THE ECONOMIC JOURNAL

The Economic Journal, **124** (*March*), 92–118. Doi: 10.1111/ecoj.12037 Published by John Wiley & Sons, 9600 Garsington Road, Oxford OX4 2DQ, UK and 350 Main Street, Malden, MA 02148, USA.

WEATHER SHOCKS, SWEET POTATOES AND PEASANT REVOLTS IN HISTORICAL CHINA*

Ruixue Jia

I use data covering 267 prefectures over four centuries to investigate two questions about historical China. To what extent did weather shocks cause civil conflict? And to what extent did the historical introduction of (drought resistant) sweet potatoes mitigate these effects? I find that before the introduction of sweet potatoes, exceptional droughts increased the probability of peasant revolts by around 0.7 percentage points, which translates into a revolt probability in drought years that is more than twice the average revolt probability. After the introduction of sweet potatoes, exceptional droughts only increased the probability of peasant revolts by around 0.2 percentage points.

In recent years, historians and climatologists have found evidence of a link between weather-induced economic decline and conflict for ancient Egypt (Fagan, 2009), the Classic Mayan culture (Diamond, 2006; Yancheva *et al.*, 2007) and the Qing and Tang Dynasties in China (Hinsch, 1988; Yancheva *et al.*, 2007). I contribute to this research using data covering 267 prefectures over more than four centuries to investigate two questions about historical China. To what extent did weather-induced bad harvests cause civil conflict? And to what extent did the historical introduction of (drought resistant) sweet potatoes mitigate these effects?

Historical China is a good testing ground for the link between weather shocks and civil conflict as there is detailed information on abnormal weather conditions and the occurrence of peasant revolts – my proxy of civil conflict – at the prefecture level going back to the fifteenth century. These data show that there was a peasant revolt in 0.22% of all prefecture-years. However, when I focus on prefecture-years when there was an exceptional drought, there was a peasant revolt in 0.58% of prefecture-years. Hence, a peasant revolt at the prefecture level was almost three times more likely in a drought year. My econometric estimates using fixed-effects models confirm that peasant revolts were more likely during droughts and show that the effect is statistically significant. I also find that peasant revolts were more likely in flood years but the impact of floods is only about half that of droughts.

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I am indebted to Antonio Ciccone, two anonymous referees and Torsten Persson whose comments and suggestions substantially improved the exposition of the article. The idea of examining the second question (the impact of sweet potatoes) originates from a conversation with Nathan Nunn. Philippe Aghion, Ying Bai, Davide Cantoni, Shuji Cao, James Fenske, Masayuki Kudamatsu, Dwight Perkins, Nancy Qian, James Robinson, David Strömberg and the participants at the Asian Economic History Conference, HiCN Workshop, EEA, LSE Economics History Workshop, STICERD Work in Progress, IIES and SITE Stockholm provided helpful comments. I thank Wenxin Du for jointly collecting the grain prices data with me and Carol Shiue for sharing her granary storage data. Editorial assistance was provided by Christina Lönnblad and financial support was provided by Handelsbanken's Research Foundations. Any remaining mistakes are my own.

Weather shocks are usually thought to affect the likelihood of civil conflict because of the associated negative income shocks (Keller, 1992; Miguel *et al.*, 2004; Ciccone, 2011). The lack of systematic agricultural output data for historical China does not allow me to check the link between abnormal weather conditions and agricultural production. But as there is prefecture-level data on agricultural prices since the eighteenth century, I can examine the link between weather and the prices of wheat and rice, two traditional staple crops in China. I find that both droughts and floods significantly raised the prices of wheat and rice, which suggests that droughts and floods decreased the local supply of these crops. The price effect of droughts is nearly three times that of floods, which indicates that droughts had more severe negative effects on local output. This may partly explain why droughts have had more of an effect on peasant revolts than floods. My finding that droughts were more likely to trigger peasant revolts than floods is consistent with historians' argument that droughts were the most important natural disasters driving historical peasant revolts (Xia, 2010).

I also analyse whether the link between abnormal weather conditions and peasant revolts changed with the introduction of sweet potatoes from the Americas. As is well known, sweet potatoes survive bad weather better than wheat and rice and also provide more calories per unit of land. Moreover, sweet potatoes can be grown on land that is inappropriate for wheat and rice and are not grown during the same season (Pomeranz, 2000; Cao, 2004). As a result, the availability of sweet potatoes translates into greater agricultural production, especially in bad weather conditions. To test whether these virtues of sweet potatoes lead to a weaker link between weather conditions and peasant revolts, I collect data on the adoption and diffusion of sweet potatoes across different provinces (provinces are collections of prefectures). Before the introduction of sweet potatoes, I find that there was a peasant revolt in 0.78% of prefecture-years with an exceptional drought. After the introduction of sweet potatoes, there was a peasant revolt in only 0.26% of prefecture-years with an exceptional drought. These comparisons suggest that the adoption of sweet potatoes might have mitigated the impact of droughts. This is confirmed by my econometric estimates using fixed-effects estimates.

One potential concern is that the mitigating effect of sweet potatoes captures the role of omitted variables. For example, better institutions might lead to the adoption of new crops as well as fewer revolts. I argue that the adoption of sweet potatoes was determined by the distance from the Chinese region where there were first adopted rather than prefecture governance and conduct tests to check whether the adoption of sweet potatoe was correlated with the (few available) proxies for development and economic policy. I do not find a statistically significant correlation between the timing of sweet potatoe adoption on the one hand and population density and land tax rates on the other for example. I also show that the timing of sweet potatoe adoption is not correlated with previous local revolts. Another concern is that the mitigating effect of sweet potatoes may capture time trends. For example, state authorities might have become more efficient in preventing revolts over time. To deal with this concern, I allow the effect of droughts on revolts to change over time by controlling for an interaction between droughts and a linear time trend. This does not change the baseline results. I also perform a so-called placebo test with maize, which was introduced in China around the same time period as sweet potatoes but had a different diffusion path across regions. If the adoption of new crops were driven by prefecture governance effects that are correlated with the outbreak of civil conflict, maize should also have an equivalent mitigating effect on the link between droughts and peasant revolts. I do not find this to be the case.

My analysis contributes to the literature on the historical link between droughts and civil conflict, for example, Davis (2001), Diamond (2006), Yancheva *et al.* (2007), Fagan (2009) and Bai and Kung (2011). So far this literature has relied exclusively on time-series variation to estimate the effect of droughts on civil conflict. One important advantage of my panel data approach is that it allows me to examine the effect of drought shocks controlling for other global drivers of conflict. Within the literature on the historical link between droughts and civil conflict, my work is most closely related to Bai and Kung who examine the effect of droughts on wars between Han China and nomadic tribes of Central Asia, Mongolia and Eastern Europe using time-series data for more than 2000 years.

My work also relates to the literature on the effect of weather shocks on civil conflict using modern panel data (Miguel *et al.*, 2004; Besley and Persson, 2009; Jensen *et al.*, 2009; Ciccone, 2011; Ferrara and Harari, 2011).[1] The link between rainfall and civil conflict in modern panel data has been examined using two main empirical specifications. Miguel *et al.* (2004) link civil conflict to year-on-year changes in rainfall and examine whether civil conflict is more likely when rainfall drops from one year to the next. On the other hand, Ciccone (2011) links civil conflict to rainfall levels and examines whether conflict is more likely following droughts. My specification is more closely linked to Ciccone (2011).[2] An important advantage of my work compared to the modern panel data literature on the effect of economic shocks on civil conflict is that I have data for a much longer period of time (over four centuries compared to periods of 20–30 years).

My analysis also contributes to evaluating the consequences of the Colombian exchange – the historical exchange of crops, diseases and ideas between the New World and the Old World. For example, Nunn and Qian (2011*b*) show that the introduction of potatoes had a significant impact on population growth and urbanisation in Europe.[3] My findings indicate that the Columbian exchanges also ended up affecting the likelihood of civil conflicts in China.[4]

The rest of the article is organised as follows. Section 1 provides a discussion of the historical background, including the existing research by historians on weather shocks

[1] Besides weather shocks, the literature that links civil conflict to shocks using modern panel data also explores other types of exogenous economic shocks such as shocks to commodity prices (Dube and Vargas, 2013; Bruckner and Ciccone, 2010) and foreign aid (De Ree and Nillesen, 2009; Dube and Naidu, 2009; Nunn and Qian, 2011*a*).

[2] Ciccone shows that the specification where conflict is caused by year-on-year weather changes is a special case of the specification where conflict is caused by weather levels, and that the two specifications can therefore be tested against one another. My data indicate that peasant revolts were driven by bad weather rather than year-on-year changes in weather to the worse.

