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| **RESEARCH ARTICLE**

Correlations between Natural Disasters and Price Indices in China during 1644-1911

Shiyao Zhang[1] ✉ **and Yubang Chen[2]**
[12]History School, Liaoning University, Shenyang, China
Corresponding Author: Shiyao Zhang, **E-mail**: shiyaostudio@163.com

| **ABSTRACT**

The disruption of natural disasters in agriculture is often seen to have influenced price indices to some extent over a certain period, especially in a relatively isolationist, predominantly agricultural economy such as ancient China. Here we use the information about historical disasters kept in *Qing History - Treatise on Famine and Relief* and the price indices for each year from 1644 to 1911, exploring the correlation between natural disasters and price indices. We next discuss the other factors that have an impact on the price index to reveal the dynamics of the influence of natural disasters on the price index. Results show that there is a weak correlation between natural disasters and price indices in general, but we find a strong correlation over a long time, and the correlation coefficient rises somewhat in the early Qing, and then decreases with time. We further show that factors such as production capacity, foreign trade and silver flows also had an impact on the price indices no less than natural disasters, and it is clear that the impact of these factors caused the correlation coefficient to change over time.

1. Introduction

Natural disasters cause enormous human suffering and result in significant economic damages. This leads to a temporary or even permanent crisis in the price stability of a country or region, which is reflected in the price indices. In recent years, as the frequency of natural disasters has risen, so too has the impact they cause (Diaz & Larroulet, 2021). Natural disasters cause enormous human suffering and result in significant economic damages. This leads to a temporary or even permanent crisis in the price stability of a country or region, which is reflected in the price indices. In recent years, as the frequency of natural disasters has risen, so too has the impact they cause. In response, a lot of research has been conducted to explore the relationship between natural disasters and various economic indicators; however, as Cavallo and Noy (2011) highlight in their paper, this relationship remains largely inconclusive. In addition, the presence of correlations between variables and unobserved country-specific factors complicates causality and thus leads to potential estimation bias, as does the price index, which is a type of economic index (Loayza et al., 2012). To minimize or eliminate the impact of these variables, we need to choose a case that is highly affected by natural disasters, and China, especially the relatively closed, predominantly agricultural ancient Chinese society, is one of the best choices (Wei et al., 2014). Previously, Gao et al. (2021) explored the relationship between volcanic climate and the collapse of ancient Chinese dynasties in this way.

2. Literature Review

Natural disasters have been recorded in China for almost as long as known written records of the history of China, and they played an even more important role from 1644 to 1911 (Zhu, 2003). On the one hand, the frequency of natural disasters in the Qing dynasty was so high that it shocked some scholars (Li, 1988). On the other hand, as the Qing dynasty was the last in China's imperial history, there is a wealth of archives and documents that have survived. There is a wealth of research on natural disasters during 1644-1911, but some gaps still need to be filled. Firstly, most early studies as well as current work focus on certain disaster types or regions, lacking a macro view of the whole of China. Secondly, statistics on natural disasters are not comprehensive, as they tend to rely on a single source, such as local chronicles. Last but not least, quantitative research is not commonly used in studies

related to natural disasters in 1644-1911, with a preference for traditional methods such as historical analysis, and technical tools are not abundant (Xiao, 2019). These problems also manifest themselves in the studies of the impact of natural disasters, including their effect on price indices.

The price index is one of the most important measures widely used to study economic fluctuations and their long-term trends and influences. As relative numbers reflect changes in socio-economic phenomena, Indices are a very important tool for economic analysis as they indicate the direction and extent of complex socio-economic changes and can also be used to analyze the factors influencing such changes and thus predict their long-term trends. The calculation of price indices has been used for centuries in Europe and the United States (Wesley, 1938). Several factors play a significant role in determining the price index, such as the limitations of the market mechanism, the general equilibrium relationship between population size and market supply, warfare and transport conditions, etc., all of which affect the price index as a result of changes in prices. However, it is generally accepted that natural disasters were the most important variable affecting prices. The continuation of production resulted from a combination of human effort and the natural environment in the relatively isolated, predominantly agricultural society of ancient China. They believe that the occurrence of natural disasters not only makes it extremely easy to cause shortages in the means of production and subsistence but also makes a considerable number of people who are producers temporarily or permanently unproductive. At the same time, the relatively isolated market did not allow a sufficient amount of goods to flow into mainland China, and these factors led to a situation of insufficient supply and soaring prices (Li et al., 2008). However, the Chinese market did not always conform to this 'common sense', at least not in the late Qing, as many studies claim (Kishimoto, 1997).

