CLIMATE SHOCKS AND SINO-NOMADIC CONFLICT

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Abstract—Employing droughts and floods to proxy for changes in precipitation, this paper shows nomadic incursions into settled Han Chinese regions over a period of more than two thousand years—the most enduring clash of civilizations in history—to be positively correlated with less rainfall and negatively correlated with more rainfall. Consistent with findings that economic shocks are positively correlated with conflicts in modern sub-Saharan Africa when instrumented by rainfall, our reduced-form results extend this relationship to a very different temporal and geographical context, the Asian continent, and long historical period.

I. Introduction

MILITARY conflict and war are sources of human suffering (World Bank, 2003), and, by destroying human and physical capital, they have a negative impact on economic growth (Kiker & Cochrane, 1973). The disastrous consequences of war and conflict have motivated research interest in understanding and measuring their causes (Bruckner & Ciccone, 2007; Collier & Hoeffler, 1998, 2001, 2002; Fearon & Laitin, 2003; Miguel, Satyanath, & Sergenti, 2004).[1] In this literature, exogenous variations in climate, rainfall in particular, are recognized as causal links between economic shocks and civil conflicts (Bruckner & Ciccone, 2007; Ciccone, 2008; Miguel et al., 2004). Accordingly, we employ climatic variations as an exogenous predictor of what is perhaps the longest and most enduring clash of civilizations in history: the Sino-nomadic conflict. This conflict lasted for more than two millennia and extended along four thousand miles of military defenses, resulting in the building of the Great Wall of China to separate the Han Chinese from the northern nomadic peoples.

The nomads discussed here refer to a sizable group of peoples from the steppes of Central Asia, Mongolia, and Eastern Europe (the Pontic steppe), peoples that both the Romans and the ethnic Han Chinese considered to be "barbaric." The aggressive invasions undertaken by these Eurasian nomads play an important role in the history of both the Eastern and Western civilizations. In Europe, for instance, these invasions occurred as early as those of the Cimmerians in the eighth century B.C. and as recently as those that took place during the migration period (300–900). Similar invasions were initiated by the Mongols and Seljuks in the High Middle Ages (1000–1300) and by the Tatars in early modern times (starting around 1500).

Nomadic economies were heavily dependent on the grazing of vast herds of animals, but these peoples often lived under unfavorable continental climatic conditions with relatively little rainfall. Under normal weather conditions, the autarkic nature of nomadic economies in terms of balancing natural resources (fodder and water) with livestock and the human population can be maintained (Graff & Higham, 2002). In times of drought, however, water shortages lead to a shortage of fodder and, accordingly, a reduction in food (meat) production, leaving the looting of settled agricultural neighbors, such as the ethnic Han Chinese, the only alternative for survival.[2]

It is well documented that stochastic climatic fluctuations have had an adverse impact on many nomadic economies, even in contemporary times.[3] A number of historians have also found that nomadic incursions into the agricultural hinterlands of the Han were actually made in response to deteriorating economic conditions brought about by adverse changes in the natural environment over the roughly two thousand years during which the Han were frequently intimidated—and in some instances fully conquered—by their nomadic neighbors across the northern frontier (Toynbee, 1987; Barfield, 1989; Huntington, 1907; Graff & Higham, 2002; Jagchild, 1989; Khazanov, 1994).[4] However, no systematic empirical studies have yet emerged from this otherwise rich corpus of work.

Employing drought as a proxy for lower precipitation and, conversely, floods (specifically levee breaches of the Yellow River) as a proxy for higher precipitation, we show that negative rainfall shocks are positively correlated with violent invasions on the Asian continent, specifically the frequent nomadic incursions of settled Han Chinese areas—sedentary agricultural communities—over more than two millennia. Following other studies that have employed rainfall to identify the causal effect of economic shocks on conflicts (Miguel et al., 2004; Bruckner & Ciccone, 2007;

Received for publication January 13, 2009. Revision accepted for publication March 17, 2010.

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We thank Leonard Cheng and the two anonymous reviewers for their thoughtful comments and suggestions on earlier drafts. We are responsible for any remaining errors.

[1] Studies have identified a variety of factors, ranging from labor market conditions (Collier & Hoeffler, 1998, 2001, 2002) and economic growth (Elbadawi & Sambanis, 2002; Fearon & Laitin, 2003; Miguel et al., 2004) to ethnic fractionalization and democracy (Sambanis, 2002), as having an effect on the incidence of civil wars and even international conflicts (Ostrom & Job, 1986; Russet, 1990; Hess & Orphanides, 1995).

[2] The Eurasian nomads domesticated horses and developed a host of weaponry, ranging from the chariot and cavalry to horse archery, which they used to invade Europe, Anatolia, and China.

