The State Civilian Granary System and the Rice Market in 18th–19th Century China

Ye Ma

Faculty of Economics and Business
University of Groningen

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Abstract

The granary system in 18th-19th century China can be seen as a special political-economic arrangement which embodies the government's attention to and recognition on the grain market. Among all these functions of the granary system, its influence on grain prices is the main focus of this paper. This paper tries to answer the question whether the state had the capacity to "stabilize" grain prices, which is supposed to be the main target of the state civilian granary system. We find that the government-organized granary system did work in some part of the country, especially in the area where the system can take advantage of the inland waterways and can be easily monitored by the central government. The effect of the granary system is regional imbalanced. However, the effect is economically insignificant. It is possible that local granaries lacked a sufficient ability to sell out or buy in such amount of grain storage that can largely affect market prices. In other words, the system could be useful but to get it started we need a huge amount of "energy". This weakens the efficiency of the system. Finally, some puzzles are remained, such as the relationship between markets and the granary system.

1 Introduction

Studies on historical grain prices have drawn more and more attention in the academic world, accompanied by a large number of grain prices available for economic analysis. Benefiting from these economic-historical studies, we get more knowledge about the long-run economic development from pre-modern ages, such as changes of general price levels and people's living standards (Wang 1972, 1989, Allen et al. 2011), the development of grain markets and trade (Shiue and Keller 2007, Földvári, van Leeuwen and Van Leeuwen-Li 2012).

The recent studies on market integration also heavily rely on historical records on grain prices. In China, for an instance, the grain price record can be traced back to the 18th century. In their opinion, the space and time attributes of grain prices will directly lead to an understanding of market behavior, which can be seen as signs of economic development. But, this is not the entire story about the Chinese grain market, where the market is not the only force in the price-formation process. In 18th-19th century China, the emperors tried to monitor local grain prices through a report system. They were also involved in the grain market actively through the state civilian granary system which had long been an important part of regular government administration in pre-modern China. Thus, before we attribute the high level of market integration derived from the price data to market performance, a hypothesis is waiting to be tested: public intervention did not contribute to it. In other words, did the granary system work as it was supposed to aim at price stabilization?

The granary system is a central topic in studies on the institutional history of the Qing Empire. According to Will and Wong (1991), it embodies a complex "political context". It represents the Qing state's opinion on how to manage the country and also a conflict between "Confucian policies" and "interventionist approaches". It also represents a government structure, formal and informal, which includes the central government, the local administrator, and the local gentry. It is so essential that it should be part of the fiscal system. The investigation into the granary system and its influence on the grain market would be a good starting point to understand the economic policies toward price stabilization that had been used centuries ago, to evaluate the Qing state's capacity to manage its economy, and to investigate political institutions that may still work in our modern economy

The structure of the paper is as follows. In section 2, I give an introduction about the granary system and summarize the related literature. Section 3 is about the data sample and a descriptive summary. Section 4 is about a structural model and the econometric method. Section 5 and 6 present the results and the robustness tests. In section 7, I give a conclusion.

2 Price interventions and the Chinese state civilian granary system

In this section, I will first introduce the background information about how the Qing state intervened into the grain market and the Chinese granary system. Then, I will summarize from the related literature what we know, what we still do not know, and some potential improvements. Working on these improvements, this paper tries to contribute to the major discussion about the granary system and the Qing state's ability

to influence the economy.

2.1 An introduction to the background

What is special for the Qing Empire is its concern about the grain market. Perhaps motivated by its own interest in political stability, the bureaucracy paid out great efforts on monitoring the grain market. The central government maintained a record of grain prices ("List Prices") reported from all provinces, which include monthly prices for a variety of crops, such as rice, wheat, millet, etc. The longest period the record covers is from the 1730s to the end of the Qing Empire. Not only collecting price information, the Qing state actually kept a closer watch on the grain market supply and demand. There are two kinds of reserves which the Qing state could rely on to influence the grain market. One is the silver reserve in the state treasury which can be used as government transfer when facing emergencies and shortages, such as food crisis. The other is the grain reserves, partly stocked in local granaries across the country[1]. Other than the precious metals stored in the far-away capital (Zhili Province, in north China), local grain storage could quickly response to fluctuations in crop production. This is the so-called state civilian granary system in China, which, according to Will and Wong (1991), can be attributed as a "penetrating and systematic achievement" in the Qing Empire.

Then, what is the granary system? As described in Will and Wong (1991), there are three types of granaries: ever-normal granaries, community granaries, and charity granaries. Distinguished from the latter two, ever-normal granaries are the most important one, which were operated by local magistracy and built up mainly through provincial treasury funds. The storage in the ever-normal granaries accounted for 65 to 85 percent of the total granary storage in the 18th century (Li 1982). Especially, only the grains in ever-normal granaries can be transferred inter-provincially. In general, rice, wheat, beans constitute the main granary storage in north Qing China, while in south Qing China, rice is the main granary holding. Will and Wong (1991) also review the development of the granary system in their book. The stock in granaries reached the peak in the 1780s, gradually decreased after that, and finally ended in the 1850s.

The related literature mentions three main functions of the granary system. First, it is used as relief against food shortages which can be caused by emergencies, such as natural disasters, or by regular harvest fluctuations. Second, it provides short-term loans to peasants in the form of seed grain, which could prevent the famine followed by natural disasters and support new land cultivation. Third, it is used for grain price stabilization, i.e. to smoothen extreme price fluctuations. Essentially, the granary system stands as a social insurance, which mitigates the influence of unwanted output shocks to the grain market and the food consumption. The national credit behind the granary system ensures a stable environment for resource allocation by limiting investment risks in agricultural production and affecting market expectation formation. It also provides a cross-insurance institution, since the granary system encourages the intra- and inter-provincial grain trade particularly when facing natural disasters. Its effect is equivalent to "a redistribution of income" through which "the people funding the granaries (most likely wealthy taxpayers) overlapped only partially with those people receiving benefits from the system" (Vogel 1995).

[1] Another part of grain reserves was in direct control of the central government, which was mainly used for military purposes. The level of grain storage was "at least equivalent to that in the local granaries" (Li 1982).

2.2 Literature review

Among these functions, the relationship between the granary system and grain prices is the focus of this paper. The rest part in this section will discuss about how local granaries were managed and operated, and the influence on grain prices. In the regulation, the local granaries should sell out about 30 percent of their total stock in March and April and buy back in September, to minimize seasonal price fluctuations. The official price was also regulated directly by the central government, the Board of Revenue, according to Will and Wong (1991). The *selling* price was set around the market price with a discount or a premium according to local needs and its maximum level was settled. Will and Wong (1991) mentions that the *purchasing* price had been fixed since the 1730s and 1740s, while the market price kept increasing during the 18^{th}-19^{th} century. However, it is still unclear that how the central government set the price for local grain stocks.

In practice, sales and purchases would be more regular in order to prevent grain spoilage. Sometimes, the restocking could not be fulfilled in one time. Actually, the rate of annual disbursal could be more than 50 percent in some cases (Li 1982, Will and Wong 1991). Thus, local governments had a certain degree of autonomy on the timing of sale and replacement, and also the quantity, with respect to specific local conditions, such as weather and spatial factors. Through regular grain sales and purchases operated by local officials, the granary system actually allows for direct intervention into the grain market supply and demand.

Based on the above description of the granary system, we could find two aspects on which grain prices can be affected. The first one is straightforward. The granary system could help to eliminate the seasonality of price fluctuations. If it does work, then a larger stock in local granaries implies a higher potential for local governments to involve in price control, which will indicate a lower seasonal fluctuation in grain prices, as illustrated in Figure 7, column 1. Except for fluctuations through months, prices can vary through regions. Then, the second aspect is price dispersion across prefectures in one province. When a province holds a larger stock in its granaries, it will have a higher capacity to spread its influence to the whole political region, which will indicate a smaller level of price dispersion, as also illustrated in Figure 7, column 2. In the data section, the price variation will be discussed in more details.

Then, would the Qing granary system influence the grain price as we expect? Actually, this is still a debate (Li 1982). In Will and Wong (1991), they conclude that the granary system indeed palyed its basic roles, although due to managerial difficulties and adverse environmental conditions it did not work very smoothly. From their viewpoint, the Qing granary system is in general a success and proves the fiscal and organizational capabilities of the Qing state. However, Chuan and Kraus question that whether the storage of granaries which was widely scattered in the whole country could effectively perform its functions (1975). In Shiue and Keller (2007), based on a test of price cointegration among regional markets they find less evidence to show that a high storage in local granaries in one province would be companied by a high rate of co-movements among prices in different intra-provincial markets.

Some improvements will help to provide a better understanding of the relationship between the granary

system and grain prices. First, a direct test on the relationship would help to settle the debate, although previous literature has found lots of detailed evidence from both side of the debate. A complete study of the three functions of the granary system may be difficult, but focusing on one function would be feasible and even more helpful. While the study of the granary system and famine relief becomes more and more important, the study around granary storage and grain prices seems to just start (Shiue 2004, 2005). Second, a study including the two potential aspects of a price variation is still missing in the literature. Especially, the relationship between seasonality of price fluctuation and the granary system is still rarely touched. In Shiue and Keller (2007), the cointegraion test of price movements across different regions is actually a measure on regional price differences. It is a test on price dispersion, rather than on seasonality. Even though the movements of prices in two regions are highly correlated, their seasonal fluctuations can be arbitrarily high or low. Thus, a rejection of a test on price dispersion cannot completely deny the effectiveness of the granary system.