3. Methodology

To determine whether there was a systematic correlation between natural disasters and price index movements during 1644-1911, we conducted a correlation analysis between the total number of natural disasters and the price index for each year across China for a total of 268 years from 1644 to 1911, and selected some specific and relatively average points in time for calculations with the following operators:

$$r = \frac{\sigma^2_{xy}}{\sigma_x \cdot \sigma_y} = \frac{\sum(x - \overline{x})(y - \overline{y})}{\sqrt{\sum(x - \overline{x})^2 (y - \overline{y})^2}}$$

When studying this type of problem, we generally use the Pearson product-momenlinearrelation coefficient to measure the degree of correlation between two variables (linear correlation) (Schober et al., 2018). Where the statistical relationship between two variables is denoted by r, also known as the correlation coefficient; σ^2_{xy} denotes the covariance between independent and dependent variables; σ_x denotes the standard deviation of independent variables, and σ_y denotes the standard deviation of dependent variables (Li et al., 2008). The correlation coefficient r ranges between -1 and +1. A value of zero indicates that there is no relationship between the two variables. The sign of the correlation coefficient r indicates the direction of the linear relationship. A negative correlation means that the variables move in opposite directions. In **Table 1**, we provided a combined chart of the three most commonly used interpretations of the r values. Authors of those definitions are from different research areas and specialities (Akoglu, 2018). For this paper, we have chosen the definition of politics because of the nature of the problem.

Table 1 Interpretation of the Pearson's and Spearman's correlation coefficients

Correlation Coefficient		Psychology	Politics	Medicine
+1	-1	Perfect	Perfect	Perfect
+0.9	-0.9	Strong	Very Strong	Very Strong
+0.8	-0.8	Strong	Very Strong	Very Strong
+0.7	-0.7	Strong	Very Strong	Moderate
+0.6	-0.6	Moderate	Strong	Moderate
+0.5	-0.5	Moderate	Strong	Fair
+0.4	-0.4	Moderate	Strong	Fair
+0.3	-0.3	Weak	Moderate	Fair
+0.2	-0.2	Weak	Weak	Poor
+0.1	-0.1	Weak	Negligible	Porr
+0	-0	Zero	None	None

4. Data availability

This paper is based on Xiao Lingbo's statistics of natural disasters in each year of the Qing dynasty, which totals 24,537 natural