[3] For instance, "In the USSR, the crop capacity of wild plants in semideserts fluctuates between 1:5.4 in different years, and for different grass-crops it even fluctuates as much as 1:40. Clearly, the resulting adverse impact of this fluctuation in crop yields has had a negative impact on pastoralism. For example, while there were 5.1 million head of sheep and goats in Turkmenia in 1956–60, in 1962 the number dropped to 4.2 million" (Khazanov, 1994, p. 72). According to Barth (1964), even a small climatic change can easily upset the "nomadic equilibrium."

[4] Huntington (1907) and Toynbee (1987) proposed the "climatic pulsation" thesis, which explains nomadic aggressions by the long-term, cumulative effect of climate change. A more recent development of this thesis stresses the material dependency of nomadic societies on their sedentary counterparts (Barfield, 1989; Khazanov, 1994; Jagchild, 1989; Graff & Higham, 2002), that is, when their natural equilibrium was upset by climatic change, nomads became dependent on sedentary economies for certain material goods, and war was the typical means of acquiring those goods.

The Review of Economics and Statistics, August 2011, 93(3): 970–981

Ciccone, 2008), we employ a reduced-form specification to estimate the impact of rainfall shocks on Sino-nomadic conflict.[5] Our work thus adds to the literature by demonstrating the existence of a strong relationship between negative income shocks and violence in a temporal and geographical context that differs radically from that of sub-Saharan Africa and one that persisted for more than two thousand years.

The remainder of the paper is organized as follows. Section II introduces our data sources and variables and presents descriptive evidence of Sino-nomadic conflict. In section III, we outline our empirical strategy and econometric models. Our empirical results are presented and discussed in section IV, followed by a brief conclusion in section V.

II. Variables, Data, and Descriptive Evidence

In this paper, we focus on the historical interactions between Inner Asia and China—interactions that were played out along a vast stretch of frontier, with the Great Wall at its center, over more than two thousand years. We divide China's territory into two broad regions (Graff & Higham, 2002). Designated as China proper, the first region refers to the densely populated, irrigated agricultural region inhabited by the Han majority, a region considered to be the origin, or cradle, of ancient Chinese civilization.[6] Also known in Chinese as the central plains (*Zhong Yuan*), China proper includes the provinces that are primarily clustered around the middle and lower reaches of the Yellow River (Henan and parts of Shanxi, Shaanxi, Hebei, and Shandong provinces in today's China, denoted as region 1 in figure 1). The second, nomadic, region (region 2) comprises what is today the northwestern Chinese provinces of Tibet, Qinghai, Xinjiang, and Inner Mongolia, three formerly Manchurian provinces in the northeast; the now independent republic of Mongolia; and parts of Russia. In contrast to China proper, the nomadic region was sparsely populated and inhabited mainly by non-Han ethnic groups (Graff & Higham, 2002; Barfield, 1989). Moreover, and in contrast to the Han Chinese who had settled into sedentary agriculture, the nomads in the northwestern and northeastern parts of China undertook seasonal migrations and relied on raising vast herds of animals on the steppes and mountain slopes of Inner Asia for their livelihood.

A. *Definition of Variables*

Our dependent variable is simply the frequency of nomadic invasions into the settled communities of the Han Chinese.[7] Although we lack detailed narratives of China's military operations, such as the use of weapons and logistics (see, for example, Graff & Higham, 2002), detailed historical records of the time (year) of a battle's outbreak and the initiating party serve our purpose. These records allow us to identify, in an unambiguous fashion, the party that initiated the battle, thus also allowing us to test our hypothesis. In our estimation, we employ the decadal frequency of attacks initiated by nomads (y_{1t}) to proxy for nomadic invasions. Because such invasions may be correlated with attacks initiated by the sedentary Han on the nomadic regions, it is also necessary to control for the decadal frequency of attacks initiated by the sedentary state on nomads (y_{2t}) in our estimations. Although our data set contains no information on the exact location of each battle, the rich historical narrative of Sino-nomadic warfare in China (Hu, 1996) does tell us that the majority of these battles were fought along the Great Wall of the Qin (221–206 B.C.) and Ming dynasties (1368–1644). We provide a summary of this information in figure 2.