The related literature indicates that the interaction with spatial factors could reinforce or weaken the influence of the granary system, but their reasoning needs tests. For instance, Will and Wong (1991) point out that a province near to the Grand Canal could benefit from the inland water transport to manage its granaries. Meanwhile, the area along the Canal is mainly overlapped with the low Yangzi-delta region which had a high level of commercialization and market integration. According to Chuan and Kraus (1975), the effect of granaries depends on the degree of commercialization. Then, it should be limited when getting near to the Canal. The arbitrary effects of the granary system around the Canal would cause inaccuracy in data analysis which ignores the interaction between the two. Another important spatial factor is related to the cost of the central government to monitor local granaries. For a province near to the national capital, the potential costs for transportation and communication should be low. Then, it is easier for the central government to keep a close watch on the management of local granaries. When getting close to the national capital, the effect of the granary system would become more significant.

Although mentioned implicitly by the related literature, there is one concern underlying the line of reasoning. Do we draw the correct circle through which we observe and study the granary system and grain prices? Here, the circle is usually the borders of a province. Skinner suggests through a model of a nested hierarchy of markets that administrative units, such as provinces, may not be "proper units for analyzing urbanization" (Skinner 1964, Li 1982). The circle may include more than one province or cover part of a province, according to similar social and economic conditions. And, the circle may change which will have impacts on the development of local markets. However, the different opinion is that political borders are determined endogenously by the process of urbanization and economic development (Alesina and Spolaore 2005). Engel and Rogers in their test of the law of one price shows that political borders do matter, which significantly increase the price dispersion between two cities which are separated by political borders (1996). After all, the study of the granary system is actually more relevant to political institutions and should focus on the area where local granaries were developed and managed. Including the spatial relationship between provinces should be a proper solution for this problem, inspired by Shiue and Keller's study on interregional grain trade (2004). The price variation in one province can be impacted indirectly by the grain stocks in its neighbor's granaries. If its neighbors hold a high stock of grain, then we would expect a low price variation in this province. This may indicate potential interprovincial transfer and cooperation against food crisis.

As explained above, improvements will be made through direct data analysis on seasonality and dispersion, respectively. The main question is whether the granary system has different impacts on price fluctuations referring to relative spatial positions.

3 Data

This section will introduce the data applied in this paper. I will first explain why this dataset is suitable for the following analysis, and then illustrate the primary relationship between granary storage and grain price. I will also point out some potential problems in the data. The descriptive statistical properties are listed in Table 1.

The data includes two periods, 1776-1796 and 1827-1846 (period 1 and 2, for short), and covers four provinces along the Grand Canal, Anhui, Jiangsu, Zhejiang, and Shandong (See Figure 1). First, why need these two periods? Except for data availability, the choice of the data is mainly supposed to capture the potential structure change in the granary system overtime. As mentioned before, the granary system prospered in the 1980s and ended in the 1850s. Although debatable, Will and Wong suggest that the decline of the granary system is actually a sign of state withdrawal in monitoring private actions (1991). Second, why choose the area along the Canal? The level of granary storage should be high in the region with a large population and convenient transport, in order to fulfill the function of the granary system as a cross-insurance system. Also, it should be the area where the central government would like to pay attention to. Thus, the Canal region is the choice. Moreover, this is the area with a high degree of commercialization and market integration (Shiue and Keller 2007, Földvári, van Leeuwen and Van Leeuwen-Li 2012). By using the data along the Canal, an interesting hypothesis can be tested: whether the market weakens the effectiveness of the granary system.

This paper uses the rice price as a representative of grain prices. Why uses rice here? The reason is that the Canal region is also in the low Yangzi-delta region which was the major rice market in the Qing Empire and where rice was the main reserve grain (Wang 1972, Will and Wong 1991). Rice was the most important agricultural product and the main food at that time. Thus, the rice price should be more sensitive to the changes in the market and the social environments. As illustrated in Figure 3, compared with wheat which was also commonly consumed and cultivated, the two crops share the similar pattern of price fluctuations and in general rice has a higher level of seasonality and price dispersion. Checking Table 1 for descriptive statistics, we find that the price data of rice and wheat are quite similar, especially when considering price seasonality. This choice also causes a problem. I have to leave Zhili province out of the dataset although it is at the end of the Grand Canal, because of the missing-data problem.

The price data contains monthly prices in prefectures measured in copper coins named *fen*[2], which combines two databases[3]. One is "the Qing-era Grain Price Database" which mainly covers the early Qing.

[2] *Fen* is a monetary unit commonly used in the daily life in the Qing Empire. One hundred of *fen* equal to one tael.

[3] One is "the Qing-era Grain Price Database", http://140.109.152.38/. The other is "Grain Price Table Between 1821 and 1912". I am grateful to Professor Bas van Leeuwen (Utrecht University) for providing the dataset and the related

The other is “Grain Price Table Between 1821 and 1912” aiming at the late Qing. Both of the two datasets are originated from the records of “list prices” reported from local governments. Thus, one concern about the data quality is that these prices may not represent the actual market prices and data manipulation is possible.

I pick up 2 years, 1780 and 1830, to observe the price fluctuations in the four provinces with great details. From Figure 4, we actually cannot find any significant seasonal price changes in the two years except that the price in autumn is slightly higher. Comparing the two years, the degree of price seasonality seems to be the same, but for some provinces the average price becomes higher. However, we do see the increasing price dispersion- points become more scattered in the year of 1830. Figure 5 shows the price difference among prefectures at any specific month in 1780 and 1830, from which we can easily recognize the change between the two years. What is interesting from this figure is that for anyone of the four provinces the pattern of price dispersion is nearly equivalent across all the months, i.e. the same price difference between two prefectures remains all year long. If the transportation cost matters only, it is good proof of the law of one price.

Then, I define the two aspects of price fluctuations, seasonality and dispersion, as following. Figure 6 (a) and (b) summarizes the two indicators of price fluctuations. In general, the degree of seasonality is lower than that of dispersion; there are no general time patterns of seasonality but the degree of dispersion is increasing through time. These findings may indicate the increasing segmentation of markets in one province. These lower-hierarchy markets in a province may work well but separately from each other. Interestingly, Li find out the similar phenomenon in north China that the local grain markets there gradually fragmented from 1738 to 1911 (2000).

Monthly provincial price ($\bar{\mathrm{p}}_{\mathrm{m}}$)

= the average price across all the prefectures in one province at month m

Yearly prefectural price ($\bar{p}_t^j$)

= the average price of prefecture j across all the months in year t

Price seasonality in province i (ps_{it})

= the standard deviation of $\bar{\mathrm{p}}_{\mathrm{m}}$ across all the months in year t

Price dispersion in province i (pd_{it})

= the standard deviation of $\bar{p}_t^j$ across all the prefectures in province i in year t

This paper uses the total stock of unhusked grain in granaries (*g*) to indicate the potential ability of the granary system to affect the grain market. To be noticed, there is no need to distinguish the three types of granaries because that they were all government-sponsored and should function similarly in practice (Li 1982, Will and Wong 1991). The dataset contains annual provincial granary storage measured in *shi*[4], which was usually collected in the end of a year. It also combines two original records from Will and Wong (1991). But, there are no big differences in the two records. Figure 6 (c) shows the changes of granary storage, which is decreasing or remains the same. To be noticed, the granary storage fluctuated more greatly in the first period, which may indicate that the bureaucracy tried to avoid the use of granary

documents.

[4] *Shi* refers to an ancient Chinese volume unit for measuring grains.

storage in the latter period. They may still intervene into the grain market but not through the granary system.

This paper studies the effect of the *total* grain storage on price fluctuations of *one* crop. It may lead to inaccuracy, since a variety of crops that were stocked in one granary was calculated all together to get to the total storage. Except for data availability, three explanations would ensure the reasonableness to analyze the relationship. First, the main food crops, such as rice and wheat, are substitutes. Thus, the fluctuations of their prices are generally in the same direction. Second, a large stock in granaries would pass out the information to the grain market that the government will behave if prices go extremely high. Similarly to the effect of foreign reserve on the exchange rate, the grain reserve would also help to decrease the price variation. Third, a large stock in granaries would also indicate the fiscal and organizational capacity of a local government to monitoring the market. Then, we would expect a relatively small price variation in this province.

With the two indicators and two periods, Figure 7 roughly shows the correlation between the degree of price fluctuations (on the Y-axis) and granary storage (on the X-axis). They are indeed negatively correlated, but it seems that only the correlation with respect to price dispersion in period 2 is significant. Interestingly, it may imply that when the bureaucracy gives up the interventionist approach, things start to go worse.

4 Models and econometric methods

There are two sections in this part. Although it is hard to totally avoid data mining, I try to first construct a mechanism or a model to explain the fluctuations in rice prices (monthly and regionally) by focusing on the role of the granary system. Then, an econometric model is built on assumptions that can simplify the original structure model and facilitate the following data analysis.

4.1 Model

What factors may affect the fluctuations of rice prices? There might be hundreds of potential answers which are all reasonable. In Figure 8, I list some important ones and denote their relationships with the granary system, through which hypothesis testing can be easily built on. Basically, all factors that determine a price will also affect price fluctuations.

The two fundamental forces are public intervention and market conditions. The strength of a central government decides the degree of political stability, which is definitely one of the essential economic-related environmental conditions. A stock of silver reserve in the central state treasury could be an indicator of a government's ability to influence its economy directly. For instant, the Qing state could directly affect local markets by government transfer especially when natural disasters burst out. Local governments use local granaries to affect local markets, which was actually at their own expenses. Thus, the central cannot directly give orders to locals about how to manage grain reserves. But, it could monitor their behavior by sending supervisors to the local. Considering the (time) cost of transport and

communication, the distance from a provincial capital to the national capital (*ca*) is not only a spatial factor, but also a good proxy for the expenses of the central monitoring. Here, the local granary storage can be interpreted as the local government's potential ability to influence all its local grain markets.

Then, two explanations are possible, which needs to be verified by hypothesis testing. If the central government gives more attention to far-away areas since they may easily misbehave, then we would expect that the level of effectiveness of the granary system is larger in far-away provinces. If the central government tends to avoid the cost of monitoring and pays more attention to the near-by areas, then we would expect the opposite.