disasters during 1644-1911 and lists them by year (Xiao, 2019). The document used by Xiao is *Qing History - Treatise on Famine and Relief*, which is one of the five major categories of the National Qing History Project (Annals, Treatises, Biographies, Chronological tables and Antique catalogues), which was founded in 2002 and is now in its final stage. The book has been finalized and will be published together with the other volumes of *Qing History* when they have been completed (Ma, 2009). Compared to other documents, this document has two advantages, one being the relative completeness of the information: *Treatise on Famine and Relief* are not merely a compilation of year-by-year records of natural disasters in historical sources, but cover multiple sources (archives, local chronicles, and private documents), especially the large number of archives that contain summaries of official reports of disasters and information on the affected areas covered by the court's relief measures. In compiling *Treatise on Famine and Relief*, information on natural disasters was filtered and summarised into seven main categories: earthquakes, windstorms, droughts, locusts, cold waves, floods and epidemics, listing the damage in each area year by year. The second advantage is the adoption standards are relatively unified: The book is a comprehensive treatment of the two main sources of historical disaster data, archives and local chronicles, and in particular supplements and revises the disaster sites in the chronicles based on the disaster archives reported to the court by local officials. As the Qing court stipulated that the standard for 'reported disasters' (disasters that met the government's standards of tax exemption and food relief) was 'half of the harvest and half of the reduction in production' (i.e. a 50% reduction in agricultural production) or more, this ensured that the disasters included in *Treatise on Famine and Relief* were screened out by a relatively uniform standard (the severity of the disaster), and the less-than-standard minor disasters that were commonly found in the records of the local chronicles were eliminated (Xiao, 2018). Both of these improve data availability. To visualize the trends in the frequency of natural disasters, we visualize this dataset as shown in **Figure 1**.
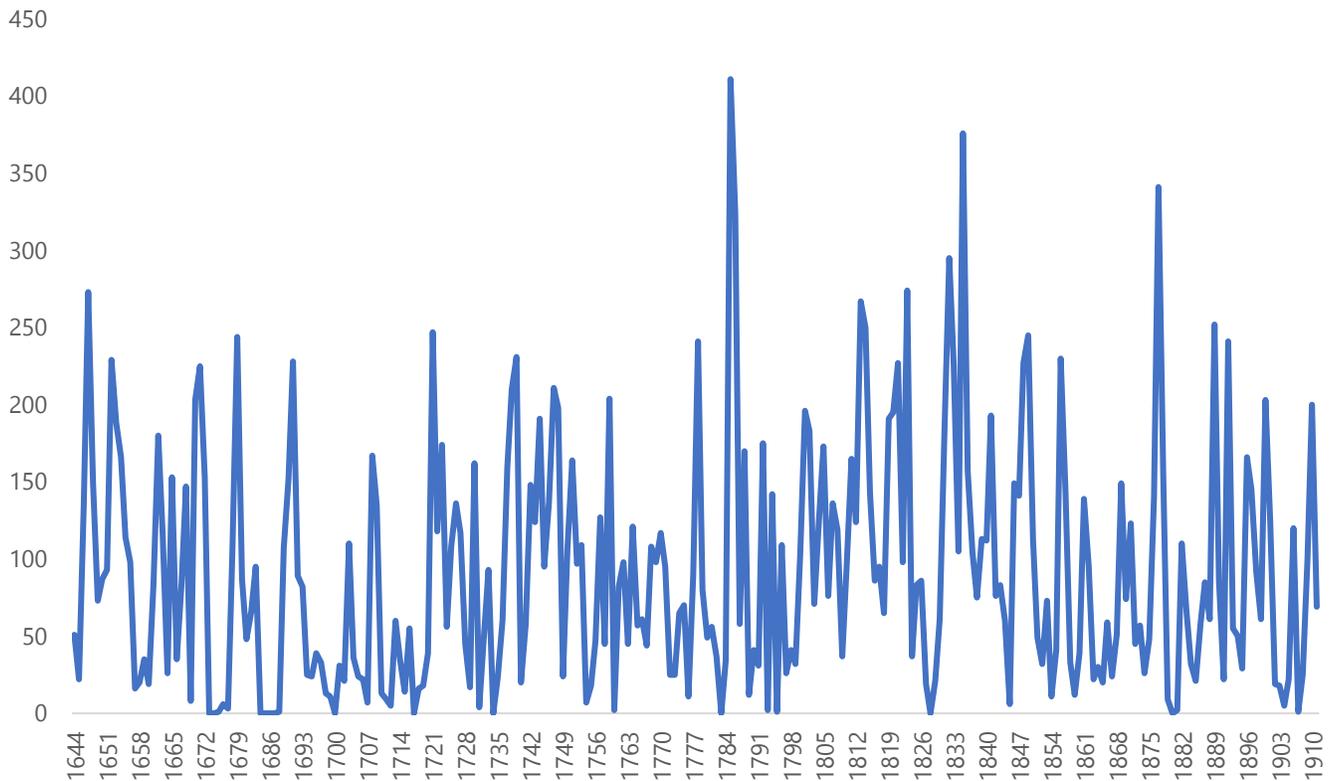
Figure 1 Trend in the number of natural disasters, 1644 to 1911