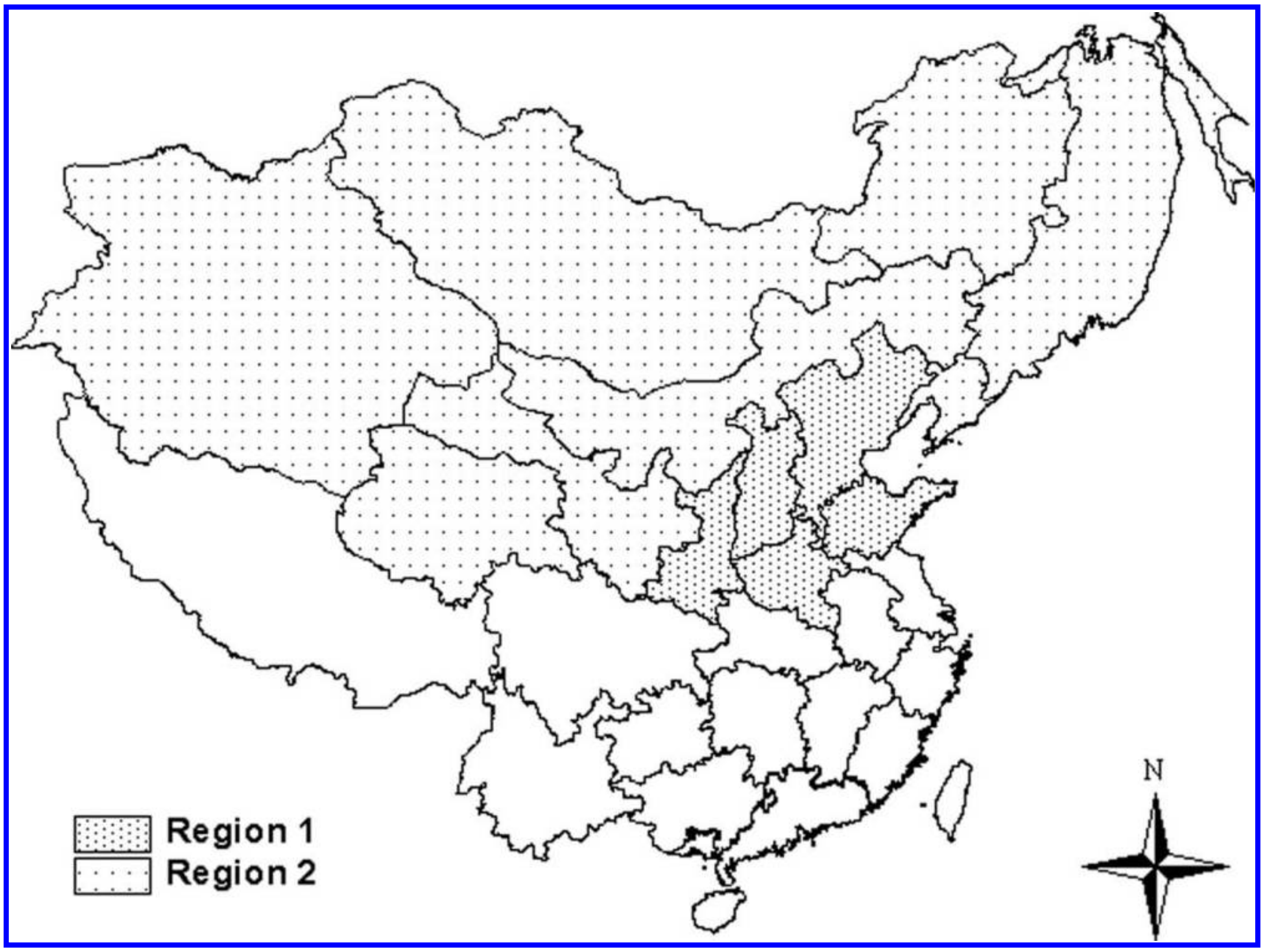
An ideal measure of poor weather in the nomadic zone would be actual deviations in rainfall from normal levels. Unfortunately, such information is not available. However, as we are able to establish strong correlations in precipitation between the two pertinent regions, both of which share the monsoon characteristics of northeast Asia (Zhang & Lin, 1992), using contemporary climate data (Appendix A), we are confident that incidences of droughts and floods in the agricultural zone serve as a good proxy for the probability of lower and higher precipitation in the nomadic zone. More specifically, we employ the decadal share of years with recorded drought disasters (x_{1t}) as our proxy for the probability of lower precipitation. These droughts occurred in region 1 (see figure 1), which was located south of the Great Wall and north of the Qinling Mountain–Huai River line, the isotherm of 0 degrees centigrade in China in January (see figure 2). Similarly, we use the decadal share of years with a levee breach of the Yellow River (x_{2t}) to proxy for the probability of higher precipitation (the location of these floods is also indicated in figure 2), because the flooding caused by such a levee breach is the most severe in the Chinese setting. We must emphasize that the effects of

[5] Rainfall shocks affect not only the economy of nomads in general and their production of food more specifically, but also the returns and costs to the agricultural economy associated with invasions. For instance, in decades afflicted by droughts, agricultural output falls and the marginal returns to looting also fall accordingly. To make up for the shortfall, nomads increase the frequency of their invasions. By the same token, although flooding is likely to render the use of horses ineffective, and thus to encourage nomads to reduce the frequency of their attacks in the short run, it may effectively encourage more looting in the longer run if it enhances the fertility of the soil. We owe this insight to an anonymous referee, but as we are unable to identify the precise channels of climate shocks, we focus on estimating their overall effect.

[6] Although the southern part of China also belongs to China proper by contemporary standards, it was not part of the ancient Chinese civilization under study. Moreover, it lies in a completely different ecological zone from that of the central plains.