Market conditions may indirectly decide how intensity the granary system performs. For instance, in an area with convenient transportation the operation of local granaries should be easier. However, some of the market-related factors may be relevant to both the granary system and market performance indicated by the degree of commercialization and market integration. Lower transportation costs imply a higher level of commercialization, which limits the functions of the granary system. Here, I use the average distance to the Grand Canal in one province (*cl*) to represent the general transportation cost in one province, which is a proxy for market conditions. To be noticed, market performance has a direct impact on the degree of price fluctuations, but it is not easy to find a proper proxy.

Also, two explanations are possible. If the private market benefits more from the decreasing transportation cost when getting near to the Canal, then we would expect a decrease in the effectiveness of the granary system. If the granary system gets more, then we would expect the opposite.

Other potential factors, such as weather conditions (*w*), should also be included in. Then, the left is regional-specific time-invariant factors (*c*), such as the bureaucratic tradition in managing local granaries (Will and Wong 1991), the status of local gentry, the level of urbanization, etc. The above relationships can be summarized in the following equation.

$$The\ degree\ of\ price\ fluctuations_{it} = f(granary\ storage_{it}, silver\ reserves_{t},\\ costs\ of central\ monitoring_{it}, market\ conditions_{it}, market\ performance_{it}, weather_{it}, c_i) + u_{it} \quad \text{(a)}$$

4.2 Econometric methods

As explained above, the effect of the granary system on price fluctuations can be arbitrary, with respect to the central-local relationship and transportation conditions. To truly uncover the puzzle about the effectiveness of the granary system and to understand how the Qing state managed the economy, econometric analysis and hypothesis testing is helpful.

The data analysis in this paper is built on several assumptions. The distance from a provincial capital to the national capital (*ca*) will be used as the proxy for the monitoring cost of the central government. The underlying assumption about this proxy is that the cost is time invariant. It could not be unchanged for a period with forty years, but relatively it could be for a period with twenty years. Thus, by including a time

dummy we assume that the monitoring cost remains unchanged in each period (1 and 2), but can be different between the two periods. Similarly, the average distance to the Grand Canal in one province (*cl*) will be used as the proxy for market conditions. The underlying assumption is that the general market condition is also time invariant. It could be reasonable since we usually refer to market conditions as some fundamental institutions that were established long time ago and will not be easily changed within twenty years and fixed investment such as public infrastructure.

The most important assumption is made about market performance in 18th-19th century China. It is difficult to find a measure for market performance not only because of data availability but also the difficulty to define an abstract concept. However, this paper chooses a special data sample, which allows me to assume that the level of market performance was constant in the forty years in the sample area. This assumption is actually supported by the main findings in Földvári, van Leeuwen and Van Leeuwen-Li (2012).They study the long-run development of market performance, focus especially on the Qing Dynasty, and point out that "there was gradual, but slow improvement in market performance" before the 1850s. Without this assumption, we cannot separate the effect of a private market on price fluctuations from that of the granary system and public intervention. I also include a time dummy here to control the average difference in market performance between the two periods in the sample.

Then, we rewrite equation (a) with the two proxies as:

$$\begin{aligned} &The\ degree\ of\ price\ fluctuations_{it} = f(granary\ storage_{it}, silver\ reserves_t, \\ &costs\ of central\ monitoring_i, market\ conditions_i, market\ performance_i, weather_{it}, c_i) + u_{it} \\ &= f(granary\ storage_{it}, silver\ reserves_t, \\ &distance\ to\ the\ Capital_i, distance\ to\ the\ Canal_i, weather_{it}, c_i) + u_{it} \\ &= f(g_{it}, r_t, ca_i, cl_i, w_{it}, c_i) + u_{it}, \text{ for short.} \end{aligned} \tag{b}$$

Including a time dummy (*dt*) for structural changes and cross terms for interaction analysis, the equation (b) can be converted to a fixed effects model. The provincial time-invariant factors and the level of market performance specific to one province constitute the fixed effects.

$$\begin{aligned} se\ (p_{it}) = {} & \beta_0 + \beta_1 \ln g_{it} + \beta_2 ca_i + \beta_3 cl_i + \beta_4 \ln r_t + \beta_5 w_{it} \\ & + \delta_0 dt + \delta_1 dt * \ln g_{it} + \delta_2 dt * ca_i + \delta_3 dt * cl_i + \delta_4 dt * \ln r_t + \delta_5 dt * w_{it} \\ & + \gamma_1 \ln g_{it} * ca_i + \gamma_2 \ln g_{it} * cl_i + \gamma_3 dt * \ln g_{it} * ca_i + \gamma_4 dt * \ln g_{it} * cl_i + c_i + u_{it}, \end{aligned} \tag{c}$$

where *i* indicates province *i*; *t* indicates year *t.* $se\ (p_{it})$ can be put in by price seasonality or dispersion. The time dummy (*dt*) treats the period 1, 1776-1796, as the control group, to compare with period 2, 1827-1846. The distance data, *ca, cl,* is calculated from "China Historical GIS"[5]. The data about the annual silver reserve is from Shi (2009). The weather data is from "Yealy Charts of Dryness/ Wetness in China for the Last 500-year Period" (State Meteorological Society, 1981)[6]. As shown in Table 1, the price variation is measured by the monetary unit, *fen;* granary storage is measured by millions of *shi*. In addition, a silver

[5] http://www.fas.harvard.edu/~chgis/

[6] The data contains the ranking of regional weather conditions. The normal condition is given the index value zero. If the general weather condition becomes drier, the index value increases, and vice versa.

reserve is measured by *taels*. These different units make it confusing to interpret marginal effects. Thus, I use the log form of grain and silver reserves.

The data analysis will start from a test on whether the two spatial factors do matter, i.e. a joint test on all these cross terms. If so, we could start to check the marginal effect of granary storage on price fluctuations (seasonality and dispersion, respectively). The coefficient will tell us: in which spatial area, the marginal effect is statistically significant, i.e. where the granary system did work; whether the marginal effect interacts with the spatial factors. With the help of time dummies (*dt*), structural changes could be observed. Except for the granary system, the effect of silver reserves on the rice price is also in our consideration. After testing the significance, we try to interpret the marginal effect, through which we could understand the granary system in great details. It is the start point to go deep into the Qing state's government structure and to perceive its behavior. Before start to evaluate the effectiveness of the granary system, robust tests are necessary since the data sample only includes four provinces along the Grand Canal. The investigation on the vast land except the low Yangzi-delta area is still rare.

The marginal effect of granary storage on price fluctuations in period 1:

$$\frac{\partial se\,(p_{it})}{\partial \ln g_{it}}_{dt=0} = \beta_1 + \gamma_1 * ca_i + \gamma_2 * cl_i. \qquad \text{(d)}$$

The marginal effect of granary storage on price fluctuations in period 2:

$$\frac{\partial se\,(p_{it})}{\partial \ln g_{it}}_{dt=1} = \beta_1 + \delta_1 + (\gamma_1 + \gamma_3) * ca_i + (\gamma_2 + \gamma_4) * cl_i. \qquad \text{(e)}$$

For instance, if we want to check to what extent the marginal effect is affected by the relative spatial position to the Canal in period 1, we first calculate the sample average of ca denoted as $\overline{ca}$. The corresponding equation is:

$$\frac{\partial se\,(p_{it})}{\partial \ln g_{it}}_{dt=0}(cl) = \beta_1 + \gamma_1 * \overline{ca} + \gamma_2 * cl_i. \qquad \text{(f)}$$

5 Empirical results

The related regressions are listed in Table 2. After testing these cross terms, we confirm that the regressions on price seasonality should include spatial factors and their cross terms with granary storage. But, the regression on price dispersion rejects both of the two spatial factors. To prove this, different specifications have been used (regression 3-6, in Table 2); however, adding cross terms does not bring new information to explain price dispersion. Thus, for price seasonality, regression 1 in Table 2 will be use, while regression 6 will be applied to price dispersion. In this section, three relationships will be discussed: granary-seasonality; granary-dispersion; silver reserves-price fluctuations (seasonality and dispersion), which will bring us a more precise picture of the granary system and its role in the 18th-19th century.

5.1 Granaries and price seasonality

The resulted relationship between granary storage and price seasonality is shown in Figure 9. In general, the granary system did work by lowering the level of price seasonality, but its working area has spatial

restrictions. The two dimensions given by the distance to the canal and the distance to the capital actually locate an area on a map. The granary system along the canal only works in period 1 within about forty kilometers to the Canal or beyond three hundred kilometers to the national capital. We also find that the absolute level of marginal effects- the effect of the granary system- increases when getting near to the Canal and getting far to the capital. As explained in section 4, the granary system makes a better use of convenient transport on the Canal than private markets. And, the central government tends to monitor far-away provinces along the canal. Thus, by holding the effect of market performance (market integration) constant, the granary system even works in the low Yangzi-delta region.

We start to interpret the marginal effect of the granary system along the canal. Is it economically significant? For instance, in Zhejiang Province where the granary storage is the highest among the 4 provinces, increasing by one percent of granary storage leads to a decrease in price seasonality by about only 0.05 *fen*. In the sample, the average seasonal price change was around 4 *fen*. It means that if the local granary system plans to eliminate all the seasonal price change, it should prepare to sell out or buy in all its stocks, which is actually around two million shi of grain. Thus, not all the provinces had the capacity to influence prices. And, it is hard to believe that pouring in such a large amount of grain (which is mainly rice) to the market only decrease the price by 5 *fen*, which is 2.5 percent of the average local rice price. To what extent would the marginal effect influence the food consumption in 18th century China? FANG Xing (1996) estimated the annual consumption basket for a farmer family with five members living in the Jiangsu-Zhejiang province. The per capita grain consumption is 0.3 shi monthly. Based on the information, the granary system could in its maximum save people living in the two provinces 1.5 fen per month (0.015 taels), which is around 1.5 percent of per capita income[7]. The influence is rather limited, although the granary system has a negative effect on price seasonality. The economic-insignificant influence even disappears completely in period 2.