For the data on price indices, this paper uses the *Author's Statistics on Rice and Price Indices since 1644* by Peng Kaixiang, which is available online through the website of Qing Historical Data Sharing Platform (Digital Qing History Laboratory) of the Institute of Qing History at Renmin University. The historical source for this dataset is *research on China's long-term rice prices (1644–2000)*. It draws on existing studies to collate, estimate and observe price data over the past approximately three and a half centuries, compiling and collating raw data on prices denominated in different currencies from different periods during 1644-2000, followed by converting the raw price data into price indices using the exchange relationships among the different currencies formed by the evolution of successive monetary system reforms (Lu & Peng, 2006). As with the natural disaster dataset, we also visualize this dataset, as in **Figure 2**.
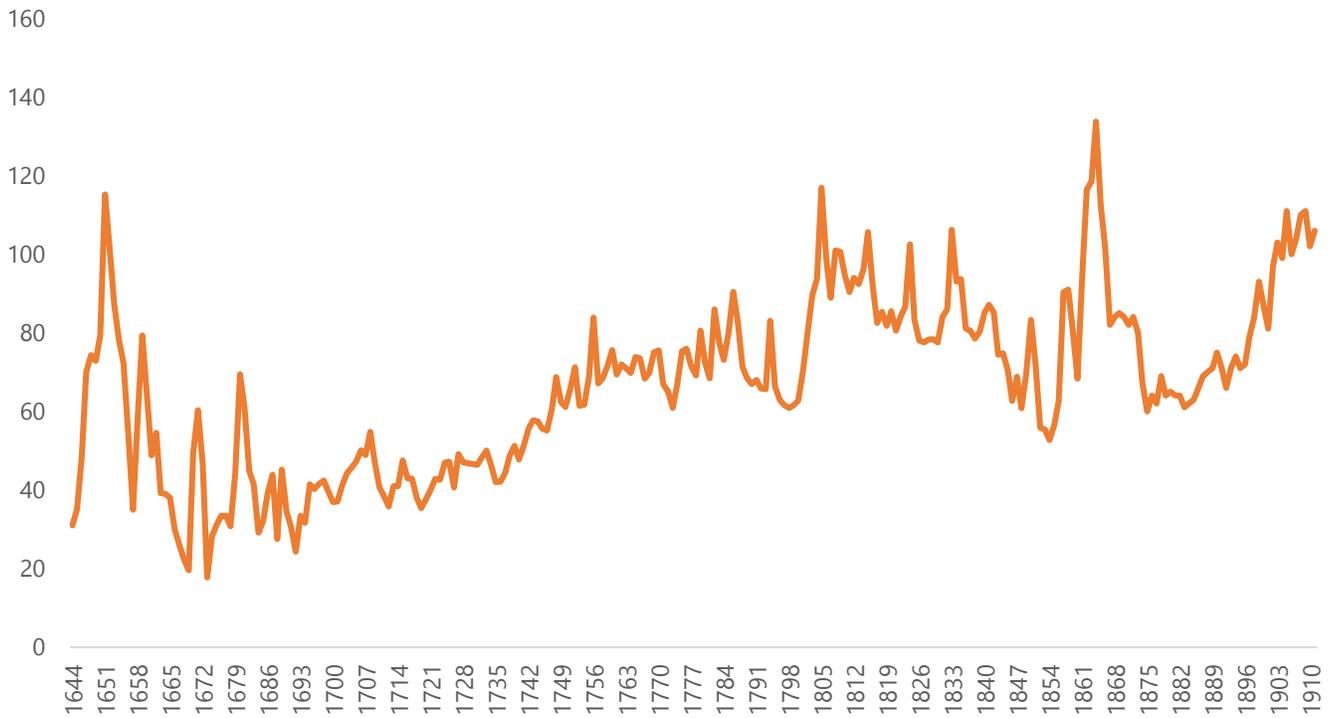
Figure 2 Movement of the price index (1913=100)