[7] Our proposed analysis of Sino-nomadic conflict is premised on the single factor of geography: the location of these sedentary and nomadic societies. If there were periods in which the nomads conquered the Han and consequently became sedentary themselves, then we must consider these nomads as having been "converted," as their economic way of life would have altered. We deal with the econometric issues arising from this exception in appendix C.

FIGURE 1.—THE GEOGRAPHY OF CONFLICT: LOCATIONS OF THE SEDENTARY AND NOMADIC REGIONS



(1) Region 1: China proper (Henan, Shanxi, Shaanxi, Hebei, and Shandong provinces of today's China); central plains; and the middle and lower reaches of the Yellow River. Region 2: Northwest—Qinghai, Xinjiang, Gansu, Ningxia and Inner Mongolia provinces of today's China and the Republic of Mongolia; Manchuria—Heilongjiang, Jilin and Liaoning provinces of today's China and parts of Russia; and boundaries of Qing-China, 1820.
Source: "CHGIS, Version 4" (Cambridge, MA: Harvard Yenching Institute, 2007).

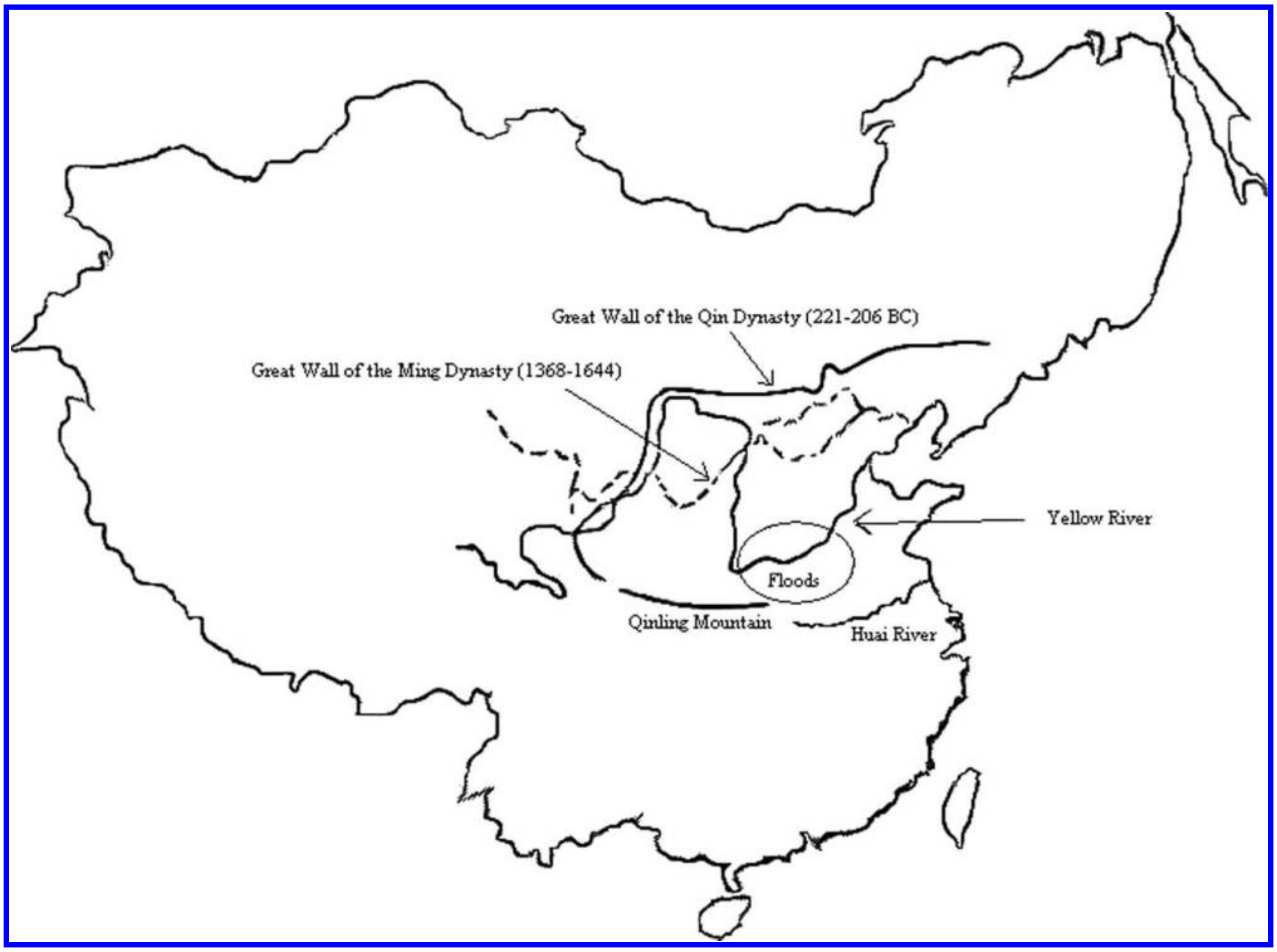
drought and flooding on the two regions were radically different. Whereas the nomads tended to suffer more than their Han counterparts in the event of lower precipitation (drought), they tended to suffer less than the Han in the event of a levee breach of the Yellow River, because such a breach would lead to floods in the Han region but not in the nomadic region.