5.2 Granaries and price dispersion

The granary system may influence price dispersion by imposing a fixed price across all areas. When local granaries have a large stock of grain, the price they set should be influential. We first expect that the influence depends on spatial positions, which is similar to that on seasonality. But, it turns out that the null hypothesis cannot be rejected. Thus, it actually implies that the influence spreads evenly across all areas. However, Will and Wong insist on regional differences in granary management. As a potential future topic, more tests are needed to uncover the form of the true model.

Although without spatial factors, the influence of the granary system on price dispersion is still interesting. The level of price difference among prefectures in one province is an indicator of intra-provincial trade. Then, would the granary system encourage and hinder the trade between prefectures? Table 3 shows that the effect is only statistically significant in period 2 when the granary system started to decline. And, still the effect is economically insignificant. Then, it is difficult to make any solid conclusions on the effect of granaries to price dispersion. Rather than solve a question, it proposes a puzzle. Compared to the 1770s-1790s, we observe a significant decline in granaries and an increase in price dispersion in the 1820s-1840s. By holding the level of market integration constant, we still cannot find a reliable

[7] We assume that the per capita GDP is about 15 taels in this period.

relationship between the two. Is it a mere coincidence? It seems to me that when the granaries are in use in period 1, we see no differences; they gradually stop work in period 2, the difference is obvious.

5.3 Silver reserves vs. granaries

As shown in Table 3, the effect of silver reserves on price seasonality is statistically significant in period 1, while the effect on price dispersion is statistically significant in period 2. Actually, all the regressions in Table 2 get the same result about silver reserves, which is rather robust.

The effects are both economically insignificant. But, the effect of silver reserves on price seasonality is a little higher than that of granaries. Increasing by one percent of silver storage leads to a decrease in price seasonality by about 0.26 *fen*, (0.05 *fen* for granaries). Based on the sample, if the central government plans to eliminate all the seasonal price change in the Canal area, it should increase the silver reserve by around 25 percent, which is actually around twenty million taels of silver.

6 Tests for Robustness

Three robustness tests will be presented here. The first two extend the analysis to the whole country by covering more provinces but fewer years. The last one intends to check whether there is spatial correlation.

6.1 Granaries, the Grand Canal, and price seasonality

From the analysis in section 5.1, we find that in the Canal area the granary system could lower seasonal variations in the rice price and its effect can be strengthened by convenient transportation, such as being near to the Canal. The key point here is that the level of market performance is believed to be time invariant in the Canal area. A similar test is difficult for a sample covering the whole country, because the level of market performance can be both regional different and time variant. For instance, a direct comparison between the Yellow river region and the Yangzi river region without controlling for the changes in market performance can be misleading.

We try to simplify the test for the whole country by using a new sample and making several assumptions about market performance. This sample covers 16 provinces but only six years, 1786-1788 and 1843-1845. By choosing these six years, special years with extreme social and natural conditions are left out, such as wars or the change of river courses. As usual, the first three-year period represents the late 18^{th} century when the granary system reaching its peak; while the later represents the early 19^{th} century when the granary system getting close to its end. By using fewer years, we could assume that the level of market performance is constant in one region. Then, a time dummy could control the difference between the two periods. To control for the regional-different level of market integration, we divide the whole country into six areas based on different river systems and assume that markets in one area share the same level of market performance (See Figure 10). Taking the no-river area as the control group, we actually test whether in an area with rivers the granary system works better. We can also compare the effect of the

granary system between different areas. Then, we can know whether the granary system works better in the other areas compared with the Canal region. The regression model is still based on equation (a) in the model section and similar to equation (c) only by substituting the variable *cl* with the dummies about rivers (There are three dummies for the Yangzi River, the Yellow River, and the Grand Canal.).

First, compared with the area with no main rivers, the effects of the granary system are all statistically significant in the rest five areas except the Yangzi region (See Table 4 (a)). It shows that getting near to a river or having convenient transportation does reinforce the effect of granaries. Second, comparing all the five river areas, it confirms that the effect of granaries is the lowest in the Canal-Yangzi region and perhaps the highest in the Canal-Yellow region (See Table 4 (b)).

6.1 Granaries, the Capital, and price seasonality

From the analysis in section 5.1, we also find that in the Canal area the effect of the granary system would be higher in the province further from the Capital, perhaps since the central government would like to pay more attention to them. Can we find the same relationship in other areas? Using the regression above, we test whether the central government gives different treats to the Canal area. Figure 11 gives the answer. The canal area is indeed special. Although slightly increased with the distance to the capital, the marginal effect of the granary system in the Canal area is nearly irrelevant to the distance to the capital. However, the marginal effect shows a different picture in the non-Canal region. In the area that is nearer to the Capital, the marginal effect is higher, perhaps since the monitoring cost is lower. But, in the Canal region, the Grand Canal itself may save the monitoring cost for the central government. Thus, distance and the related cost become less relevant.

6.3 Granaries and spatial correlations

Until now, we discussed that the effect of the granary system can be reinforced or weakened by its spatial position based on the structure model (equation c). There is another possibility. The price variation in one region can be closely linked with that in nearby regions (Wang 1989). The local granaries can also be linked together through spatial correlations. If the granary system works through the cooperation of local governments, we would observe a low price variation in a region where its neighbors have high granary storage. By including spatial correlations, we can also measure the degree of market integration in an interprovincial level. Thus, missing spatial correlations may cause a serious endogeneity problem.

The following regression model is used to check whether we should include in spatial correlations.

$$se\ (p_{it}) = \beta_0 + \rho W * se\ (p_{it}) + \beta_1 g_{it} + \beta_2 ca_i + \beta_3 cl_i + \beta_4 \mathrm{lnr_t} + \beta_5 w_{it} + \delta_1 W * g_{it} + c_i + u_{it}$$

, where "*W*" is the spatial matrix, denoting the first-order spatial relationship among provinces.

The result is listed in Table 5. Rho is the coefficient for the interprovincial price relationship. The direct effect of the granary system means that price variations in one region can be affected by its own granaries; while, the indirect effect means that price variations in one region can also be affected by its neighbors' granaries. It turns out that we cannot reject the null hypothesis that there is no need to add spatial

correlations to the regression model.

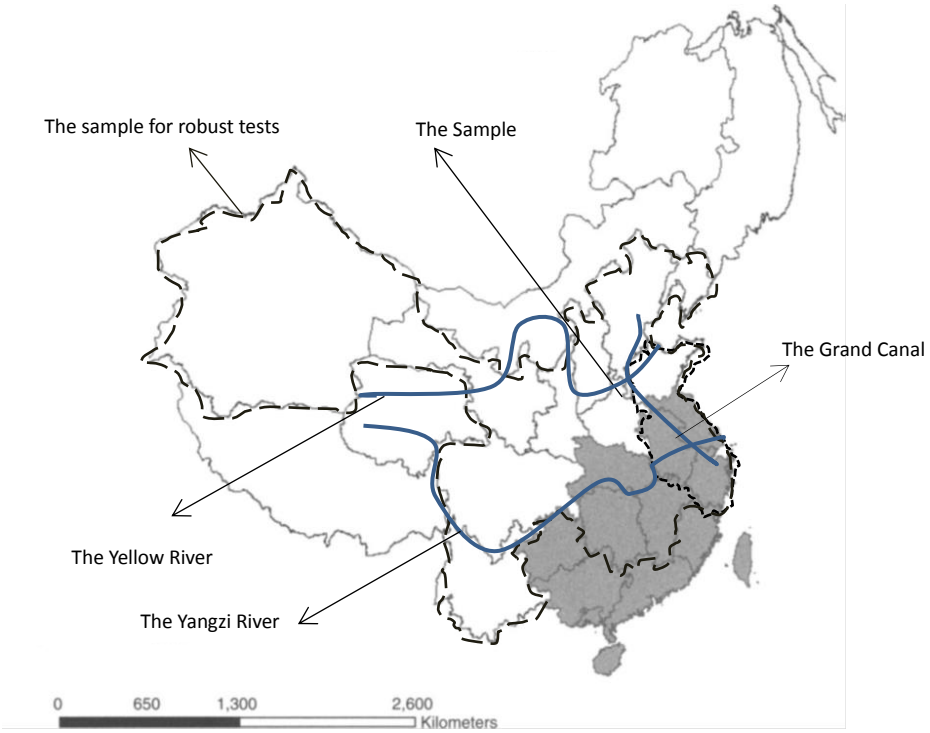
7 Conclusions

Now, we can answer the question whether the Qing state had the capacity to stabilize grain prices, at least partially. The state civilian granary system did work in some part of the country, especially those areas that can take advantage of the inland waterways and can be easily monitored by the central government. However, its influence on the Yangzi-Canal region is indeed economically insignificant. Here, my finding supports Shiue and Keller's conclusion on the Yangzi-delta region (2007). The economically insignificance is possibly from the fact that Local granaries lack a sufficient ability to sell out or buy in such amount of grain stocks that can largely affect prices. In other words, the system is useful but to get it start we need a huge amount of energy. This weakens the efficiency of the granary system. Compared to local granary storage, the silver reserve that managed by the central government even has a higher influence on eliminating price fluctuations. Finally, we find that to rank the effect of the granary system in different areas, the Yangzi-Canal region is at the bottom, while the Yellow-Canal region is at the top. The effect is regional unbalanced.