[3] Their identification strategy exploits suitability data from FAO-GAEZ. In the case of sweet potatoes in China, the suitability data differ greatly from real cultivation: only South China is suitable for sweet potatoes in the FAO-GAEZ data but sweet potatoes have been cultivated across China since their adoption. Hence, I cannot use the same identification strategy. Instead, I explore the variation in the adoption timing.

[4] A recent working paper examines the effect of potatoes on conflict in Europe (Iygun *et al.*, 2012).

and peasant revolts as well as the diffusion of sweet potatoes. Section 2 describes the data. Section 3 presents the empirical strategy and the main results. Section 4 reports robustness checks regarding the mitigating impact of sweet potatoes. Section 5 concludes the article.

1. Historical Background

I first review the literature on the link between weather and conflict and then the literature on the impact of sweet potatoes in Chinese history.

1.1. *Weather Shocks and Peasant Revolts*

During its long history as an agrarian society, China was very vulnerable to adverse changes in weather. The link between weather changes and peasant revolts was already mentioned by influential Chinese historian Deng Tuo, who pointed out that 'the repeated occurrence of peasant revolts, regardless of their range or duration, is triggered by famine, that is, triggered by natural disasters. This has become a rule of history' (Deng, 1937). Ecologists were the first to try and test the correlation between weather and warfare in China. For instance, Zhang *et al.* (2007) show that almost all peaks of conflict frequency and dynastic change in China over the last millennium occurred in cooling phases. Bai and Kung (2011) focus on Sino-Nomadic wars and find that they were more likely during droughts. My analysis differs from this previous work in focusing on peasant revolts, which are the majority of recorded civil conflicts and are a relatively homogenous type of conflict, and examining the link between weather and conflict at the local (prefecture) level.

1.2. *Sweet Potatoes in China and Their Impact*

Sweet potatoes are native to the tropical parts of South America and were brought into China in the mid-seventeenth century from Burma, Malaysia and Vietnam. They gradually moved from the South to the North of China and eventually became widely spread. In the 1920s, China produced over one-fourth of all sweet potatoes in the world and today the share is over 90% (FAO, 2010). The advantages of sweet potatoes over wheat and rice, the traditional staple food in China, are well known (Xu, 1628; Cao, 2005; Song, 2007). Sweet potatoes are drought resistant and have higher yields per unit of land than rice and wheat. Moreover, sweet potatoes can grow on land of relatively poor quality and are usually cultivated in a different season from rice and wheat (Pomeranz, 2000; Cao, 2005). These properties of sweet potatoes imply that they allow farmers to both reduce downside risk and increase yields in good times. An historical literature has attributed rapid population growth in China during the Ming and Qing Dynasties to these 'insurance' and 'productivity' effects of sweet potatoes (Ho, 1979). However, it remains unclear how much sweet potatoes contributed to China's population growth quantitatively (Lee, 1982). It is worthwhile mentioning that the mitigating effect of sweet potatoes on the link between droughts and peasant revolts may arise because sweet potatoes provided insurance during droughts but also because the productivity effect of sweet potatoes allows farmers to build a larger buffer stock of food. However, the latter effect might dissipate over time, as population catches up with the greater supply of food.

Despite their widespread use as food, sweet potatoes are considered poor man's food in China, both historically and today (Simoons, 1991). Xu (1628) explains that sweet potatoes can help people survive in years of crop failure, whereas they can be turned into alcohol in years of good harvest. Buck (1937) provides the earliest quantitative document of sweet potato consumption in China. He conducted a detailed survey of 16,786 farms in rural villages across China in the 1920s, where sweet potatoes were mentioned by 84% of the farm families. When people were asked why they decreased their consumption of sweet potatoes as compared to the previous year, 100% answered that they switched to rice or wheat.

According to the historical literature, sweet potatoes were introduced in China by Chinese businessmen working in Southeast Asia. They brought sweet potatoes to China when they realised that this crop survived droughts (Chen, 1981; Wang *et al.*, 2010). Sweet potatoes then moved slowly across nearby regions. Therefore, the adoption timing of sweet potatoes was closely related to the distance from the Chinese region where it was first adopted. Central government promotion appears to have played a role only since the mid-eighteenth century (Chen, 1981; Wang *et al.*, 2010).

2. Data

I now describe my data sources for two dependent variables (peasant revolts and grain prices), two main independent variables of interest (weather shocks and the diffusion of sweet potatoes) and a few control variables. The data on the location of peasant revolts and weather shocks are available at the prefecture level between 1470 and 1900, whereas the data on grain prices are available at the prefecture level between 1750 and 1900. The timing of the adoption of sweet potatoes is only available at the provincial level.

2.1. *Peasant Revolts*

My data source for peasant revolts is a multi-volume book entitled 'Chronology of Warfare in Dynastic China' (The Editing Committee of China's Military History, 1985). Revolts are listed by year with information on where a revolt took place, who the leaders were, and a brief summary of the spread and result of the revolt. The same data source has been used in existing studies on climate shocks and wars such as Zhang *et al.* (2007) and Bai and Kung (2011). Zhang *et al.* (2007) summed all wars together, whereas Bai and Kung (2011) focus on Sino-Nomadic wars. I focus on civil conflict, particularly peasant revolts.

To give an example of a typical revolt, the Rebellion of Li Zhen in Yanshan is presented as follows. 'In September of the thirteenth year of Emperor Zhengde (the year of 1518), Li Zhen and other peasants in Yanshan, Jiang Xi Province revolted and occupied the county capital. The number of participants was nearly 3,000. The provincial governor, Sun Sui, commanded vice governor Wang Lun and the army to suppress the revolt. Li Zhen was killed and the revolt failed'.

The example represents the descriptions of most of the revolts, although some do not include the number of participants. As illustrated by this example, the descriptions allow me to identify when and where the revolt happened as well as the parties. Unfortunately, there is neither information about the severity of the revolts, such as the number of casualties for example, nor information about the causes of the revolts. The two parties in a peasant revolt are a group of peasants and the local or central government. This feature of peasant revolts corresponds to the definition of modern civil conflict. For example, most of the existing empirical studies on modern civil war rely on the Correlates of War (COW) data set or the UCDP/PRIO data set. To be classified as a civil war in the COW data set, the central government should be actively involved in military action with effective resistance on both sides, and there should be at least 1,000 battle-related deaths during the civil war. In the UCDP/PRIO data set, conflict is defined as a contested incompatibility that concerns government and/or territory where the use of armed forces between two parties, of which at least one is the government of a state, results in at least 25 battle-related deaths. Most of the peasant revolts in my data were local and were very quickly suppressed by the government. Hence, the average scale of a peasant revolt might be smaller than the average scale of a modern civil war.

In most cases, there was at most one peasant revolt in a prefecture within one year. Only in a few rare cases did a revolt lead to repeated battles within a prefecture within one year, in which case I still count them as one. This yields 249 peasant revolts between 1470 and 1900. The summary statistics for peasant revolts expressed in percentage points are presented in panel (*a*) of Table 1, with a mean of 0.22 percentage points.

Table 1

Summary Statistics: Prefecture by Year Data

	Mean	SD	Min	Max	Obs.	Period
Panel (a): Dependent variables						
Revolts × 100*	0.22	4.73	0	100	111,199	1470–1900
Wheat price: Upper bound†	176.40	77.33	27	1,680	23,276	1750–1900
Wheat price: Lower bound†	125.59	53.42	11	1,092	23,276	1750–1900
Rice price: Upper bound†	314.23	113.97	107	1,070	4,389	1750–1900
Rice price: Lower bound†	229.23	74.71	56	646	4,389	1750–1900
Panel (b): Independent variables of interest						
Exceptional drought‡	0.06	0.24	0	1	111,199	1470–1900
Exceptional flood‡	0.06	0.25	0	1	111,199	1470–1900
Limited drought‡	0.14	0.35	0	1	111,199	1470–1900
Limited flood‡	0.17	0.37	0	1	111,199	1470–1900
Sweet potato§	0.44	0.50	0	1	111,199	1470–1900
Panel (c): Control variables (time-invariant)						
Longitude¶	111.65	5.68	95.79	121.54	111,199	
Latitude¶	30.55	4.97	20.01	40.97	111,199	
Agricultural suitability‖	0.82	0.33	0	1	107,320	

Data sources and notes. *The Editing Committee of China's Military History's (1985). †Wang (2009). Prices are measured by Tales per 100 Dan. The prices refer to August prices, and rice refers to mid-grade rice. ‡The State Meteorological Society (1981). §Guo (1979). ¶China Historical GIS: http://www.fas.harvard.edu/zchgis/. ‖Ramankutty *et al.* (2002).