To ensure that our estimations are reasonably robust, it is necessary to control for a number of factors. The first is the possible impact of snow and frost, because they may be correlated with our key explanatory variables of drought and flood. Accordingly, following the construction of these key explanatory variables, we employ the decadal share of years with recorded snow disasters (w_{1t}) and the decadal share of years with recorded frost and other cold-related calamities (w_{2t}) to proxy for the possible effect of these adverse temperature deviations. Moreover, as paleoclimatologists have shown, average temperatures have changed significantly in the past thousand years (Zhang, 1996), which is likely to be correlated with our two key explanatory variables. It is thus also necessary to control for the possible effects of changes in average temperatures (w_{3t}).[8]

Equally important is that we control for instances in which the nomads actually settled in the central plains and ruled the Han Chinese after their conquest, an extreme case in point being the settlement and governance of all of China by the Manchu during the Qing dynasty. That such nomadic settlement in the central plains reduced the odds of invasion suggests that the nomadic-ruled sedentary regime had a qualitatively different relationship with the nomads who still resided in the nomadic region. Once again, the Qing dynasty provides a good case in point. Unlike its predecessors and cemented by intermarriage among royal families, the Qing regime enjoyed a mellifluous relationship with

[8] As paleoclimatologists provide information only on past temperatures in relation to the present (the difference in degrees between past and present temperatures), we have to add present temperatures to their estimations to obtain the actual temperatures of the distant past. Our calculations of present temperatures are based on data provided by the National Climate Data Center for the 1957–1990 period.

FIGURE 2.—LOCATIONS OF SINO-NOMADIC BATTLES, DROUGHTS, AND FLOODS



Source: "CHGIS, Version 4" (Cambridge, MA: Harvard Yenching Institute, 2007).

various Mongolian tribes (Graff & Higham, 2002). In light of such anecdotal evidence, we control for the three time periods in which we expect to observe significantly fewer nomadic invasions. In addition, we perform a robustness check by dropping the years in which the agricultural lands were directly under nomadic control.[9] The first of these periods stretches from 317, which saw the collapse of the West Jin empire, to 589, which saw its reunification by the Sui dynasty (w_{4t}). The second, w_{5t}, covers three subperiods: the Jurchen Jin (1126–1234), pre-Yuan Mongol (1234–1279), and Mongol Yuan (1279–1368) subperiods. Finally, the third period, w_{6t}, from 1644 to 1839, began with the foundation of the Qing dynasty and lasted until the outbreak of the Opium War. Additionally, we include the decades −22 (220–211 B.C.) to 183 (1830–1839) as a variable to control for the time trend (w_{7t}).[10]

[9] We thank an anonymous reviewer for alerting us to the need to do this.

[10] To the extent that data on the more contemporary periods are more accurate and detailed, failure to control for such a bias is likely to result in spurious correlations.

B. *Data Sources*

The data used in this study cover 2,060 years (from 220 B.C. to 1839 A.D.) of Sino-nomadic warfare in China. They are compiled from four Chinese sources: *A Chronology of Warfare in Dynastic China* (China's Military History Editorial Committee, 2003), *A Compendium of Historical Materials on Natural Disasters in Chinese Agriculture* (Zhang et al., 1994), *A Concise Narrative of Irrigation History of the Yellow River* (Editorial Committee of Irrigation History of the Yellow River, 1982), and the *Handbook of the Annals of China's Dynasties* (Gu, 1905). The chronology of warfare contains detailed information on warfare between the sedentary and nomadic regimes, including the year of occurrence and the battle initiator, and the *Compendium* provides information on both climatic conditions in general and various natural calamities in particular. The irrigation history provides important information on all of the levee breaches of the Yellow River in ancient China, including their exact time of occurrence, and the final source contains information on the periods during which China proper was ruled by the conquering nomads. The summary statistics