Two puzzles are remained, which are potential for future research. One is how the granary system affected price dispersion. The other is how the granary system interacted with private markets. The difficulty is obvious. After all, how the system worked is still puzzling. Can we still interpret the granary system as one form of national reserves even if it is actually managed locally? Considering the dilemma of a national state (North 1981), is the granary system redundant to the economy with respect to market integration? Or, is it possible that the Qing state actually overprotected its grain market through the granary system, which in turn caused underinvestment in industrial production?

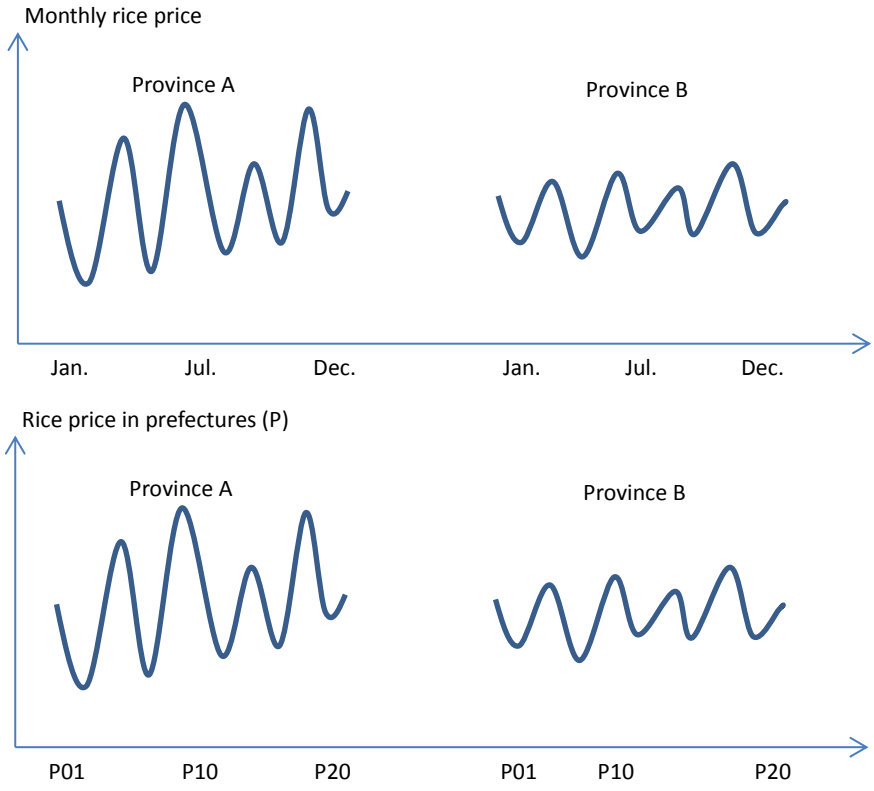
Figures and tables

Figure 1 The map of Qing China and the data samples



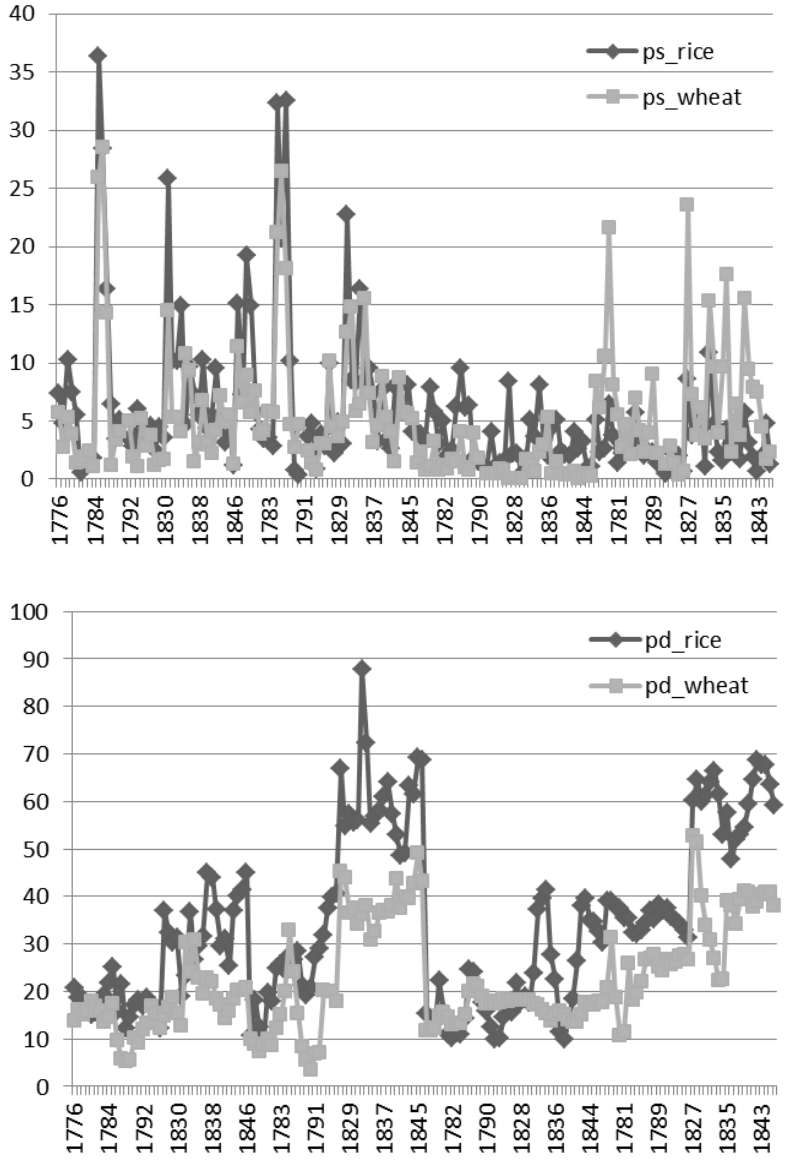
Note: The figure is from Shiue and Keller (2007) and revised by the author.

Figure 2 How to interpret price fluctuations



Note: Province B has a higher stock in its local granaries than that of Province A.

Figure 3 Rice and wheat, seasonality and dispersion, 4 provinces, 1776-1796, 1827-1846, *fen*

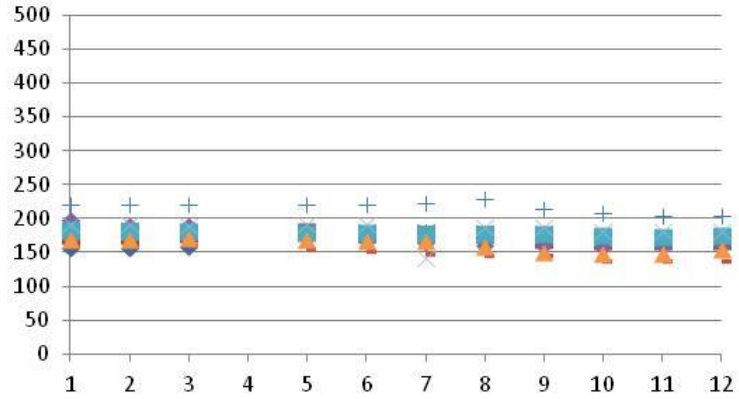


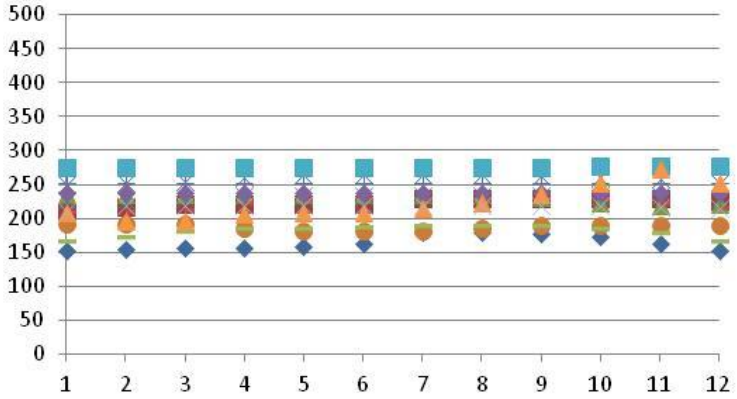
Note: ps is short for price seasonality, which denotes the price variation through months; pd is short for price dispersion, which denotes the price difference across regions. The unit is *fen*.

Figure 4 Seasonality, rice prices among months in different prefectures, 4 provinces, 1780, 1830, fen

