhou	13	1300	0.97	0.17
	Hubei	9	900	1.35	0.23
	Hunan	13	1300	1.19	0.16
	Jiangsu	10	1000	1.82	0.32
	Jiangxi	14	1400	1.43	0.19
	Zhejiang	11	1100	1.57	0.20
Total of rice provinces		119	11900	1.41	0.34

Table 2. Statistical description of the key variables.

Variable name	Meaning	Mean	S.D.	Min.	Max.
PC_{ijt}	Price correlation coefficient of two prefectures during 1746-1795	0.21	0.29	-0.71	0.96
$Disaster_{ijt}$	Sum of the weighted disaster frequency between two prefectures during 1746-1795	0.97	0.35	0.10	1.95
$Distance_{ij}$	Distance between two prefectures (km)	992.16	486.87	5.49	2495.19
$River_{ij}$	Whether a river connects two prefectures or not (1=yes, 0=no)	0.04	0.19	0.00	1.00
Crop	Crop type (1=rice, 0=wheat)	0.35	0.48	0.00	1.00

Table 3. Natural disasters and food market integration: Regression model.

Variable	Price correlation coefficient		
	R1	R2	R3
$Disaster_{ijt}$	0.19***	0.05***	0.23***
	(0.00)	(0.00)	(0.01)
$Distance_{ij}$		-0.33***	-0.08***
		(0.00)	(0.01)
$Disaster_{ijt}$*$Distance_{ij}$			-0.27***
			(0.01)
Constant	0.02***	0.45***	0.27***
	(0.00)	(0.01)	(0.01)
Observation	39,802	39,802	39,802
Adjusted R^2	0.044	0.322	0.338

Note: Robust standard errors are in parentheses. *** Significant at 1 percent level. ** Significant at 5 percent level. * Significant at 10 percent level.

Table 4. Natural disasters and food market integration: Controlling traffic and crop type.

Variable	Price correlation coefficient			
	R1	R2	R3	R4
$Disaster_{ijt}$	0.05***	0.23***	0.07***	0.11***
	(0.00)	(0.01)	(0.00)	(0.01)
$Distance_{ij}$	-0.32***	-0.09***	-0.30***	-0.12***
	(0.00)	(0.01)	(0.00)	(0.01)
$River_{ij}$	0.07***	0.12***	0.09***	0.07***
	(0.01)	(0.02)	(0.01)	(0.02)
Crop(1=rice, 0=wheat)			0.08***	-0.31***
			(0.00)	(0.01)
$Disaster_{ijt}$*$Distance_{ij}$		-0.27***		-0.21***
		(0.01)		(0.01)
$Disaster_{ijt}$*$River_{ij}$		-0.06***		-0.00
		(0.02)		(0.02)
$Disaster_{ijt}$*Crop				0.39***
				(0.01)
Constant	0.44***	0.27***	0.37***	0.35***
	(0.01)	(0.01)	(0.01)	(0.01)
Observation	39,802	39,802	39,802	39,802
Adjusted R^2	0.325	0.340	0.340	0.390

Note: Robust standard errors are in parentheses. *** Significant at 1 percent level. ** Significant at 5 percent level. * Significant at 10 percent level.

Table 5. Natural disasters and grain market integration: Hysteresis effect.

Variable	Price correlation coefficient						
	R1	R2	R3	R4	R5	R6	R7
$Disaster_{ijt-1}$	0.23***	0.11***	0.20***	0.11***	0.20***	0.11***	0.04***
	(0.00)	(0.00)	(0.01)	(0.00)	(0.01)	(0.00)	(0.01)
$Distance_{ij}$		-0.32***	-0.19***	-0.31***	-0.20***	-0.30***	-0.23***
		(0.00)	(0.01)	(0.00)	(0.01)	(0.00)	(0.01)
$River_{ij}$				0.07***	0.11***	0.08***	0.06***
				(0.01)	(0.02)	(0.01)	(0.02)
Crop(1=rice,0=wheat)						0.07***	-0.26***
						(0.00)	(0.01)
$Disaster_{ijt-1}$*$Distance_{ij}$			-0.14***		-0.13***		-0.09***
			(0.01)		(0.01)		(0.01)
$Disaster_{ijt-1}$*$River_{ij}$					-0.05**		0.01
					(0.02)		(0.02)
$Disaster_{ijt-1}$*Crop							0.33***
							(0.01)
Constant	-0.02***	0.38***	0.29***	0.37***	0.29***	0.33***	0.41***
	(0.00)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Observation	39,802	39,802	39,802	39,802	39,802	39,802	39,802
Adjusted R^2	0.063	0.333	0.337	0.336	0.339	0.348	0.381