TABLE 1.—DEFINITION OF VARIABLES, DATA SOURCES AND SUMMARY STATISTICS

Variables		Proxies	Mean	s.d.
Dependent variables				
Nomadic attacks	y_{1t}	Frequency of attacks initiated by the nomads on the sedentary society in a given decade[a]	2.52	*(3.50)*
Sedentary attacks	y_{2t}	Frequency of attacks initiated by the sedentary society on the nomads in a given decade[a]	1.89	*(2.35)*
Explanatory variables				
Lower precipitation	x_{1t}	Share of years with records of drought disasters on the central plains in a given decade[b]	0.50	*(0.31)*
Higher precipitation	x_{2t}	Share of years with records of levee breaches of Yellow River in a given decade[c]	0.18	*(0.21)*
Control variables				
Snow disasters	w_{1t}	Share of years with records of snow disasters on the central plains in a given decade[b]	0.12	*(0.14)*
Low-temperature disasters	w_{2t}	Share of years with records of low-temperature calamities (for example, frost) on the central plains in a given decade[b]	0.16	*(0.19)*
Average temperature	w_{3t}	Average temperature[e]	9.46	*(0.89)*
Nomadic conquest 1	w_{4t}	= 1 if the central plains of China were governed by the nomads (317–589)*[d]	0.13	*(0.33)*
Nomadic conquest 2	w_{5t}	= 1 if the central plains of China were governed by the nomads (1126–1368)*[d]	0.11	*(0.32)*
Nomadic conquest 3	w_{6t}	= 1 if the central plains of China were governed by the nomads (1644–1839)*[d]	0.09	*(0.29)*
Time trend	w_{7t}	Decade: −22−183; years: 219 B.C.–1839 A.D.[d]	80.50	*(59.61)*

*Nomadic conquest of the central plains is indicated by the decadal share of their reign in relation to the Han. For instance, the nomadic conquest period is 317–589; thus, for the decade 310–319, there are three years during which the central plains were ruled by the nomads, and the corresponding share is 0.3.
[a]China's Military History Editorial Committee (2003).
[b]Zhang et al. (1994).
[c]Editorial Committee of Irrigation Committee of the Yellow River (1982).
[d]Gu (1998).
[e]Zhang (1996).

TABLE 2.—CORRELATION MATRICES OF THE VARIABLES EMPLOYED IN THE REGRESSION ANALYSIS

	Nomadic Attacks y_{1t}	Sedentary Attacks y_{2t}	Lower Precipitation x_{1t}	Higher Precipitation x_{2t}	Snow Disasters w_{1t}	Low-Temperature Disasters w_{2t}	Average Temperature w_{3t}	Nomadic Conquest 1 w_{4t}	Nomadic Conquest 2 w_{5t}	Nomadic Conquest 3 w_{6t}	Time Trend w_{7t}
y_{1t}	1.000										
y_{2t}	0.142**	1.000									
x_{1t}	0.153**	−0.001	1.000								
x_{2t}	0.024	−0.134*	0.472***	1.000							
w_{1t}	0.038	−0.149**	0.366***	0.097	1.000						
w_{2t}	−0.066	−0.067	0.557***	0.243***	0.401***	1.000					
w_{3t}	−0.006	0.013	−0.205***	−0.373***	0.023	−0.140**	1.000				
w_{4t}	−0.119*	0.250***	−0.069	−0.225***	0.020	−0.010	−0.087	1.000			
w_{5t}	0.156**	−0.121*	0.290***	0.081	0.396***	0.226***	−0.028	−0.141**	1.000		
w_{6t}	−0.192***	−0.054	0.494***	0.223***	0.176**	0.503***	−0.258***	−0.127*	−0.119*	1.000	
w_{7t}	0.143**	−0.069	0.720***	0.626***	0.293***	0.468***	−0.202***	−0.235***	0.269***	0.512***	1.000

Significant at *10%, **5%, ***1%.

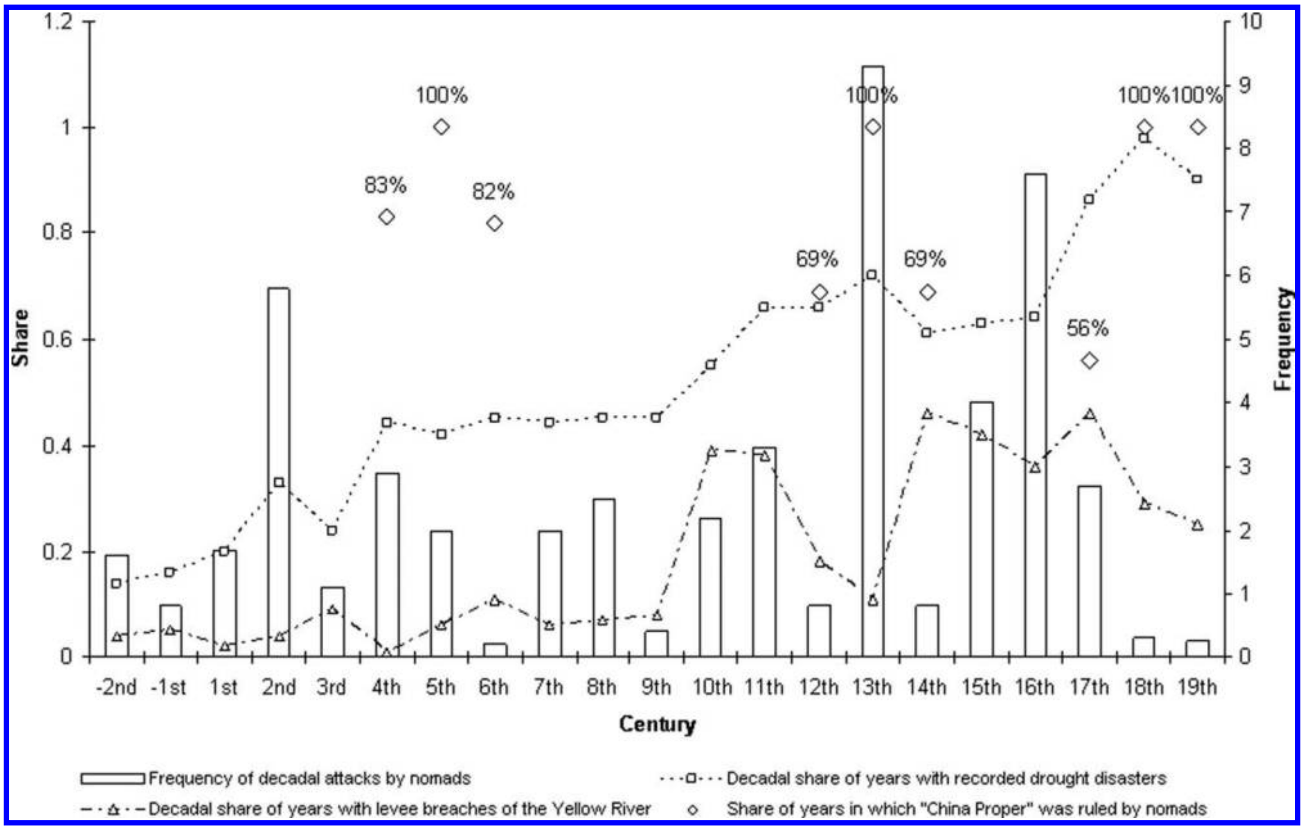
of all of the pertinent variables employed in our empirical analysis are presented in table 1.