2.2. *Grain Prices*

Historical data on grain yields across China are currently not available. However, there is monthly prefecture-level grain prices data since the 1750s. From 1736, provincial government officials were required to report grain prices in each prefecture within their province. Thanks to more than 30 years of work by Yeh-chien Wang, data from the archives have become a complete database (Wang, 2009). The data start from 1736 but is very incomplete before the 1750s. Part of the data has been used in Keller and Shiue (2007) to examine the market integration of China in the eighteenth century. The price data include information on both the upper bound and the lower bound of prices in every month. The summary statistics for prices of wheat and mid-grade rice in the month of August are presented in panel (*a*) of Table 1.[5]

2.3. *Weather Shocks*

Historical weather data come from the State Meteorological Society (1981), which provides annual information on the weather for locations throughout China back to 1470. This data source was also used in Keller and Shiue (2007). A systematic record of rainfall began as early as in the Tang Dynasty (618–907 AD). At least from the seventeenth century onward, the collection of weather reports at the prefecture level had become standard government practice. The sources of weather indicators for the historical period in the State Meteorological Society (1981) include rainfall records from weather stations, official documents in the two dynasties (the Veritable Records of the Ming and Qing Dynasties, the History of the Ming Dynasty and the Qing Dynasty), as well as more than 2,200 local gazetteers. This data contain a variable denoted dryness, which is a discrete indicator of the degree of wetness and aridity, due to floods, droughts, monsoons or rainfall. Normal weather is indicated by the number 3. Exceptional floods and exceptional droughts are indicated by the numbers 1 and 5, respectively, whereas limited floods and limited droughts are indicated by the numbers 2 and 4 respectively. The indicators are assigned by the meteorologists based on the measurements of the closest weather stations. On average, one weather station roughly covers about two prefectures. In the prefecture-year data, the distribution of the weather indicators is close to symmetric, with about 6.1% exceptional droughts (the indicator is 5), 6.5% exceptional floods (the indicator is 1), 14.3% limited droughts (the indicator is 4), 17% limited floods (the indicator is 2) and 56.4% normal weather.[6] The summary statistics of the weather conditions are presented in panel (*b*) of Table 1.

[5] I focus on August because it is after the harvest season. The results below are robust to using price data in other months. The observations of rice prices are fewer than those of wheat because rice was mainly grown in South China.

[6] Normal weather also includes the cases when the weather indicators were not assigned because abnormal weather was identified with priority in the historical records used in the State Meteorological Society (1981). Dropping them does not affect the main results on the strong and positive impact of droughts on revolts and the mitigating effect of sweet potatoes. However, the positive effect of floods on revolts becomes even weaker, which is also consistent with the historians' emphasis on the role of droughts in revolts.

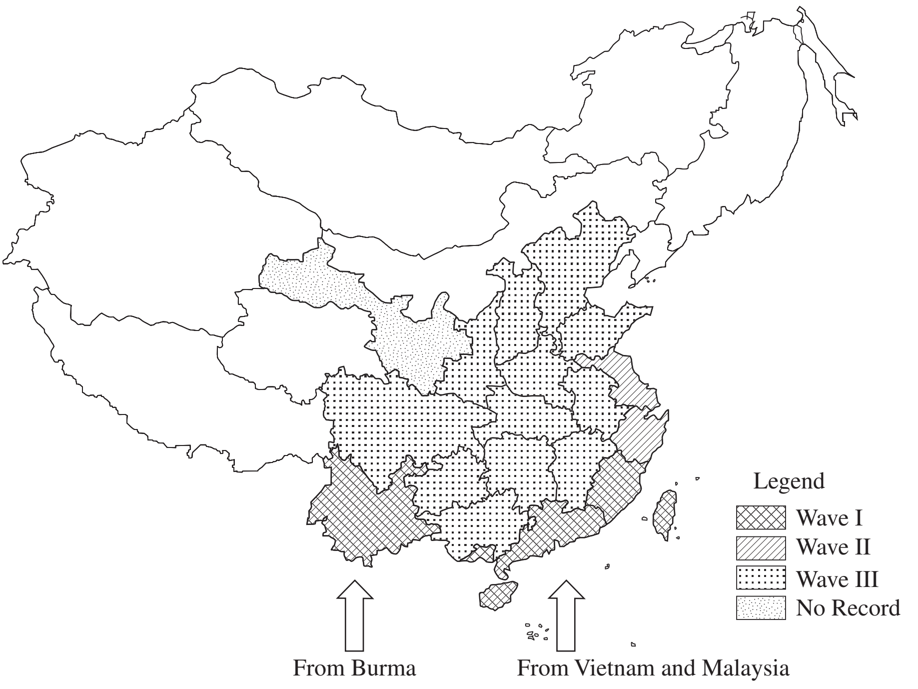

Fig. 1. *Adoption Timing of Sweet Potatoes*
Note. In the first wave, Yunnan in the southwest adopted sweet potatoes from Burma, whereas provinces in the southeast adopted them from Vietnam and Malaysia.

2.4. *Diffusion of Sweet Potatoes*

Guo (1979) presents information on the time of the adoption of sweet potatoes and maize in different provinces, as well as the cultivation of these crops in the mid-eighteenth century. Chen and Kung (2012) show that the introduction of maize increases population growth in China. I also use a second source (Wu, 1983) for adoption to double check the consistency. The two sources provide consistent information on sweet potatoes and maize, except for the time of the adoption of sweet potatoes in Yunnan Province. Below, I only present the results using the information from Guo (1979) but my results are robust to the exclusion of Yunnan Province. Figure 1 illustrates the timing of diffusion where I distinguish four waves of adoption: Wave I from the 1570s to the 1600s; Wave II from the 1600s to the 1630s; Wave III from the 1730s to the 1760s; Wave IV for the single province with no record of sweet potatoes by the 1760s. The exact years are listed in Table 2. Roughly speaking, provinces in the South had adopted sweet potatoes by the mid-seventeenth century (the late Ming dynasty), whereas provinces in the North had adopted sweet potatoes by the mid-eighteenth century (the mid-Qing dynasty).

Table 2

The Number of Revolts and the Adoption Timing by Province

Province	Total revolts	Adoption year	Dynasty
Yunnan	11	1576	Ming
Guangdong	26	1580	Ming
Fujian	8	1593	Ming
Jiangsu	7	1608	Ming
Zhejiang	6	1608	Ming
Sichuan	22	1733	Qing
Guangxi	20	1736	Qing
Jiangxi	14	1736	Qing
Hubei	18	1740	Qing
Henan	15	1743	Qing
Shandong	16	1742	Qing
Hunan	17	1746	Qing
Shaanxi	14	1746	Qing
Zhili	7	1748	Qing
Guizhou	26	1752	Qing
Shanxi	5	1756	Qing
Anhui	6	1768	Qing
Gansu	11	NA	Qing

Notes. The province of Gansu did not adopt sweet potatoes in the data. Ming Dynasty started in 1368 and ended in 1644 whereas Qing Dynasty started in 1644 and ended in 1911.

2.5. *Control Variables*

In my estimation, I control for the interaction of a few spatial characteristics of prefectures with a linear time trend to take into account their impacts over time. These characteristics include from longitude and latitude obtained from Chinese Historical GIS (CHGIS, 2007) as well as suitability of agriculture used in Ramankutty *et al.* (2002).[7] The summary statistics for these variables are reported in panel (*c*) of Table 1. They show that over 82% of the prefectures are suitable for agriculture.

3. Estimation Strategy and Main Results

I first examine the impact of weather shocks on peasant revolts, where I also link weather shocks to grain prices. Then, I investigate whether the introduction of sweet potatoes mitigated the impact of weather shocks on revolts.

3.1. *The Impact of Weather Shocks on Peasant Revolts and Grain Prices*

To examine how weather shocks affect the likelihood of revolts, I employ a linear-probability model linking peasant revolts to weather shocks:

$$R_{it} = \beta_1 D_{it} - \beta_2 F_{it} + \beta_3 LD_{it} + \beta_4 LF_{it} + \boldsymbol{\lambda} \boldsymbol{X}_i t - \alpha_i + \gamma_t + \varepsilon_{it}, \quad (1)$$

where R_{it} is a dummy indicating whether there is a revolt in prefecture *i* and year *t*. D_{it} and F_{it} are dummy variables for exceptional droughts (the weather indicator is 5) and exceptional floods (the weather indicator is 1) in prefecture *i* and year *t*. Similarly, LD_{it}

[7] This suitability information is not available for nine prefectures.

and LF_{it} are dummy variables for limited droughts (the weather indicator is 4) and limited floods (the weather indicator is 2).