Note: Frequency of natural disasters using data of pre-fifty years (1696-1745). Robust standard errors are in parentheses. *** Significant at 1 percent level. ** Significant at 5 percent level. * Significant at 10 percent level.

Table 6. Natural disasters and market integration: The result of segmented regression.

Variables	Price correlation coefficient					
	R1	R2	R3	R4	R5	R6
$Disaster_{ijcurrent}$	0.15***	0.09***	0.28***			
	(0.00)	(0.00)	(0.01)			
$Disaster_{ijprevious}$				0.10***	0.04***	0.16***
				(0.00)	(0.00)	(0.01)
$Distance_{ij}$		-0.25***	-0.01*		-0.26***	-0.09***
		(0.00)	(0.01)		(0.00)	(0.01)
$River_{ij}$		0.09***	0.08***		0.09***	0.06***
		(0.01)	(0.01)		(0.01)	(0.01)
Crop(1=rice, 0=wheat)		0.10***	0.09***		0.09***	0.04***
		(0.00)	(0.01)		(0.00)	(0.01)
$Disaster_{ij}$*$Distance_{ij}$			-0.27***			-0.19***
			(0.01)			(0.01)
$Disaster_{ij}$*$River_{ij}$			-0.01			0.01
			(0.01)			(0.01)
$Disaster_{ij}$*Crop			0.01***			0.06***
			(0.01)			(0.01)
Constant	0.12***	0.35***	0.18***	0.21***	0.46***	0.35***
	(0.00)	(0.01)	(0.01)	(0.00)	(0.01)	(0.01)
Period fixed-effects	Yes	Yes	Yes	Yes	Yes	Yes
Observation	99,505	99,504	99,504	99,505	99,505	99,505
Adjusted R^2	0.048	0.159	0.176	0.035	0.153	0.163

Note: The key independent variable in models R1, R2, and R3 of Table 6 is the frequency of the current natural disasters. The key independent variable in models R4, R5, and R6 is the frequency of previous natural disasters. Robust standard errors are in parentheses. *** Significant at 1 percent level. ** Significant at 5 percent level. * Significant at 10 percent level.