Historians are of the view that collections of war data can be politically biased. Such bias is arguably severe in this study, as our data were reported only by Chinese sources, who may have had the incentive to reduce the frequency of nomadic attacks on the one hand and exaggerate the strength of Han Chinese retaliation on the other. Because cross-referencing all of our data with data collected from sources in different countries would be a monumental task, and infeasible, we validate only those pertaining to the Sino-Manchurian-Mongolian wars of the sixteenth to seventeenth centuries with similar data from Perdue (2005) in appendix B. Columns 1 and 2 of this appendix present the year and particulars of each battle employed in this study using Perdue's periodization, and columns 3 and 4 present a summary of his description of these battles and the relevant pages on which they are cited to allow comparison. Of the 24 battles employed in this study, 18 are explicitly identified in Perdue's study, with an additional 5 described but not named. The only instance for which we fail to find a match is the one battle fought between the Qing army and Lobzang Danjin in 1724, which is included in our data source but nowhere mentioned in Perdue. We are thus satisfied with the accuracy of our data on Sino-nomadic conflict.

C. *Descriptive Evidence of the Relationship between Precipitation Changes and Nomadic Invasions*

To support our hypothesis, we present descriptive evidence to demonstrate how changes in precipitation are correlated with the frequency of nomadic invasions. First, as table 2 shows, the decadal share of droughts (x_{1t}) is positively correlated with the frequency of nomadic attacks (y_{1t}), although the levee breaches of the Yellow River (x_{2t}) are not significantly correlated with these attacks, possibly because the breaches are correlated with other independent variables.

FIGURE 3.—TRENDS OF NOMADIC ATTACKS, DROUGHTS AND LEVEE BREACHES OF THE YELLOW RIVER



Data source: Same as table 1.

Second, the bar chart in figure 3 shows the relationship between the decadal share of droughts (x_{1t}) (represented by the rectangular-shaped dashed line) and levee breaches of the Yellow River (x_{2t}) (represented by the triangular-shaped dashed line) with the frequency of nomadic attacks (y_{1t}). In addition, the scattered, unconnected diamonds labeled with different percentages represent the share of years that China proper was ruled by nomads in a given century (w_{4t}, w_{5t}, w_{6t}).

The most striking finding in figure 3 is that nomadic invasions tend to be positively correlated with increasing incidences of drought and negatively correlated with increasing incidences of flooding. For instance, Sino-nomadic conflict intensified during the second century A.D., a period that coincided with growing incidences of drought, eventually resulting in the conquer of China proper (317–589). Likewise, the secular increase in incidences of drought-related disasters between the ninth and thirteenth centuries also predictably led to an intensification of conflict. This period witnessed the Mongol defeat of the Chechen Jin, who had conquered the central plains only a century earlier. The nomadic rule of China proper, in contrast, appears to have reduced the incidence of conflict. For instance, although incidences of drought remained relatively stable between the fourth and ninth centuries, incidences of Sino-nomadic conflict varied sharply, dropping precipitously in the fifth century following the conquer of the central plains by the nomads, who then became sedentary themselves, in the subsequent century. A similar pattern can be seen in the sixteenth to nineteenth centuries. Despite a sharp increase in drought over this period, conflicts actually declined, particularly in the eighteenth and nineteenth centuries, following the conquer of China proper by the nomads in 1664 and the firm establishment of the Qing dynasty.