5. Results and Discussion

Based on the above two datasets, we conduct a correlation analysis between the number of natural disasters and price indices in the 268 years of the Qing dynasty and produce a correlation of r = 0.21005140399472, a weak correlation according to the above criteria of correlation, so it can be argued that natural disasters are only a minor, rather than a major, factor in the fluctuations of price indices for the overall period 1644-1911. We also compare the two trends (**Figure 3**), and we can see that the frequency of natural disasters and the fluctuations in price indices do not always coincide over a long time.
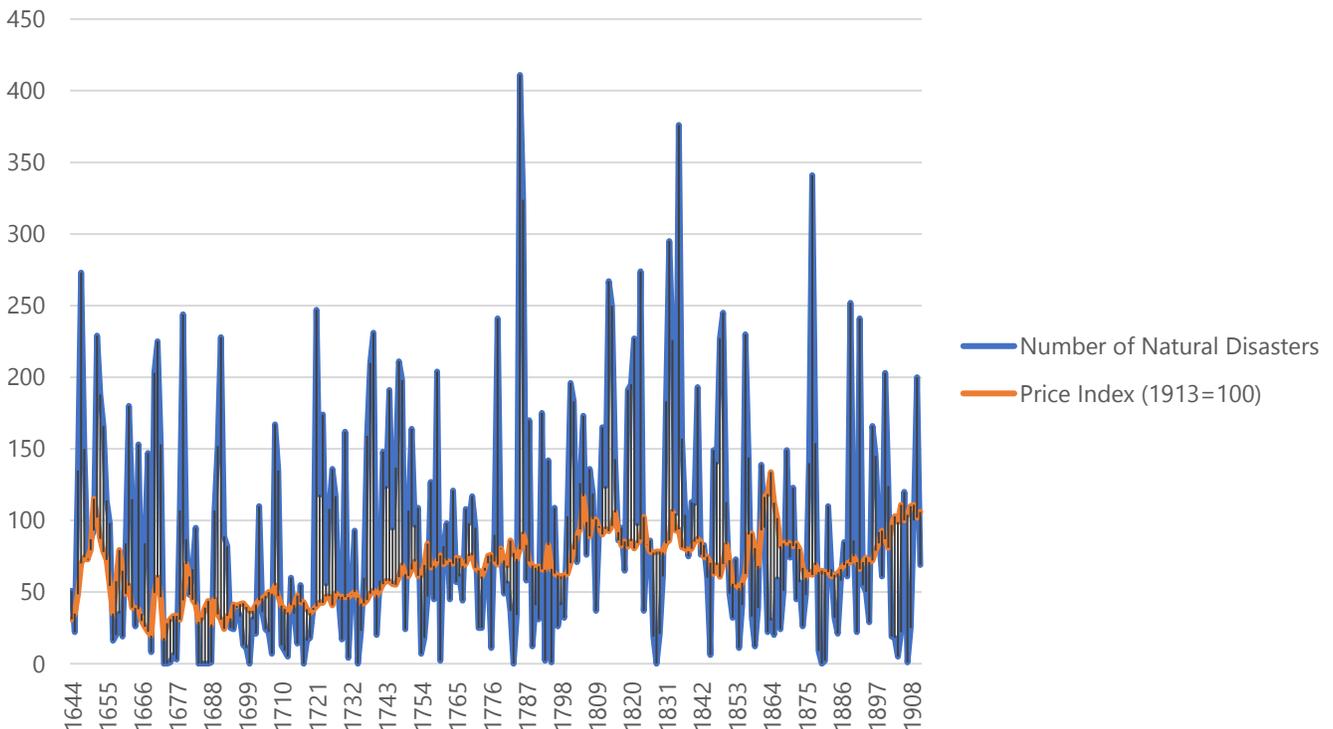

Figure 3 A comparison of trends in natural disasters and price indices, 1644 to 1911

To determine whether there is a systematic correlation between natural disasters and price indices during 1644-1911, we select some specific and relatively average periods for our calculations; the results are shown in **Table 2**.

Table 2 Correlation coefficients at different time periods

Time Period	Correlation Coefficient
1644-1650	0.489227573
1651-1660	0.601105482
1661-1700	0.347257143
1701-1750	0.435148043
1751-1800	0.306120227
1801-1850	0.086503848
1851-1900	-0.083944444

It can be seen that, in terms of different periods, there is a strong correlation (r =0.489227573150587) during the early Qing period, with the correlation coefficient fluctuating to a lesser extent as time goes on. At the same time, we find that there is a certain upward trend in the correlation coefficient during the early Qing period, such as the period 1651-1660.

This phenomenon was dictated by the characteristic of the Ming-Qing economic system, which developed from the outset in response to external conditions, and whatever changes were made to a particular economic element could be seen as some reasonable adaptation to the changed external conditions (Xu, 1991). From a broader regional perspective, Atwell argues that global climate change, famines and fluctuations in the production of silver in the 1630s and 1640s led to a crisis across East Asia in the 17th century, experienced by both Edo period Tokugawa Japan and the Ming dynasty, which resulted in Japan weathering the storm, while in China the crisis became one of the causes of the fall of the Ming dynasty (Reid, 1990). Inevitably, the knock-on effects of this regional crisis were far greater than the impact of natural disasters. The wars and civil strife brought about by the change of dynasties had a devastating effect. Most of the land throughout China was affected by the war, and many water projects were damaged. According to official statistics, the total area of arable land was reduced by 42.1%, which had a disastrous effect on the country's economy based largely on agriculture (Wang, 1972). The nation's productive capacity was violently disrupted, and changes in supply naturally led to changes in the price index. At this point, the impact of natural disasters is minimal in relation to these factors.