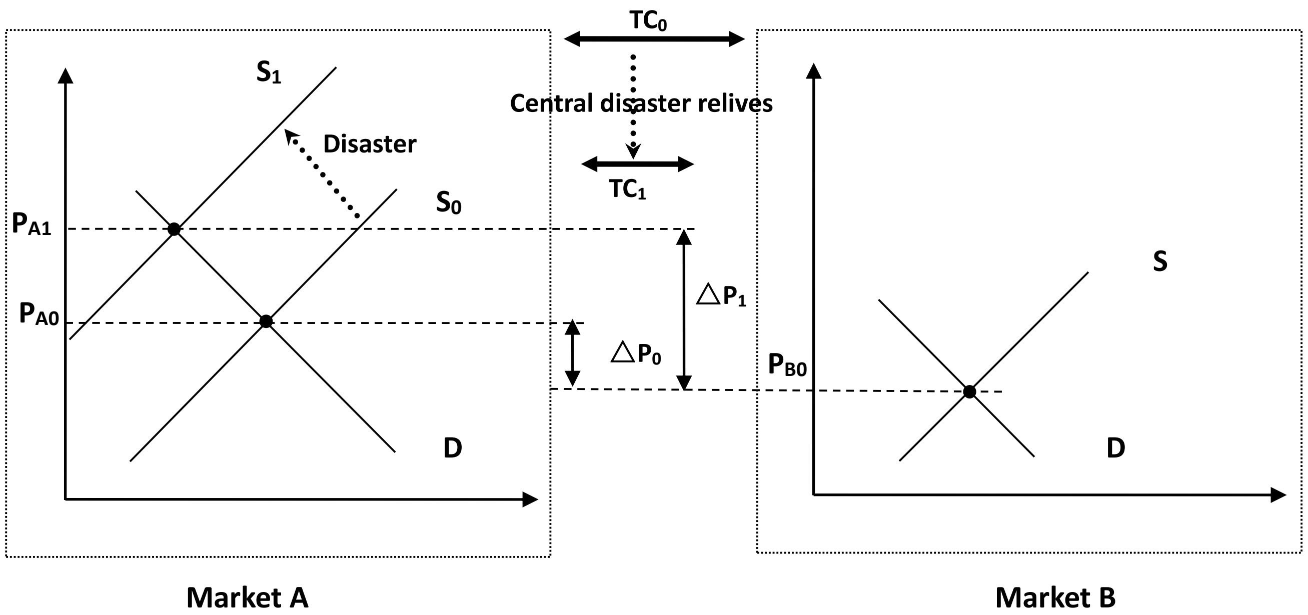

Figure 1. The effects of natural disasters on market integration.