α_i and γ_t denote prefecture fixed effects and year fixed effects. Prefecture fixed effects control for all time-invariant differences between prefectures. Year fixed effects control for time-variant changes that affect all prefectures similarly. I also control for the interactions of observable prefecture characteristics with a linear time trend ($\boldsymbol{X}_i t$). $\boldsymbol{X}_i$ is a vector of spatial characteristics of prefectures including longitude, latitude and suitability of agriculture. Instead of $\boldsymbol{X}_i t$, I can control for prefecture-specific time trends by including the interactions of prefecture dummies and a linear time trend ($pref_i t$). This way, I allow the estimates to take into account widening differences across regions during the long time horizon of this study. To take care of autocorrelation concerns of weather shocks, standard errors are clustered at the weather station level.[8]

The results are presented in Table 3. To facilitate the reading of the regression tables, the dependent variable is multiplied by 100. Thus, the coefficients can be interpreted as the probability of revolts expressed in percentage points. Column 1 shows the ordinary least squares (OLS) result without controlling for any fixed effects. Column 2 shows the result after controlling for prefecture and year fixed effects. Column 3 presents the result after controlling for the interactions of observable prefecture characteristics and a linear time trend ($\boldsymbol{X}_i t$), whereas column 4 presents the

Table 3

The Impact of Weather Shocks on Revolts

	Revolts			
	(1)	(2)	(3)	(4)
Exceptional drought	0.429***	0.470***	0.464***	0.476***
	(0.060)	(0.103)	(0.107)	(0.104)
Exceptional flood	0.121**	0.201***	0.182***	0.211***
	(0.059)	(0.070)	(0.069)	(0.071)
Limited drought	0.234***	0.298***	0.277***	0.307***
	(0.042)	(0.076)	(0.071)	(0.078)
Limited flood	0.077*	0.142***	0.130***	0.151***
	(0.039)	(0.044)	(0.044)	(0.044)
Prefecture and year FE		Y	Y	Y
Controls × year			Y	
Preference dummy × year				Y
No. clusters		86	86	86
No. observations	111,199	111,199	107,320	111,199

Notes. *Significant at 10%, **5%, ***1%. Reported in parentheses are standard errors clustered at the weather station level in columns 2 and 4. The dependent variable is 0 or 100, and hence the coefficients can be interpreted as percentage points. Exceptional drought (or exceptional flood) is set at 1 when the weather indicator is 5 (or 1). Limited drought (or limited flood) is set at 1 when the weather indicator is 4 (or 2). The controls include longitude, latitude and agricultural suitability. Controls × Year indicates the interactions of these controls and a linear time trend and Preference dummy × Year indicates prefecture-specific time trends.

[8] The results are robust to clustering standard errors at different levels. See Table C1 in Appendix C for standard errors clustered at the province level, the year level as well as two-way clustered at both the province and the year level.

results controlling for prefecture-specific time trends ($pref_i t$).[9] The estimates are stable across different specifications. On average, an exceptional drought and an exceptional drought flood increased peasant revolts by about 0.46 and 0.18 percentage points respectively. These results also show that the impacts of limited droughts and floods were smaller than exceptional droughts and floods, suggesting that the data on weather shocks are reasonable.

The finding that the impact of droughts on revolts is more than twice that of floods is consistent with qualitative historical studies. For instance, Xia (2010) argues that droughts were the most important natural disasters that affected peasant revolts in historical China because they affected larger areas and lasted longer than floods.[10] On top of this, droughts did not kill people directly as floods often did, leaving hungry and motivated peasants for revolts.

Table 4 presents the results when I also include lagged weather conditions as determinants of peasant revolts.[11] Column 1 shows that an exceptional drought increases the probability of revolts one year later by about 0.3 percentage points. The specification in column 1 imposes that the marginal effect of weather in year t is independent of weather in year $t-1$. I test the validity of this hypothesis by allowing for interaction effects between current and lagged weather shocks. As shown in column 2, none of these interactions have a significant impact on revolts and the estimated coefficients are also jointly insignificant (with a p-value of 0.80), which suggests that the specification in column 1 is valid. The results in column 1 also indicate that peasant revolts were caused by bad weather rather than year-on-year changes in weather to the worse. To see this, note that if peasant revolts were caused by year-on-year changes in weather to the worse, the effect of a lagged exceptional drought should be equal to minus the effect of a current exceptional drought – as the two scenarios imply changes in weather of the same magnitude but opposite sign. Hence, if exceptional droughts in year t increase the probability of peasant revolts in year t, exceptional droughts in year $t-1$ should decrease the probability of revolts in year t. However, this is not the case in my data as the impact of a current and a lagged exceptional drought are both significantly positive. Analogous implications regarding limited droughts, exceptional floods and limited floods are also rejected by the results in column 1.[12]

To test the impacts of droughts and floods further, I link weather shocks to grain prices between 1750 and 1900. The relationship between weather shocks and grain prices will help us understand the channel through which weather shocks affect peasant revolts. The empirical specification for the price effects of weather is analogous to (1),

[9] Because $\boldsymbol{X}_i t$ is redundant once $pref_i t$ is included, I only present the results after controlling for $\boldsymbol{X}_i t$ in the Sections below. Including $pref_i t$ instead of $\boldsymbol{X}_i t$ does not change the results.

[10] The conjecture that droughts were more persistent than floods is confirmed by the results in Table A1 in Appendix A.

[11] Table A1 in Appendix A reports the persistence of droughts/floods, and Table A2 in Appendix A reports the impact of different combinations of the lags and leads.

[12] The hypothesis that the effect of a current exceptional drought is equal to minus the effect of a lagged exceptional drought is rejected with a p-value very close to 0. Analogous implications for limited droughts, exceptional floods, and limited floods are rejected with p-values of 0.005, 0.089 and 0.033 respectively. The four hypotheses are jointly rejected with a p-value very close to 0.

Table 4

The Impact of Lagged Weather Conditions

	Revolts	
	(1)	(2)
Exceptional drought t	0.415***	0.372***
	(0.100)	(0.126)
Exceptional flood t	0.187***	0.243**
	(0.068)	(0.096)
Limited drought t	0.267***	0.309***
	(0.071)	(0.086)
Limited flood t	0.130***	0.131**
	(0.044)	(0.052)
Exceptional drought $t-1$	0.283***	0.320**
	(0.091)	(0.133)
Exceptional flood $t-1$	−0.034	−0.021
	(0.055)	(0.067)
Limited drought $t-1$	−0.050	−0.036
	(0.045)	(0.042)
Limited flood $t-1$	−0.006	0.010
	(0.040)	(0.047)
Exceptional drought t × exceptional drought $t-1$		0.037
		(0.261)
Exceptional drought t × limited drought $t-1$		0.104
		(0.226)
Limited drought t × exceptional drought $t-1$		−0.163
		(0.213)
Limited drought t × limited drought $t-1$		−0.115
		(0.108)
Exceptional flood t × exceptional flood $t-1$		−0.113
		(0.160)
Exceptional flood t × limited flood $t-1$		−0.164
		(0.151)
Limited flood t × exceptional flood $t-1$		−0.004
		(0.119)
Limited flood t × limited flood $t-1$		−0.010
		(0.084)
Prefecture and year FE	Y	Y
Controls × year	Y	Y
No. observations	107,068	107,068
Joint significance of the interactions		p = 0.80

Notes. The specification is the same as column 3 in Table 3 except that lagged weather conditions and their interactions with current weather conditions are also included.

$$\ln P_{it} = \beta_1 D_{it} - \beta_2 F_{it} - \beta_3 L_{it} + \beta_4 LF_{it} + \boldsymbol{\delta}_i \boldsymbol{X}_i t + \alpha_i + \gamma_t + \varepsilon_{it}, \qquad (2)$$

where ln P_{it} is the log of the wheat and rice prices. As prices are in logs, β_i is approximately equal to the percentage change in prices due to weather shocks.[13] As in (1), I also control for prefecture and year fixed effects as well as the interactions of prefecture characteristics and a linear time trend.

The results are presented in Table 5. Columns 1 and 2 present the results for the upper bound of the wheat price using fixed effects regressions with and without

[13] Table A3 in Appendix A reports results of the impact of the lag/lead of weather conditions on grain prices.