With the restoration of peace and order in the provinces, production gradually stabilized. It is important to note, however, that it was not until the suppression of the Revolt of the Three Feudatories in 1682 and the recovery of Taiwan the following year that the Qing court was able to take firm control of China (Wang, 1995) ; (Shi, 2006). Before this, the movement opposing the Qing dynasty led by Koxinga in Taiwan was able to trade with people in coastal areas and launched repeated attacks on the Qing military. To cut off supplies to the anti-Manchu group, the Qing court declared a strict ban on private maritime activity by forcing coastal residents to move inland and forbidding ships to enter Chinese ports. On the one hand, the ban brought foreign trade to an almost complete halt for over twenty years. On the other hand, as China has few rich silver mines, silver is highly dependent upon imports, and the ban made it difficult for silver to flow into China (Thierry, 1998). The effects of natural disasters naturally recovered as factors capable of having an impact on the price index, such as production capacity, foreign trade and the inflow of silver, temporarily disappeared.

With the restoration of peace and order and the lifting of the ban on foreign trade in the early 1780s, China entered a period of long-term political and economic stability, which likewise means that one of the factors that previously had a significant impact on price indices, namely natural disasters, is being or will be gradually replaced. The lifting of the trade ban opened up a new period of trade between China and the West, especially between China and Britain. On the one hand, the increase in the volume of international trade was bound to have an impact on the domestic market and lead to changes in the price index. On the other hand, while the demand for Chinese goods such as tea, silks and porcelain increased rapidly in the West, China had no great interest in Western goods, thus allowing China to have a large trade surplus for a considerable period, with a large amount of silver flowing into the domestic market. Because silver was the main medium of exchange and means of payment in China, the influx of silver had a significant impact on the market and price indices (Quan, 1957). The opening of markets and the increase in the volume of trade was a gradual process, so foreign trade had an increasing impact on the price index and natural disasters a decreasing one. Similarly, if the change in the price index in the 18th century was due to the influx of silver, the outflow of silver during the late Qing had the same effect (Wang, 1972). It is also worth noting that the monetization of silver and the dramatic increase in its supply during the 18th century, the heyday of the traditional Chinese economy, stimulated the rise of long-distance trade and regional merchant communities, and the increase in industrial and agricultural production, all reflecting the general economic development of the period, a trend that was by no means limited to the 18th century. In the late Qing, as the above

factors continued to gather momentum, the money supply and government financial actions had an increasing impact on the economy, which eventually translated into price indices (Yan, 2009). These factors combine to make the impact of natural disasters on price indices increasingly insignificant.

6. Conclusion

In this work, in order to determine whether there was a systematic correlation between natural disasters and price index movements, we evaluated the correlation between natural disasters and price indices across China for a total of 268 years from 1644 to 1911. We found that China's economy during the Qing dynasty developed from the outset in response to external conditions, as reflected in the changes in the price indices. Global climate change, famines and fluctuations in the production of silver in the 1630s and 1640s led to a crisis across East Asia in the 17th century, the knock-on effects of which in China had a significant impact on the price indices. Later, with the enactment of the ban on trade, external influences were removed, and the traditional influences from natural disasters returned, which explains the strong correlation and the increase in the correlation coefficient in the early Qing. However, with the lifting of the trade ban, imported goods and silver flows began to hit the domestic market again, and with the subsequent changes made to the domestic economy to accommodate the foreign market, the impact of natural disasters was steadily weakened, causing the correlation between the two to decrease.

Unlike previous studies that were based on traditional document analysis, we combine quantitative analysis with a holistic historical perspective, making the paper more scientifically relevant and the findings more generalizable. At the same time, the use of new historical sources has increased the value of this text as literature. However, this paper has some limitations, such as the lack of depth in the analysis of individual influencing factors, the lack of descriptive analysis of the intrinsic nature of the phenomenon, etc. In future research, I hope that researchers can enrich and expand the data and conclusions of this paper by making extensive use of relevant historical sources while retaining the scientific rigour of quantitative research.

Conflicts of Interest: The authors declare no conflict of interest.
ORCID iD: Shiyao Zhang: https://orcid.org/0000-0002-7093-3506 Yubang Chen: https://orcid.org/0000-0001-8370-7121

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