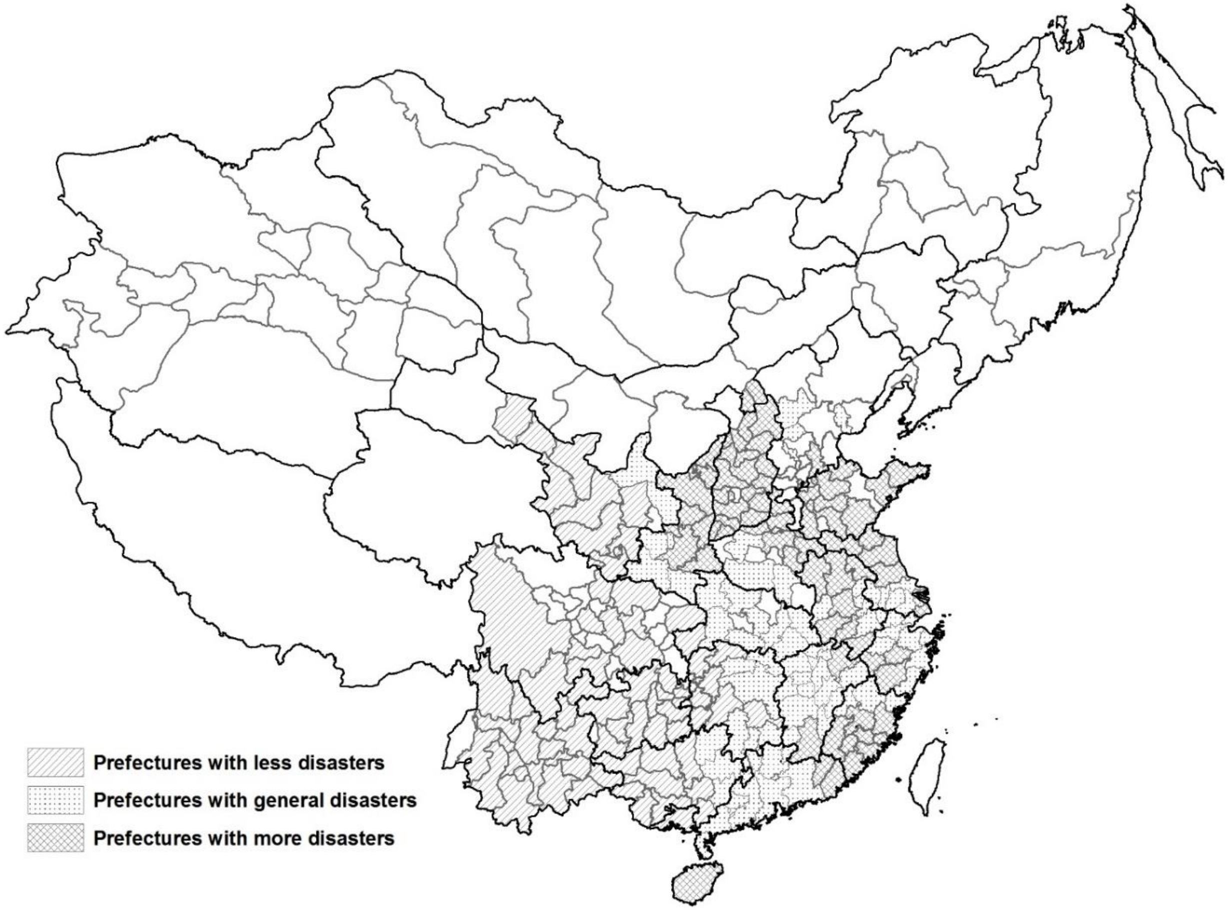

Figure 2. Natural disasters in China (1746-1795).