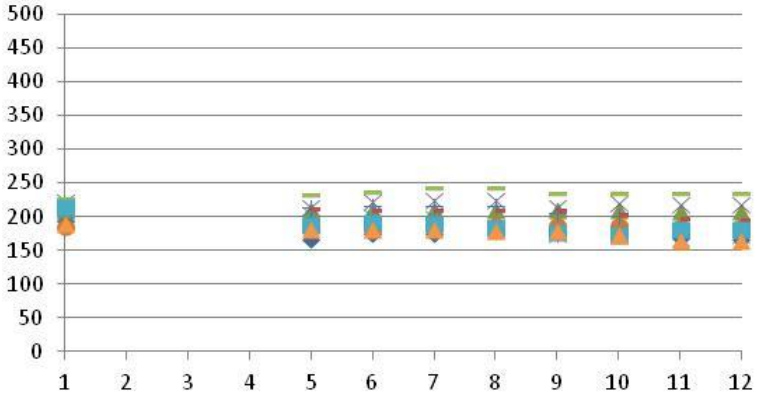
Provinces 1780 1830

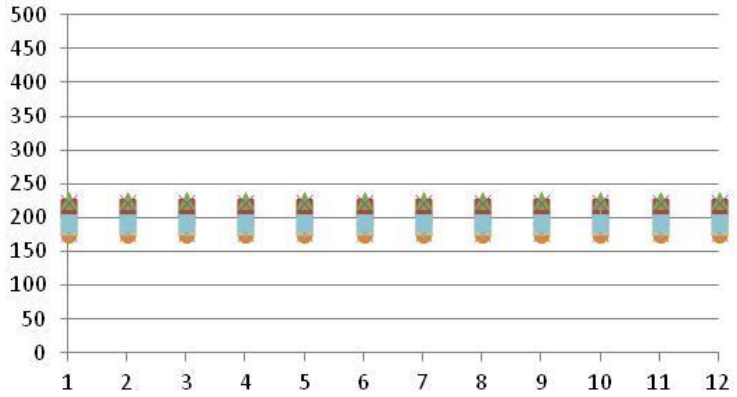
Anhui



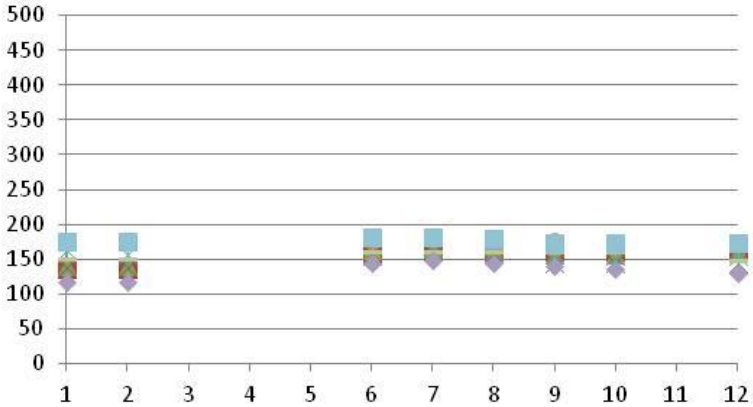


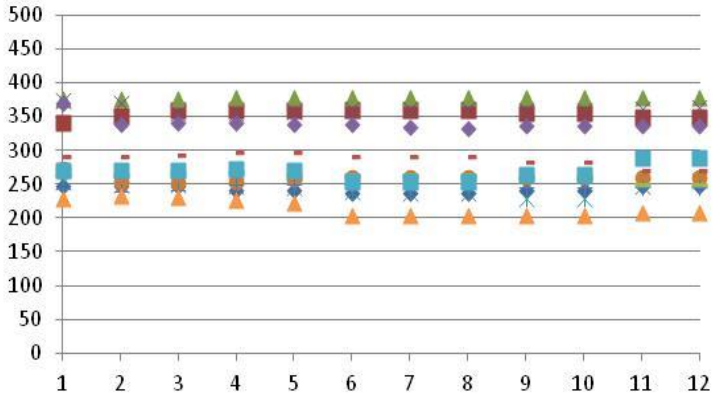
Jiangsu



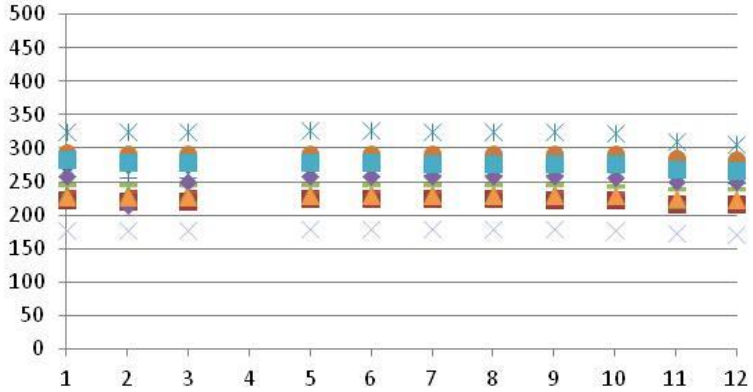


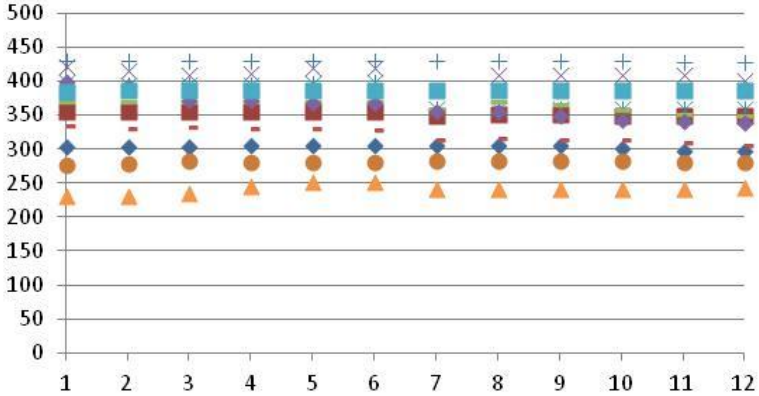
Zhejiang





Shandong

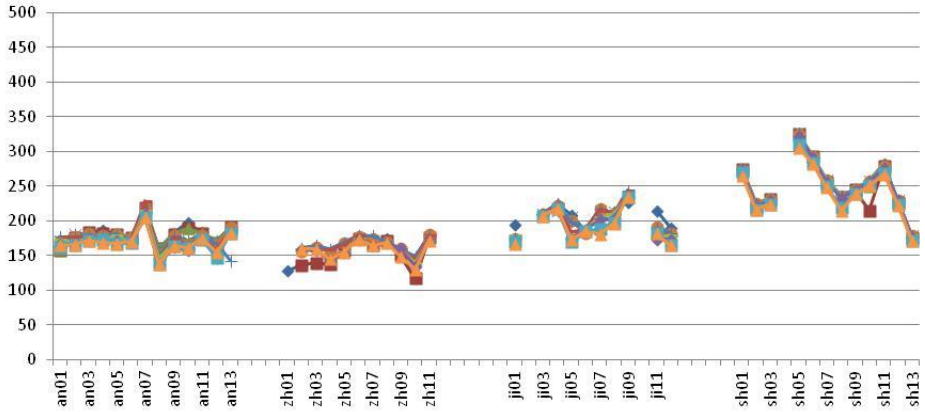




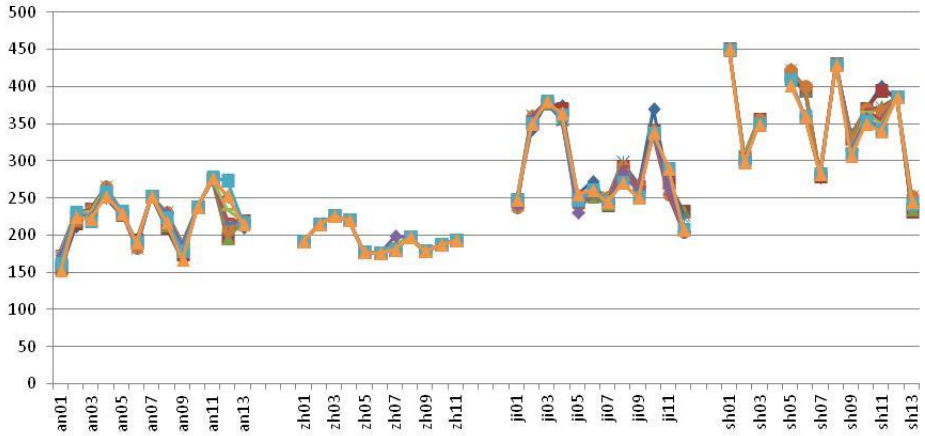
Note: Calculated by the author. Different shapes indicate different prefectures in one province.

Figure 5 Dispersion, Rice prices among prefectures in different months, 4 provinces, 1780, 1830, *fen*

1780



1830

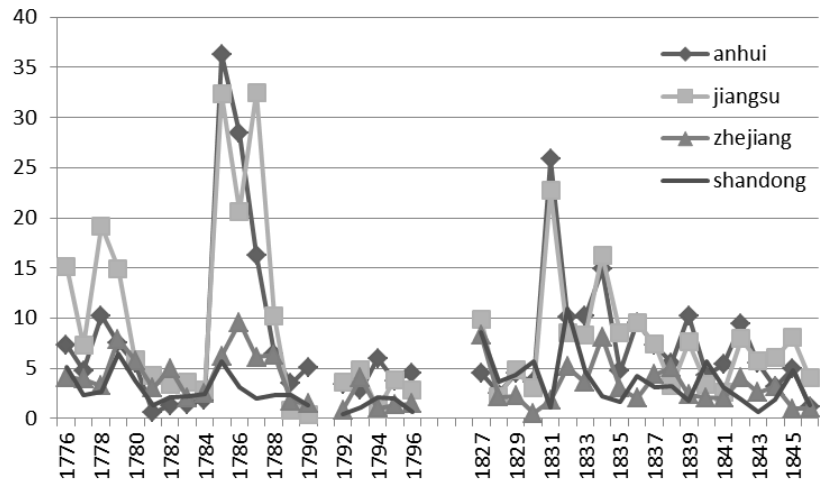


Note: calculated by the author. Different shapes indicate different months in one year.

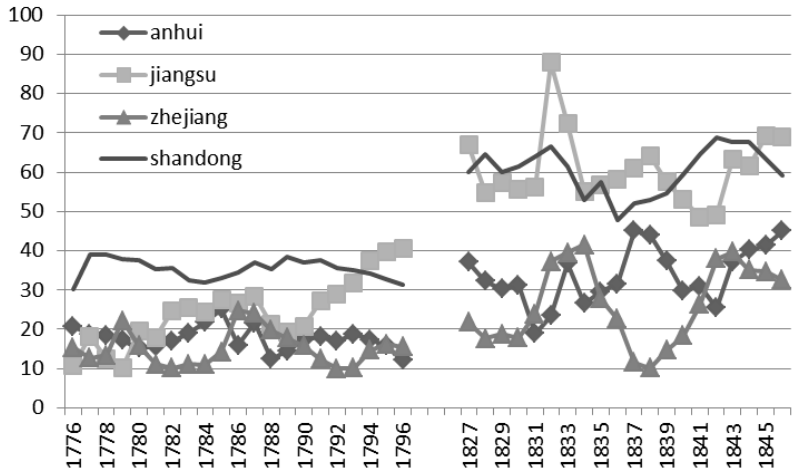
The abbreviations used here are: au for Anhui, zh for Zhejiang, ji for Jiangsu, sh for Shandong.