Table 5

Weather Shocks and Prices of Wheat and Rice in August (1750–1900)

	Wheat: upper		Wheat: lower		Rice: upper		Rice: lower	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Exceptional drought	0.107***	0.105***	0.099***	0.099***	0.079***	0.076***	0.051***	0.054***
	(0.013)	(0.014)	(0.014)	(0.015)	(0.019)	(0.018)	(0.017)	(0.017)
Exceptional flood	0.038***	0.037***	0.048***	0.045***	0.035***	0.033***	0.034***	0.033***
	(0.011)	(0.011)	(0.011)	(0.012)	(0.008)	(0.008)	(0.011)	(0.012)
Limited drought	0.052***	0.053***	0.046***	0.047***	0.055***	0.052***	0.035***	0.033***
	(0.010)	(0.010)	(0.010)	(0.010)	(0.011)	(0.010)	(0.011)	(0.012)
Limited flood	0.034***	0.034***	0.031***	0.032***	0.030***	0.028***	0.020**	0.024***
	(0.008)	(0.008)	(0.010)	(0.010)	(0.008)	(0.008)	(0.009)	(0.008)
Prefecture and year FE	Y	Y	Y	Y	Y	Y	Y	Y
Controls × Year		Y		Y		Y		Y
No. clusters	79	78	79	78	28	28	28	28
No. observations	22,151	21,465	22,151	21,465	4,012	4,004	4,012	4,004

Notes. *Significant at 10%, **5%, ***1%. Reported in parentheses are standard errors clustered at the weather station level. The dependent variables are in logs. Columns 1–4 are the results for wheat prices. Columns 5–8 are the results for mid-grade rice. Exceptional drought (or exceptional flood) is set at 1 when the weather indicator is 5 (or 1). Limited drought (or limited flood) is set at 1 when the weather indicator is 4 (or 2). The controls include longitude, latitude and agricultural suitability. Controls × Year indicates the interactions of these controls and a linear time trend.

controlling for the interactions of prefecture characteristics and time trends. In addition, columns 3 and 4 present the results for the lower bound of wheat price. The corresponding results for the price of rice are shown in columns 5–8. The impacts of exceptional droughts and floods are larger than those of limited droughts and floods, which once again confirms that the weather indicator contains useful information on weather conditions. On average, an exceptional drought increased the upper bound of wheat price by about 10.5%, while an exceptional flood increased the upper bound wheat price by about 3.7%. Similarly, droughts increased the upper bound of rice price by about 7.6%, while floods increased the upper bound of rice price by about 3.3%. Hence, the impact of droughts is nearly three times that of floods (in terms of wheat). This quantitative finding contributes to historical studies on why floods have less of an effect on peasant revolts than droughts.

3.2. *The Mitigating Impact of Sweet Potatoes*

Before evaluating the impact of sweet potatoes, one would like to know more about the relationship between the timing of adoption and provincial economic development as well as governance. Information on China's regional development in the sixteenth century is very limited and often only available for a certain year. Liang (1981) provides provincial population sizes and population density in 1578.[14] Huang (1974) is one of

[14] Three provinces changed their boundaries from the Ming Dynasty to the Qing Dynasty. Liang (1981) provided data from 15 provinces in 1578 (in the Ming Dynasty). For the results here, I assume that new provinces in the Qing Dynasty had the same population density, land tax *per capita* and land tax rate in 1578 if the provinces were identical at that point in time.

the most influential historical works on government finance and taxation in this period. The author cites data from the official governmental records on land area and land tax revenues in 1578. The information on population, taxation, weather and revolts before the adoption provides some observable provincial characteristics. I check the correlations between these characteristics and the adoption timing using the following OLS regression:

$$Adopt_p = \Pi \boldsymbol{C}_p + \xi_p, \tag{3}$$

where $\boldsymbol{C}_p$ is a vector including three sets of provincial characteristics: the number of revolts 100 years (and 50 years) before the adoption divided by population size in 1578; the share of exceptional droughts and exceptional floods 100 years (and 50 years) before the adoption; population density; land tax rates and land tax *per capita* in 1578.[15]

The correlations are presented in Table 6. Columns 1–3 present the results using the adoption year as the dependent variable, whereas columns 4–6 present the results

Table 6

Correlations Between Adoption Timing and Provincial Characteristics

	Year			Order		
	(1)	(2)	(3)	(4)	(5)	(6)
Revolt likelihood 100 years before	0.125	0.043	0.050	0.075	−0.676	−0.689
	(0.109)	(0.112)	(0.152)	(0.804)	(0.865)	(1.119)
Revolt likelihood 50 years before	−0.123	−0.052	−0.044	−0.165	0.601	0.722
	(0.087)	(0.098)	(0.125)	(0.640)	(0.757)	(0.922)
Exceptional drought likelihood 100 years before		−0.047	0.023		0.393	1.321
		(0.176)	(0.241)		(1.356)	(1.776)
Exceptional drought likelihood 50 years before		−0.110	−0.185		−0.914	−1.843
		(0.137)	(0.194)		(1.052)	(1.427)
Exceptional flood likelihood 100 years before		0.233*	0.218		1.539	1.408
		(0.116)	(0.134)		(0.896)	(0.983)
Exceptional flood likelihood 50 years before		−0.103	−0.099		−0.718	−0.598
		(0.083)	(0.108)		(0.640)	(0.795)
Population density			0.012			0.103
			(0.019)			(0.138)
Land tax *per capita*			−0.015			−0.159
			(0.019)			(0.141)
Land tax rate			−0.012			0.106
			(0.083)			(0.610)
No. observations	17	17	17	17	17	17

Notes. *Significant at 10%, **5%, ***1%. The Table shows there to be no systematic correlations between the adoption timing of sweet potatoes and provincial characteristics, including (1) the number of revolts 100 years (and 50 years) before the adoption divided by population size in 1578; (2) the share of exceptional droughts and floods 100 years (and 50 years) before the adoption and (3) population density, land tax rates and land tax *per capita* in 1578.

[15] Land is measured in Mu (about 667 square metres) and the value of land tax is measured in Dan (about 90 kg).

using the order of adoption as the dependent variable. The results from a limited of number of observations suggest that there are no statistically significant correlations between these characteristics and the adoption timing. Nevertheless, I will also control for the interactions of droughts and these characteristics as a robustness check when I examine the impact of sweet potatoes.

The strategy to examine the impact of sweet potatoes is similar to a differences-in-differences (DD) strategy. The specification is as follows:

$$\begin{aligned} R_{it} = {} & \beta_1 D_{it} + \beta_2 F_{it} - \beta_3 D_{it} \times S_{it} - \beta_4 F_{it} \times S_{it} - \beta_5 LD_{it} + \beta_6 LF_{it} \\ & + \beta_7 LD_{it} \times S_{it} + \beta_8 LF_{it} \times S_{it} + \beta_9 S_{it} + \boldsymbol{\delta}_i \mathbf{X}_i t + \alpha_i + \gamma_t + \varepsilon_{it}, \end{aligned} \quad (4)$$

where S_{it} is set at 1 for all years after the time of the adoption in prefecture i.[16] β_1 (or β_2) measures the effect of exceptional droughts (or exceptional floods) before the introduction of sweet potatoes. β_3 (or β_4) measures the interaction effect of sweet potatoes and exceptional droughts (or exceptional floods), that is, the difference in the impacts of exceptional droughts (or exceptional floods) in prefectures that have adopted sweet potatoes and in those that have not yet adopted. β_5 to β_8 are analogous for limited droughts and floods.

The results are presented in Table 7. The dependent variable and the controls in columns 1–3 are the same as in Table 3. They show that an exceptional drought increased the probability of a peasant revolt by about 0.7 percentage points before the introduction of sweet potatoes. To control for potential impacts of the provincial characteristics discussed above, column 4 presents the result after including the interactions of exceptional droughts and these characteristics ($D_{it} \times \boldsymbol{C}_p$) as further control variables. The interaction effect of drought and sweet potatoes is close to previous results (around −0.52), implying that the adoption of sweet potatoes mitigated the effect of droughts significantly. After the adoption of sweet potatoes, exceptional droughts only increased the probability of a peasant revolt by around 0.2 percentage points. Besides, sweet potatoes also exerted a mitigating effect for limited droughts.

The mitigating impact of sweet potatoes provides further evidence on the channel of the impact of droughts on peasant revolts: droughts led to more peasant revolts due to negative impact on food supply. Drought-resistant sweet potatoes dampened the impact of droughts on food supply and hence weakened the link between droughts and revolts.

4. Robustness Checks

I conduct robustness checks regarding the mitigating impact of sweet potatoes. The first concern is that the mitigating effect of sweet potatoes captures the role of time trends. For example, state authorities might have become better in preventing revolts

[16] I use prefecture-level data in the main specification. The data can aggregated horizontally (province-year data) and vertically (prefecture-decade data) to check for consistency. These estimation results are presented in Tables B1 and B2 in Appendix B.