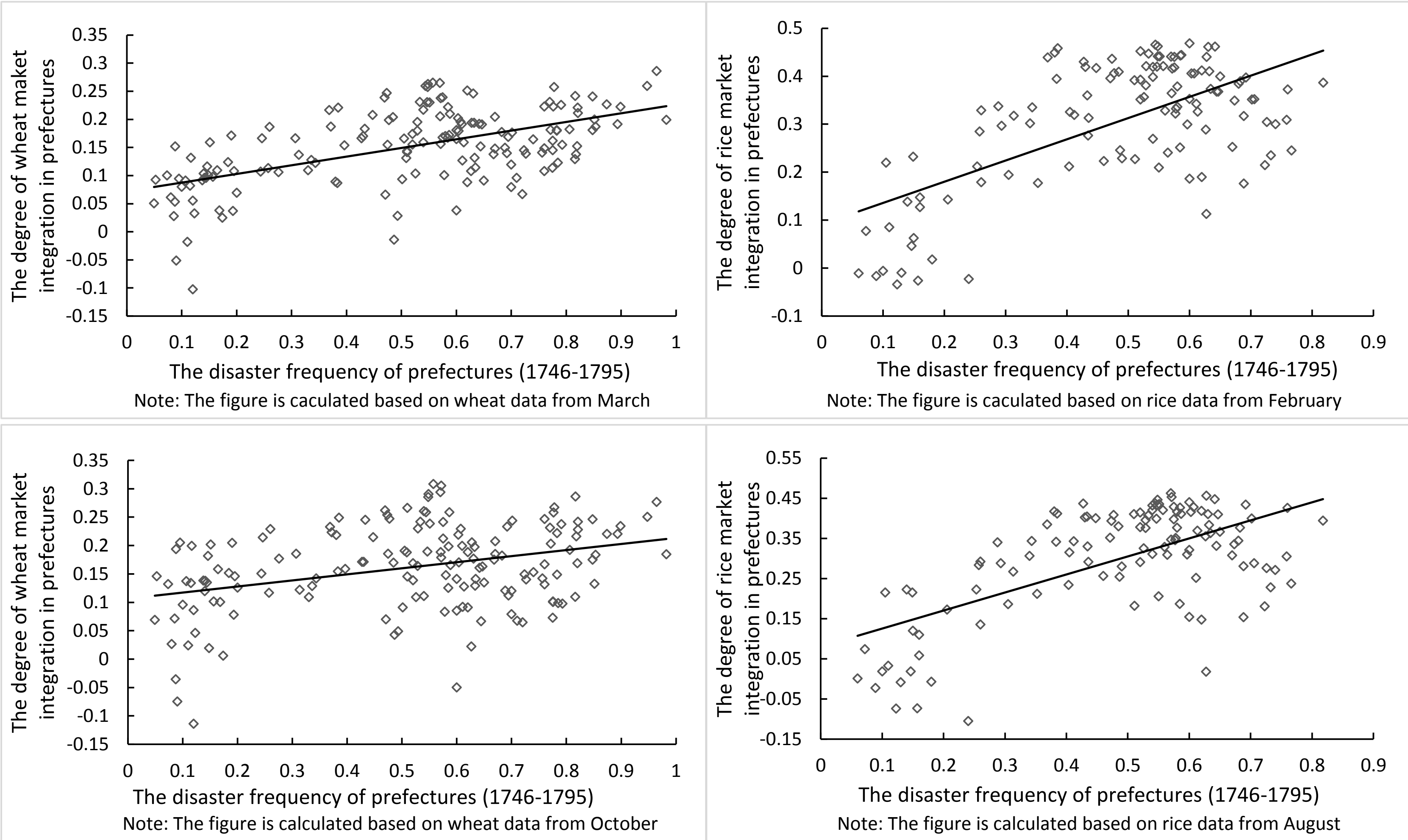

Figure 3. Scatter plot of the relationship between grain market integration and natural disaster frequency in the prefectures of the Qing dynasty.

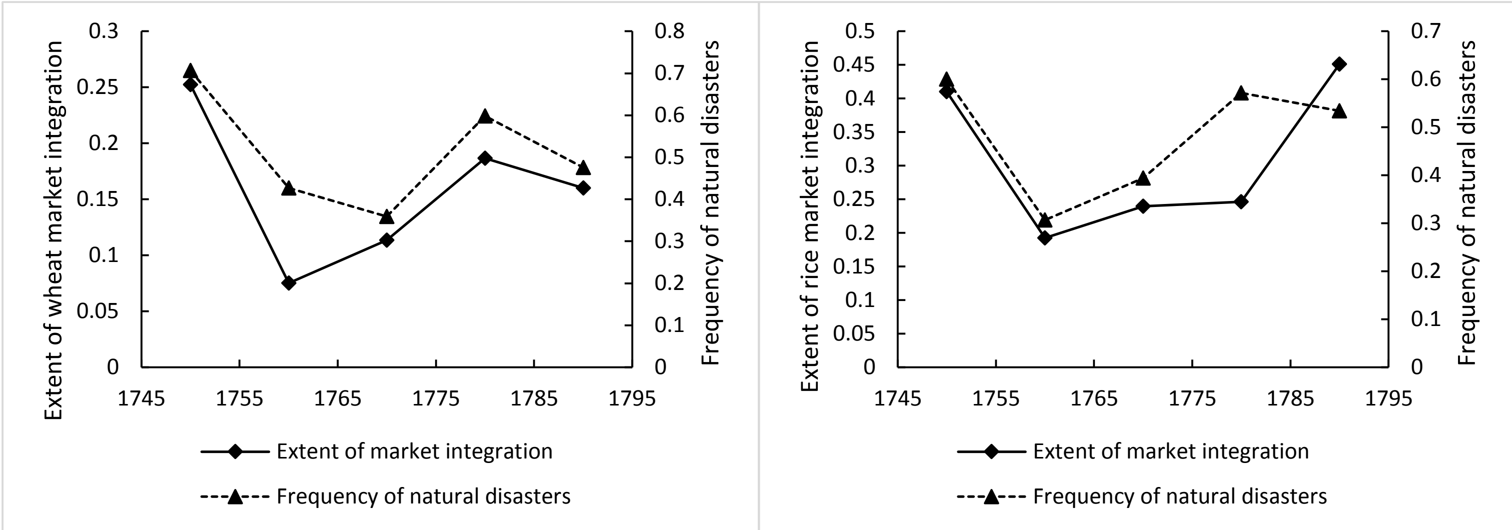

Figure 4. The line chart relating grain market integration and natural disasters in the Qing dynasty.