Figure 6 Price fluctuations and granary stocks, 4 provinces, 1776-1796, 1827-1846

(a) Seasonality



(b) Dispersion



(c) Granary stocks

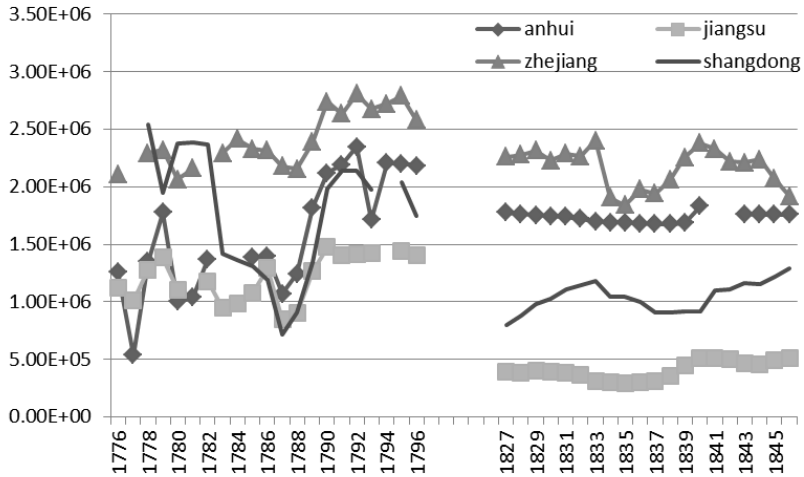
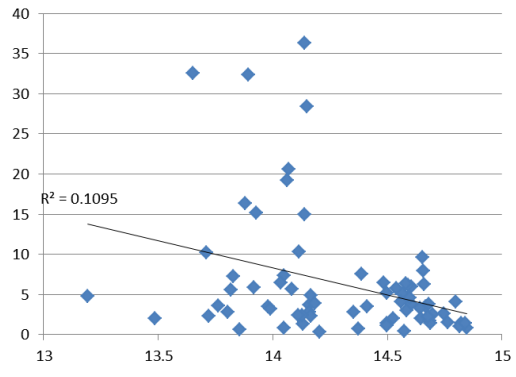
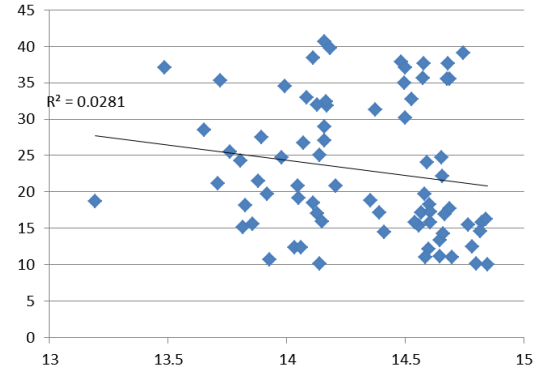
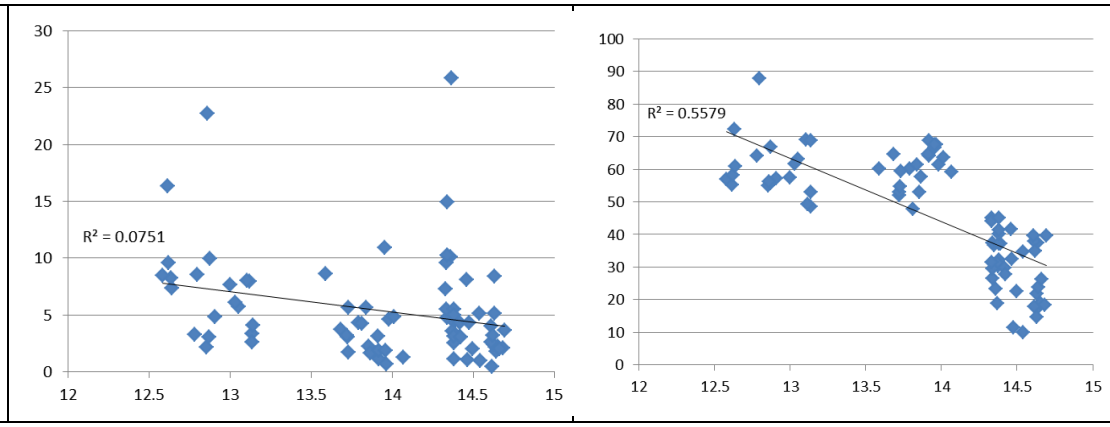


Figure 7 Price fluctuations and granary stocks, rice prices

Period	Seasonality and granary stocks	Dispersion and granary stocks
1		

2	

Note: calculated by the author. The x-axis denotes ln (granary storage). Period 1 denotes 1776-1796; period 2 denotes 1827-1846.

Figure 8 The model

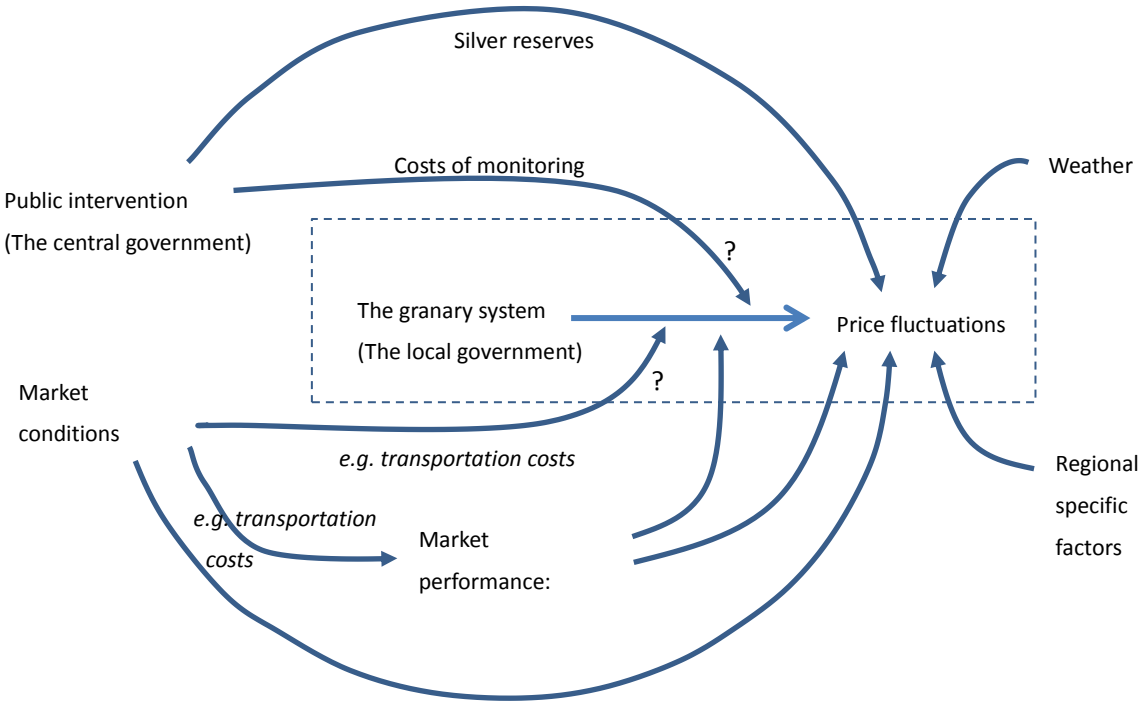
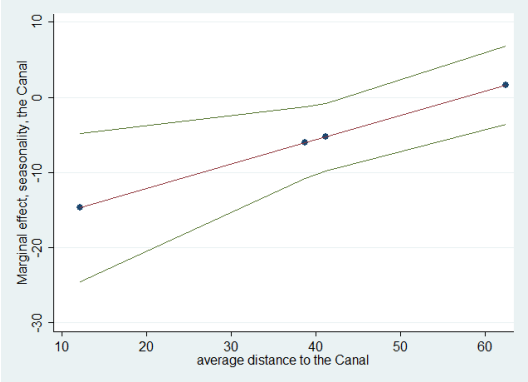
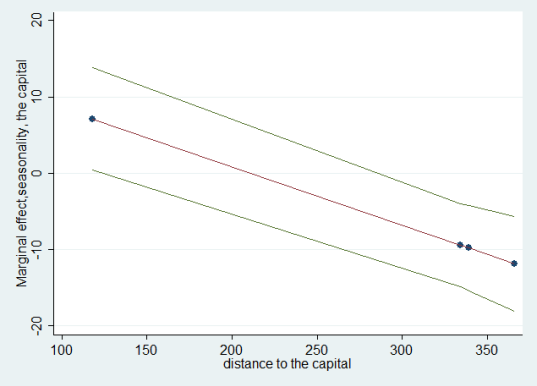
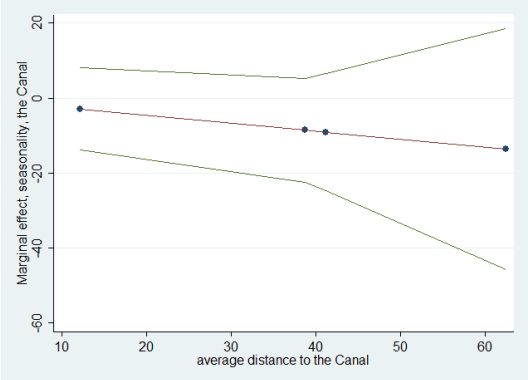
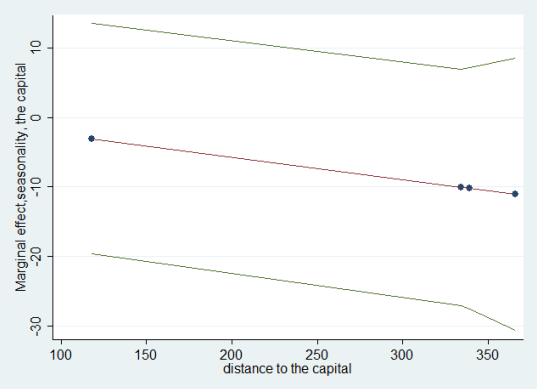


Figure 9 Regression results: marginal effect of granaries on price seasonality w.r.t. distance to the Canal and the Capital

Period	w.r.t. distance to the Canal	w.r.t. distance to the Capital
1		
2		

Note: Period 1 denotes 1776-1796; period 2 denotes 1827-1846.