Table 7

The Mitigating Effect of Sweet Potatoes

	Revolts			
	(1)	(2)	(3)	(4)
Exceptional drought × sweet potato	−0.420***	−0.465**	−0.568***	−0.525***
	(0.123)	(0.183)	(0.183)	(0.195)
Exceptional drought	0.594***	0.661***	0.704***	0.937*
	(0.078)	(0.158)	(0.167)	(0.504)
Exceptional flood × sweet potato	−0.076	−0.161	−0.215	−0.214
	(0.118)	(0.145)	(0.151)	(0.153)
Exceptional flood	0.164**	0.277**	0.286**	0.290**
	(0.082)	(0.117)	(0.122)	(0.124)
Sweet potato	−0.105***	−0.119*	−0.094	−0.076
	(0.038)	(0.060)	(0.058)	(0.062)
Limited drought × sweet potato	−0.179**	−0.255**	−0.285**	−0.268**
	(0.085)	(0.117)	(0.124)	(0.128)
Limited drought	0.313***	0.408***	0.403***	0.389***
	(0.056)	(0.101)	(0.104)	(0.109)
Limited flood × sweet potato	−0.004	−0.096	−0.127	−0.138
	(0.079)	(0.093)	(0.097)	(0.100)
Limited flood	0.089	0.184**	0.188**	0.206**
	(0.056)	(0.073)	(0.078)	(0.081)
Prefecture and year FE		Y	Y	Y
Controls × year			Y	Y
Drought × provincial characteristics before adoption				Y
No. clusters		86	86	82
No. observations	111,199	111,199	107,320	103,439

Notes. *Significant at 10%, **5%, ***1%. Reported in parentheses are standard errors, clustered at the weather station level in columns 2–4. The dependent variable is 0 or 100, and hence the coefficients can be interpreted as percentage points. Exceptional drought (or exceptional flood) is set at 1 when the weather indicator is 5 (or 1). Limited drought (or limited flood) is set at 1 when the weather indicator is 4 (or 2). Sweet Potato is set at 1 for the years after adoption. The controls include longitude, latitude and agricultural suitability. Controls × Year indicates the interactions of these controls and a linear time trend. Columns 4 also control for the interaction of droughts and the provincial characteristics before the adoption presented in Table 6.

over time. To deal with this concern, I control for the interaction of droughts (including both exceptional ones and limited ones) and a linear time trend.

The second concern is that the adoption of new crops such as sweet potatoes was mainly driven by prefecture governance effects. To deal with this concern, I perform a placebo test with maize. Maize was introduced in China over the same period as sweet potatoes but the diffusion path across provinces differed somewhat. If the adoption of new crops were driven by prefecture governance effects correlated with the outbreak of peasant revolts, maize should have a similar mitigating effect on the link between droughts and peasant revolts as sweet potatoes.

The third concern is that other historical events affecting peasant revolts are omitted. In particular, granary storage was introduced in the eighteenth century as a way of disaster relief. I therefore also control for provincial granary storage and its interaction with droughts as a robustness check.

As a final robustness check, I examine the impact before and after the adoption. Using a more flexible specification, I examine whether the mitigation impact varies over time.

4.1. *The Role of Time Trends*

A competing hypothesis to explain the finding on sweet potatoes is that the state authority might become more efficient in preventing revolts over time. To deal with this concern, I run a horse-race test between sweet potatoes and time trends by including the interaction of droughts and a time trend ($D_{it}t$) as well as the interaction of limited droughts and a times trend ($LD_{it}t$).

If the alternative hypothesis of time trends explains the mitigating effect of sweet potatoes, one would expect β_3 and β_7 in (4) to become insignificant once $D_{it}t$ and $LD_{it}t$ are included. The results are presented in columns 1 and 2 of Table 8.[17]

Table 8

Robustness Checks: Trends, Maize and Granaries

	Revolts					
	(1)	(2)	(3)	(4)	(5)	(6)
Exceptional drought × sweet potato		−0.602**		−0.471*		−0.521***
		(0.250)		(0.270)		(0.197)
Exceptional flood × sweet potato		−0.214		−0.067		−0.107
		(0.151)		(0.158)		(0.154)
Exceptional drought × trend	−0.001**	0.000				
	(0.001)	(0.001)				
Exceptional drought × maize			−0.448*	−0.146		
			(0.261)	(0.362)		
Exceptional flood × maize			−0.274	−0.239		
			(0.198)	(0.227)		
Exceptional drought × granary					−0.181***	−0.033
					(0.065)	(0.062)
Exceptional flood × granary					−0.147***	−0.120***
					(0.036)	(0.037)
Exceptional drought	0.717***	0.680***	0.740***	0.753***	0.516***	0.694***
	(0.218)	(0.210)	(0.225)	(0.224)	(0.119)	(0.166)
Exceptional flood		0.286**	0.370**	0.378**	0.237***	0.279**
		(0.123)	(0.183)	(0.184)	(0.080)	(0.119)
Sweet potato		−0.089		−0.161**		−0.130*
		(0.061)		(0.072)		(0.061)
Maize			0.119	0.140*		
			(0.081)	(0.080)		
Granary storage					−0.016	−0.029
					(0.030)	(0.029)
Precture and year FE	Y	Y	Y	Y	Y	Y
Controls × year	Y	Y	Y	Y	Y	Y
No. clusters	86	86	86	86	86	86
No. observations	107,320	107,320	107,320	107,320	107,320	107,320

Notes. *Significant at 10%, **5%, ***1%. Reported in parentheses are standard errors clustered at the weather station level. Limited Droughts, Limited Floods and their interactions with sweet potatoes, trends, maize and granaries are also controlled for but not reported. Columns 1–2 present the results for time trends and the horse-race results between sweet potatoes and time trends. Columns 3–4 present the results for maize and the horse-race results between sweet potatoes and maize. Columns 5–6 present the results for granary storage and the horse-race results between sweet potatoes and granary storage. The controls include longitude, latitude and agricultural suitability. Controls × year indicates the interactions of these controls and a linear time trend.

[17] The impacts of limited droughts, limited floods and their interactions with trends and sweet potatoes are also included but not reported. This also applies to the results regarding maize and granaries. The baseline results in Table 7 are not changed by including them.

Column 1 shows the result for $D_{it}t$ and $LD_{it}t$, and column 2 shows the results for a horse-race test between trends and sweet potatoes. As shown in column 2, the inclusion of $D_{it}t$ and $LD_{it}t$ does not dilute the interaction effect of sweet potatoes and droughts.

4.2. *Using Maize as a Placebo*

As mentioned above, maize was introduced in China around the same time as sweet potatoes but its diffusion path across provinces was different.[18] If the adoption of new crops were mainly driven by prefecture governance, both sweet potatoes and maize should matter for the mitigation effects. To see whether mitigation effects are specific to sweet potatoes, I run a test using information on the introduction of both sweet potatoes and maize. The information on the adoption of maize comes from Guo (1979) and Wu (1983).

The results are presented in columns 3 and 4 of Table 8. Column 3 presents the results for maize and column 4 shows the results after including both sweet potatoes and maize. As shown in column 4, the impact of maize is close to 0 once I control for sweet potatoes. Hence, the introduction of maize itself does not mitigate the effects of weather shocks on peasant revolts. This finding is consistent with the fact that maize does not survive droughts as well as sweet potatoes (Song, 2007). The magnitude and the precision of the mitigating impact of sweet potatoes are decreased once maize is included. This is expected, since the adoption years of sweet potatoes and maize are correlated.

4.3. *The Disaster-relief Policies*

Another concern for the analysis in this article is that some government disaster-relief policies might confound the effect of sweet potatoes. In particular, a prominent institution for disaster relief discussed by economic historians is the system of state granaries introduced in the Qing dynasty. Many granaries were created to help smooth harvest shocks, but the policy did not exist before the Qing dynasty. Li (2007) provides a general description of the institutional background. Shiue (2004) quantitatively examines the relationship between weather shocks and grain storage and finds that the frequency of disaster relief in the Qing dynasty is not correlated with weather patterns. Hence, this policy will not confound the main results of this article, as I am mainly interested in whether the adoption of sweet potatoes mitigated the effects of weather shocks.

Still, as a further robustness check, I also control for the amount of granary storage. The data are available at the province level since 1742. As a nationwide policy, there is little variation in terms of the time of having granary storage across provinces. However, the amount of storage varies across provinces, from 0.2 to

[18] Besides sweet potatoes and maize, a few other American crops were also introduced into historical China, including white potatoes, peanuts and tobacco. The latter two have never been important food crops in China. As discussed at length in Nunn and Qian (2011*a, b*), white potatoes played an important role in European population growth. However, it was not introduced to China until the late nineteenth century (Bray, 1984).

4.6 million Dan (units of about 90 kg). I assume that the storage is 0 when the relief policy was not yet available and use the amount of storage when it is available. Under this assumption, the availability of granary storage is also correlated with the adoption of sweet potatoes. Hence, I run another horse-race test between granary storage and sweet potatoes. The results are presented in columns 5 and 6 of Table 8. Column 5 shows the results for granary storage itself and column 6 shows the results after including both granary storage and sweet potatoes. Once more, the mitigation result of sweet potatoes holds after controlling for the impact of provincial granary storage.

4.4. *The Dynamics of the Mitigating Effect*

To check whether the mitigation effect varies over time, I allow for a more flexible specification as follows:

$$R_{it} = \beta_1 D_{it}^2 + \beta_2 F_{it}^2 + \sum_{\tau=-1,0,1+} \beta_\tau^D D_{it}^2 \times S_{i\tau} + \sum_{\tau=-1,0,1+} \beta_\tau^F F_{it}^2 \times S_{i\tau} + \sum_{\tau=-1,0,1+} \beta_\tau \times S_{i\tau} + \boldsymbol{\delta}_i \boldsymbol{X}_i t + \alpha_i + \gamma_t + \varepsilon_{it}. \quad (5)$$

Here, $S_{i\tau}$ is a set of three dummy variables indicating that τ centuries have passed since the adoption of sweet potatoes in prefecture i, where S_{i1+} refers to one century and more after the adoption. The comparison group is the period more than one century before the adoption. Because the number of revolts in each period is limited, the drought indicator includes both exceptional droughts and limited droughts. Similarly, the flood indicator includes both exceptional floods and limited floods.

The coefficients of interest are β_τ^D. If β_{-1}^D does not differ significantly from zero, the parallel-trend assumption of the fixed-effects models is likely to hold. The results are presented in Table 9. These results suggest that β_{-1}^D is not significantly different from zero. Besides, if the results are mainly driven by some omitted variables such as better institutions, similar negative effects should be seen of the interactions of floods and the period dummies. As shown by the results of β_τ^F, this is not the case.

Since the impact for the century of adoption (β_0^D) is around -0.49, whereas the impact for the period more than a century after adoption (β_{1+}^D) is around -0.47, the mitigation impact seems not to become significantly weaker over time after the adoption. As discussed in the historical background, sweet potatoes have both 'insurance' and 'productivity' effects. The latter effect might dissipate over time in a Malthusian equilibrium, as population catches up with the greater supply of food. The finding on the dynamic effects provides more support for the 'insurance' channel.[19]

[19] Naturally, this finding is subject to the length of the revolts data, which stop at 1900. Besides, it does not deny that the 'productivity' effect might matter for peasant revolts in the short run.

Table 9

Results from More Flexible Specifications

	Revolts		
	(1)	(2)	(3)
Drought × adoption (−100–0 years)	−0.201	−0.112	−0.198
	(0.147)	(0.167)	(0.168)
Drought × adoption (0–100 years)	−0.443***	−0.412***	−0.494***
	(0.120)	(0.120)	(0.125)
Drought × adoption (100+ years)	−0.355**	−0.388***	−0.466***
	(0.138)	(0.134)	(0.134)
Drought	0.649***	0.541***	0.582***
	(0.105)	(0.106)	(0.111)
Flood × adoption (−100–0 years)	0.105	0.169	0.118
	(0.121)	(0.130)	(0.126)
Flood × adoption (0–100 years)	−0.136*	−0.111	−0.168*
	(0.079)	(0.085)	(0.091)
Flood × adoption (100+ years)	−0.032	−0.045	−0.095
	(0.082)	(0.098)	(0.097)
Flood	0.250***	0.150**	0.175**
	(0.063)	(0.073)	(0.077)
Prefecture and year FE		Y	Y
Controls × year			Y
No. clusters		86	86
No. observations	111,199	111,199	107,320

Notes. *Significant at 10%, **5%, ***1%. Reported in parentheses are standard errors clustered at the weather station level. The coefficients can be interpreted as the difference in revolts likelihood in a century before adoption (−100–0 years), the century of adoption (0–100 years) and the period more than a century after adoption (100+ years), compared to the period more than a century before the adoption of sweet potatoes. The drought indicator includes both exceptional drought and limited drought and the flood indicator includes both exceptional flood and limited flood. The controls include longitude, latitude and agricultural suitability. Controls × Year indicates the interactions of these controls and a linear time trend.

5. Conclusion

This article investigates two questions. First, to what extent did weather-induced bad harvests cause peasant revolts – a common form of civil conflict in past societies? Second, to what extent did the historical introduction of new crop varieties mitigate these effects?

Combining various sets of historical data from China, I find that an exceptional drought increased the probability of a peasant revolt by about 0.46 percentage points on average. However, the adoption of sweet potatoes mitigated the impact of droughts on revolts significantly. Before the introduction of sweet potatoes, an exceptional drought increased the probability of a peasant revolt by about 0.7 percentage points.

My answer to the first question relates to the growing literature on the determinants of civil conflict. The finding on the positive impact of droughts on peasant revolts supports the hypothesis put forward by historians that weather shocks were linked to violence in past societies. The finding that the price effect of droughts is three times that of floods is consistent with qualitative historical studies that stress the special role of droughts in triggering peasant revolts.

My answer to the second question provides further evidence that droughts led to more revolts due to their negative impact on food supply. With the introduction of drought-resistant sweet potatoes in historical China, the negative impact of droughts on food supply was mitigated. Consequently, the link between droughts and peasant revolts was weakened.

Appendix A: The Lags and Leads of Weather Conditions

In the main text, I focus on the impact of weather conditions in year t in close connections with the impact of sweet potatoes adoption and only include the impacts of lagged weather conditions as a robustness check. Naturally, one can consider the impacts of weather shocks in a more flexible way by examining the weather conditions in t–1, t–2, t + 1 and t + 2.

A.1. *The Persistence of Exceptional Droughts and Floods*

Before employing these lags and leads, I explicitly examine the persistence of exceptional droughts and floods by running autoregressive (AR) models while controlling for prefecture fixed effects. The results are presented in Table A1. Columns 1–3 show that the results at order 1, 2 and 3 for exceptional droughts. They show that the correlation is decreasing significantly over time and is very close to 0 at $t - 3$. Columns 4–6 report the corresponding results for floods, suggesting that the persistence of exceptional floods is weaker than that of exceptional droughts. This is consistent with the conjecture in historical studies that droughts were more persistent and mattered more for revolts in historical China (Xia, 2010).

Table A1

The Persistence of Exceptional Drought and Floods

	Exceptional drought t			Exceptional flood t		
	(1)	(2)	(3)	(4)	(5)	(6)
Exceptional drought $t-1$	0.140***	0.139***	0.139***			
	(0.005)	(0.005)	(0.005)			
Exceptional drought $t-2$		0.011***	0.010***			
		(0.004)	(0.004)			
Exceptional drought $t-3$			0.001			
			(0.004)			
Exceptional flood $t-1$				0.071***	0.071***	0.071***
				(0.004)	(0.004)	(0.004)
Exceptional flood $t-2$					−0.002	−0.002
					(0.004)	(0.004)
Exceptional flood $t-3$						0.004
						(0.004)
Prefecture FE	Y	Y	Y	Y	Y	Y
No. observations	110,938	110,679	110,420	110,938	110,679	110,420

Notes. *Significant at 10%, **5%, ***1%. The results are obtained from AR regressions.

Table A2

The Impact of the Lag/Lead of Weather Conditions on Revolts

	Revolts						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Exceptional drought $t+2$					0.081		
					(0.074)		
Exceptional flood $t+2$					−0.019		
					(0.066)		
Exceptional drought $t+1$				−0.017			−0.095
				(0.058)			(0.059)
Exceptional flood $t+1$				−0.021			−0.036
				(0.048)			(0.047)
Exceptional drought t	0.464***					0.412***	0.421***
	(0.107)					(0.100)	(0.102)
Exceptional flood t	0.182***					0.189***	0.194***
	(0.069)					(0.068)	(0.069)
Exceptional drought $t-1$		0.354***				0.266***	0.285***
		(0.094)				(0.090)	(0.091)
Exceptional flood $t-1$		−0.015				−0.024	−0.034
		(0.056)				(0.054)	(0.055)
Exceptional drought $t-2$			0.141			0.094	
			(0.093)			(0.090)	
Exceptional flood $t-2$			−0.029			−0.034	
			(0.059)			(0.057)	
Prefecture and year FE	Y	Y	Y	Y	Y	Y	Y
Controls × year	Y	Y	Y	Y	Y	Y	Y
No. clusters	86	86	86	86	86	86	86
No. observations	107,320	107,068	106,819	107,068	106,819	106,818	106,818

Notes. *Significant at 10%, **5%, ***1%. Reported in parentheses are standard errors clustered at the weather station level. Limited droughts and limited floods and their lags and leads are also included but not presented. The dependent variable is 0 or 100, and hence the coefficients can be interpreted as percentage points. The controls include longitude, latitude and agricultural suitability. Controls × year indicates the interactions of these controls and a linear time trend. Column 1 replicates the results in column 3 of Table 3.

A.2. *The Impacts of Lagging and Leading Weather Conditions*

The specification to examine the impacts of these lags and leads on revolts is the same as (1) except that the drought and flood indicators are replaced with the lags and leads of weather conditions. The results for extreme droughts and floods are presented in Table A2 (where limited droughts and limited floods and their lags and leads are also included but not presented).