Figure 10 The three main rivers and six regions of the country, robustness tests

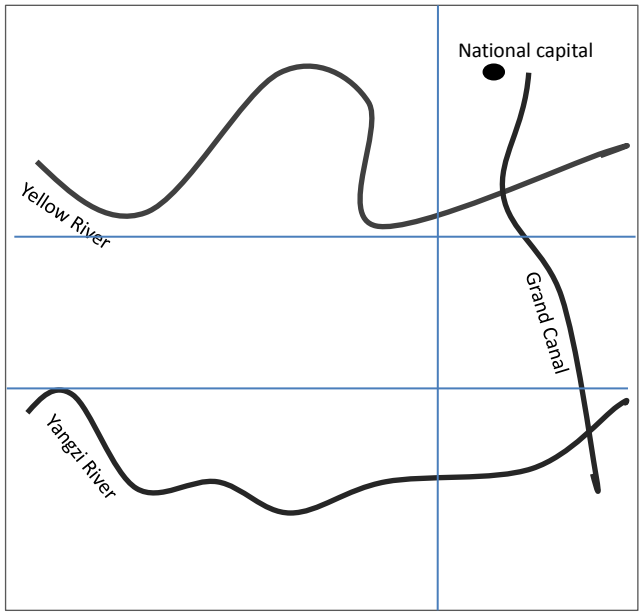
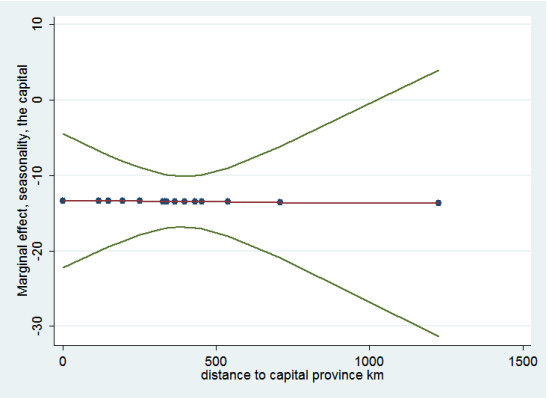


Figure 11 The robustness test, marginal effect of granaries on price seasonality w.r.t. distance to the Capital

The Canal region



The non-Canal region

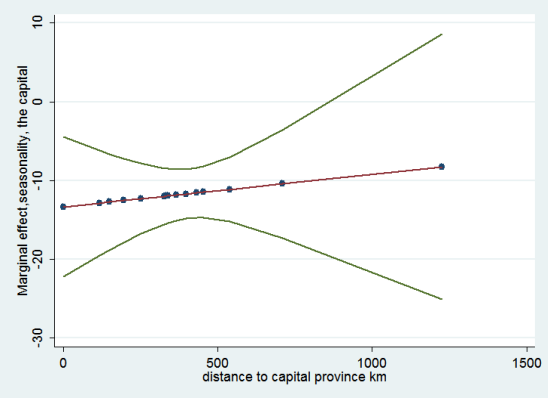


Table 1 Descriptive statistics

Definitions		Variable	unit	Period	Obs	Mean	Std. Dev.	Min	Max
Price fluctuations (Rice)	Seasonality	ps	Qian	1	80	5.96	7.29	0.33	36.30
				2	80	5.47	4.41	0.50	25.86
	Dispersion	pd	Qian	1	84	23.11	9.32	10.01	40.59
				2	80	45.32	17.43	10.05	87.88
Price fluctuations (Wheat)	Seasonality	ps	Qian	1	80	5.02	6.05	0.34	28.56
				2	80	5.47	4.67	0.00	23.51
	Dispersion	pd	Qian	1	84	16.48	6.53	3.57	32.87
				2	80	28.12	11.37	12.82	52.78
Granary storage	Total stock	g	Million shi	1	76	1.75	0.59	0.54	2.81
				2	78	1.3	0.69	0.29	2.40

Note: Period 1 denotes 1776-1796; period 2 denotes 1827-1846.

Table 2 Regression results

VARIABLES	(1) seasonality	(2) seasonality_d	(3) dispersion	(4) dispersion_canal	(5) dispersion_capital	(6) dispersion_d
lng	3.518	-1.385	11.85	11.57	4.315	1.675
	(8.524)	(2.462)	(10.67)	(9.133)	(7.899)	(3.007)
cl	0	0	0	0	0	0
	(0)	(0)	(0)	(0)	(0)	(0)
ca	0	0	0	0	0	0
	(0)	(0)	(0)	(0)	(0)	(0)
lnr	-25.88**	-21.27*	-13.30	-13.26	-11.78	-11.59
	(10.87)	(10.94)	(13.69)	(13.42)	(13.60)	(13.43)
w	2.926***	2.416***	0.400	0.388	0.346	0.328
	(0.683)	(0.678)	(0.864)	(0.831)	(0.861)	(0.835)
dt	-582.7	-444.7**	75.01	455.2*	-358.8	162.3
	(475.0)	(199.2)	(602.9)	(271.7)	(361.8)	(244.3)
dt_lng	5.583	1.505	-11.78	-38.25***	20.45	-16.01***
	(31.23)	(2.482)	(39.71)	(10.11)	(20.61)	(3.047)
dt_cl	7.758	0.0245	-9.166	-14.25**	0.0236	0.0400
	(7.350)	(0.0906)	(9.338)	(6.206)	(0.113)	(0.110)
dt_ca	-0.640	-0.0140	0.725	-0.0675**	1.397*	-0.0103
	(0.963)	(0.00972)	(1.224)	(0.0307)	(0.821)	(0.0119)
dt_lnr	27.83**	23.66**	6.639	6.271	5.197	4.156
	(10.99)	(11.07)	(13.84)	(13.60)	(13.74)	(13.60)
dt_w	-3.115***	-2.490***	0.0293	-0.0250	0.0523	-0.280
	(0.932)	(0.925)	(1.181)	(1.145)	(1.179)	(1.143)
lng_cl	0.324**		-0.196	-0.217		
	(0.150)		(0.186)	(0.179)		

lng_ca	-0.0766***		-0.00568		-0.0132	
	(0.0226)		(0.0282)		(0.0273)	
dt_lng_cl	-0.538		0.646	1.005**		
	(0.518)		(0.658)	(0.436)		
dt_lng_ca	0.0441		-0.0556		-0.102*	
	(0.0674)		(0.0857)		(0.0588)	
Constant	563.2***	411.5**	226.0	217.3	229.3	209.2
	(192.2)	(192.4)	(240.7)	(232.7)	(240.3)	(235.4)
Observations	150	150	154	154	154	154
R-squared	0.226	0.147	0.796	0.796	0.794	0.787
Number of nr	4	4	4	4	4	4
adj R^2	0.133	0.0724	0.773	0.775	0.773	0.769

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 3 Regression results about price dispersion and silver reserves

From Table 2	Regression 6	Regression 1	Regression 6
Periods	Price dispersion granaries	price seasonality silver reserves	Price dispersion silver reserves
1	1.66	-25.88**	-11.59
	(0.5784)	(0.0187)	(0.3896)
2	-14.34***	1.95	-7.43***
	(0.0000)	(0.1830)	(0.0001)

P-value in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 4 Marginal effect of the granary system on price seasonality in the five regions

a. Compared with the region where covers no main rivers:

Regions:	1786-88	1843-45
Yangzi river	0.0023	0.0022
	(0.3898)	(0.1948)
Yellow river	0.0104***	0.0192***
	(0.0003)	(0.0000)
Grand Canal	0.0198***	0.0250***
	(0.0034)	(0.0005)
Yangzi river and Grand Canal	0.0158*	0.0090
	(0.0576)	(0.3305)
Yellow river and Grand Canal	0.0285***	0.0260***
	(0.0009)	(0.0062)

P-value in parentheses

*** p<0.01, ** p<0.05, * p<0.1

b. Compared with the area with both the Canal and the Yangzi River,

1786-88	1843-45
yangzi+canal vs.yangzi	yangzi+canal vs. yangzi
0.01358	0.00680
(0.1153)	(0.4912)
yangzi+canal vs. yellow	yangzi+canal vs. yellow
0.00542	-0.01019
(0.5581)	(0.3454)
yangzi+canal vs. canal	yangzi+canal vs. canal
-0.00397	-0.01597 *
(0.5837)	(0.0629)
yangzi+canal vs yellow+canal	yangzi+canal vs. yellow+canal
-0.01268 ***	-0.01699 ***
(0.0000)	(0.0000)

P-value in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 5 Spatial correlation

	rho	direct effect of granaries	indirect effect of granaries
price seasonality			
Period 1	0.17*	0.10	0.18
	(1.7557)	(0.6292)	(0.8127)
Period 2	0.11	-0.29	0.43
	(1.0921)	(-1.4268)	(1.2457)
price dispersion			
Period 1	-0.13	-0.11	0.13
	(-1.2258)	(-0.7964)	(0.7197)
Period 2	-0.17	-0.22	1.98**
	(-1.5414)	(-0.4390)	(2.3949)

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