Column 1 in Table A2 replicates the results in column 3 of Table 3. Columns 2–5 present the results for exceptional droughts and floods in year $t-1$, year $t-2$, year $t+1$ and year $t+2$ separately. As expected, an exceptional drought in year $t-1$ also had a positive impact on revolts in year t, whereas an exceptional drought in year $t-2$ did not have a significant impact. Not surprisingly, droughts in the leads did not have any significant impact on revolts. Column 6 includes weather conditions in years t, $t-1$ and $t-2$, whereas column 7 includes the weather conditions in years $t-1$, t and $t+1$ to show that the baseline results in column 1 are robust.

Similarly, I use the same specification as in column 7 of Table A2 to examine the impact of the lags and leads of weather conditions on the prices of rice and wheat in August at year t. The results are presented in Table A3. As expected, exceptional droughts in years t and $t-1$

Table A3

The Impact of the Lag/Lead of Weather Conditions on August Prices

	Wheat: upper (1)	Wheat: lower (2)	Rice: upper (3)	Rice: lower (4)
Exceptional drought $t+1$	0.019**	0.011	0.038*	0.021
	(0.009)	(0.010)	(0.021)	(0.015)
Exceptional flood $t+1$	0.011	0.024**	0.023**	0.033***
	(0.010)	(0.010)	(0.009)	(0.011)
Exceptional drought t	0.084***	0.081***	0.061***	0.043**
	(0.011)	(0.012)	(0.016)	(0.018)
Exceptional flood t	0.032***	0.039***	0.031***	0.030**
	(0.010)	(0.010)	(0.008)	(0.011)
Exceptional drought $t-1$	0.128***	0.118***	0.050***	0.065***
	(0.014)	(0.013)	(0.014)	(0.014)
Exceptional flood $t-1$	0.052***	0.055***	0.051***	0.055***
	(0.012)	(0.013)	(0.013)	(0.011)
Prefecture and year FE	Y	Y	Y	Y
Controls × year	Y	Y	Y	Y
No. clusters	78	78	28	28
No. observations	21,149	21,149	3,956	3,956

Notes. *Significant at 10%, **5%, ***1%. Reported in parentheses are standard errors clustered at the weather station level. Limited droughts and limited floods and their lags and leads are also included but not presented. The dependent variables are in logs. The controls include longitude, latitude and agricultural suitability. Controls × year indicates the interactions of these controls and a linear time trend.

increased the prices. In contrast, the impact of an exceptional drought in year $t+1$ was weak and only occasionally significant.

Appendix B: Using Aggregated Data

The baseline results use prefecture-year data. One can aggregate the data into province-year data or prefecture-decade data as robustness check. I focus on the role of exceptional droughts and floods in these robustness checks.

B.1. *Using Province-year Data*

One Consider the following specification:

$$R_{pt}= \beta_1 D_{pt}+\beta_2 F_{pt}+\beta_3 D_{pt} \times S_{pt}+\beta_4 F_{pt} \times S_{pt}+\beta_5 S_{pt}+\delta_p prov_p t + \alpha_p+\gamma_t+\varepsilon_{pt}, \quad \text{(B.1)}$$

where α_p and γ_t denote province fixed effects and year fixed effects. The dependent variable R_{pt} indicates the number of revolts in province p and year t. Among the independent variables, I define exceptional drought (or exceptional flood) in province p and year t as at least one of the prefectures in province p and year t has the weather indicator of 5 (or 1).

Table B1 presents the results using the number of revolts as the dependent variable. The standard errors are clustered at the province level. An exceptional drought increased the number of revolts in an average province-year by about 2.6 percentage points. This result on sweet potatoes is also consistent with the baseline finding using prefecture-year data.

Table B1

Results from the Province-by-year Data

	Revolts			
	(1)	(2)	(3)	(4)
Exceptional drought	2.462***	2.561***	3.548***	3.858***
	(0.805)	(0.787)	(1.044)	(1.053)
Exceptional flood	0.704	0.816	0.698	0.985
	(0.447)	(0.476)	(0.717)	(0.784)
Exceptional drought × Sweet potato			−2.508**	−2.947**
			(1.155)	(1.149)
Exceptional flood × Sweet potato			−0.012	−0.404
			(0.794)	(0.904)
Sweet potato			−2.491*	−1.456
			(1.364)	(1.597)
Province and year FE	Y	Y	Y	Y
Province dummy × year		Y		Y
No. clusters	18	18	18	18
No. observations	7,758	7,758	7,758	7,758

Notes. *Significant at 10%, **5%, ***1%. Reported in parentheses are standard errors clustered at the province level. The dependent variable is the number of revolts multiplied by 100. Exceptional drought (or flood) is set at 1 for a province if at least one prefecture had an exceptional drought (or flood) in the province.

B.2 *Using Prefecture-decade Data*

Another way to look at the data is to aggregate the revolts and weather shocks by decade. On the one hand, the disadvantage of doing so is that the precise information on droughts, floods and peasant revolts is sacrificed. On the other hand, using decade information might better handle the prospective problem of autocorrelation in differences-in-differences estimation. Consider the following specification:

Table B2

Results from the Prefecture by Decade Data

	Revolts			
	(1)	(2)	(3)	(4)
Exceptional drought	1.424**	1.410**	2.100**	2.299**
	(0.591)	(0.603)	(0.863)	(0.878)
Exceptional flood	0.630*	0.706**	0.795	0.939
	(0.344)	(0.341)	(0.508)	(0.601)
Exceptional drought × Sweet potato			−1.505	−1.903*
			(0.911)	(0.947)
Exceptional flood × Sweet potato			−0.323	−0.478
			(0.615)	(0.702)
Sweet potato			−1.210*	−0.417
			(0.691)	(0.742)
Prefecture and decade FE	Y	Y	Y	Y
Prefecture dummy × Decade		Y		Y
No. clusters	44	44	44	44
No. observations	11,354	11,354	11,354	11,354

Notes. *Significant at 10%, **5%, ***1%. Reported in parentheses are standard errors clustered at the decade level.The dependent variable is the number of revolts multiplied by 100. Exceptional drought (or flood) is set at 1 for a decade if at least one year had an exceptional drought (or flood) in the decade.

$$R_{id}= \beta_1 D_{id}+\beta_2 F_{id}+\beta_3 D_{id} \times S_{id}+\beta_4 F_{id} \times S_{id}+\beta_5 S_{id}+\delta_i pref_i t_d+\alpha_i+\gamma_d+\varepsilon_{id}, \tag{B.2}$$

where R_{id} indicates the number of revolts in prefecture i within a decade d. D_{id} indicates whether there was any exceptional drought in prefecture i within a decade d. α_i and γ_d are prefecture fixed effects and decade fixed effects.

The estimation results are presented in Table B2, with the standard errors clustered at the decade level. The results are similar to the earlier ones. An exceptional drought increased the number of peasant revolts in an average prefecture-decade by about 2.5 percentage points. The diffusion of sweet potatoes mitigated the effects of droughts.

Appendix C: Clustering Standard Errors at Different Levels

Table 3 in the main text presents the baseline results using prefecture-year data, where standard errors are clustered at the weather station level. Table C1 presents standard errors clustered at the year level, the province level or two-way clustered at both the province and the year level. The results are robust to clustering the standard errors at different levels.

Table C1

Clustering Standard Errors at Different Levels

	Revolts			
	(1)	(2)	(3)	(4)
Exceptional drought	0.429	0.470	0.464	0.476
	(0.060)	(0.113)	(0.121)	(0.113)
		[0.116]	[0.120]	[0.116]
		<0.114>	<0.122>	<0.114>
Exceptional flood	0.121	0.201	0.182	0.211
	(0.059)	(0.088)	(0.089)	(0.090)
		[0.071]	[0.073]	[0.070]
		<0.086>	<0.088>	<0.087>
Limited drought	0.234	0.298	0.277	0.307
	(0.042)	(0.091)	(0.088)	(0.094)
		[0.058]	[0.058]	[0.058]
		<0.087>	<0.086>	
Limited flood	0.077	0.142	0.130	0.151
	(0.039)	(0.052)	(0.053)	(0.054)
		[0.046]	[0.047]	[0.047]
		<0.053>	<0.055>	<0.056>
Prefecture and year FE		Y	Y	Y
Controls × year			Y	
Prefecture dummy × year				Y
No. clusters		86	86	86
No. observations	111,199	111,199	107,320	111,199

Notes. The specifications and the estimated coefficients in this Table are the same as in Table 3. The standard errors in columns 2–4 are clustered at the province level (in parentheses), the year level (in square brackets) as well as two-way clustered both the province and the year level (in angle brackets).

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Submitted: 9 June 2011
Accepted: 19 December 2012

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