III. Estimation Strategy

Battles are rarely isolated events, particularly when two parties retaliate against each other over extended periods of time. To account for the inherent path-dependent nature of battles, it is appropriate to employ dynamic models in our empirical estimations. The baseline estimation of the effects of adverse precipitation on invasions assumes the following autoregressive distributed lag (ARDL) model,

$$y_{1t} = \mu_1 + \sum_{i=1}^{r} \alpha_{1i}^1 y_{1t-i} + \sum_{i=0}^{p1} \beta_{1i}^1 x_{1t-i} + \sum_{i=0}^{p2} \beta_{2i}^1 x_{2t-i} + \pi^1 W_t + \varepsilon_t^1, \quad (1)$$

where y_{1t-i} is the ith lag of y_{1t}, r is the length of the lags of y_{1t-i}, x_{1t} and x_{2t} are our explanatory variables, and W_t is a 7 × 1 vector of our control variables. When dynamic regression models are employed, it is important to determine the appropriate lag period. Of the commonly employed procedures, we opted for the general-to-simple approach (although it may overfit the model), mainly because the results generated by the alternative—the simple-to-general approach—are subject to biased and inconsistent estimations. We also employ the Akaike (1973) information criterion (AIC) to select the lag order, the purpose of which is to minimize the AIC to ensure it is less than the largest number of lags. Furthermore, we test the model's stability by checking whether the roots of the characteristic equation,

$$A(\lambda) = 1 - \alpha_{11}^{1}\lambda - \alpha_{12}^{1}\lambda^{2} - \cdots - \alpha_{1r}^{1}\lambda^{r} = 0,$$

are greater than 1 in terms of absolute value. Finally, we check whether there is any remaining autocorrelation by computing the Durbin-Watson statistics. Following Jorgenson (1966), the model that we adopt is essentially a rational lag model that can reveal not only the short-run effects of the variables but also their possible impact over the long run. In the ARDL model, $C(L)y_t = \mu + B(L)x_t + \varepsilon_t$, L is the lag operator, and the long-run effect can be computed by $B(1)/C(1)$.

As previously noted, nomadic invasions into the Han hinterland may be correlated with attacks initiated by the sedentary agricultural regime on the nomadic regions. We thus need to control for this possibility by including the decadal frequency of battles initiated by the sedentary state on the nomads (y_{2t}) in our estimation. As this variable has a possible simultaneity bias, however, the unqualified inclusion of it and its lags in equation (1) is problematic. To correct for possible simultaneity, we extend equation (1) into equation (2):

$$Y_t = \mu + \sum_{i=1}^{P} A_i Y_{t-i} + BX_t + \Pi W_t + \varepsilon_t \quad Y_t = \begin{bmatrix} y_{1t} \\ y_{2t} \end{bmatrix}, \quad (2)$$

where ε_t is a vector of disturbances that is not autocorrelated with the zero means and the contemporaneous covariance matrix, $E[\varepsilon_t \varepsilon'_t] = \Omega$. For example, without loss of generality, equation (3) expresses the structure of a vector autoregression (VAR) with both first- and second-order lags:

$$\begin{bmatrix} y_{1t} \\ y_{2t} \end{bmatrix} = \begin{bmatrix} \mu_1 \\ \mu_2 \end{bmatrix} + \begin{pmatrix} \alpha_{11}^{1} & \alpha_{21}^{1} \\ \alpha_{11}^{2} & \alpha_{21}^{2} \end{pmatrix} \begin{bmatrix} y_{1t-1} \\ y_{2t-1} \end{bmatrix} + \begin{pmatrix} \alpha_{12}^{1} & \alpha_{22}^{1} \\ \alpha_{12}^{2} & \alpha_{22}^{2} \end{pmatrix} \begin{bmatrix} y_{1t-2} \\ y_{2t-2} \end{bmatrix} + \begin{pmatrix} \beta_{1}^{1} & \beta_{2}^{1} \\ \beta_{1}^{2} & \beta_{2}^{2} \end{pmatrix} \begin{bmatrix} x_{1t} \\ x_{2t} \end{bmatrix}. + \Pi W_t + \begin{bmatrix} \varepsilon_t^{1} \\ \varepsilon_t^{2} \end{bmatrix} \quad (3)$$

In this special case, there are two equations comprising 28 unknown parameters, with 14 in each equation. As previously noted, the VAR model requires us to select the lag order first. Then we can test the residual autocorrelation after running the regressions and checking the stability condition of the model to ensure that all eigenvalues of the coefficient matrix lie inside the unit circle.

IV. Empirical Results

A. Baseline Results

Table 3 reports the results of our estimates of the overall effect of precipitation changes on the frequency of nomadic attacks based on the ARDL model. Columns 1 and 2 report the baseline results, whereas columns 3 and 4 control for the lags in attacks initiated by the Han Chinese. We test the lag order of the ARDL model by minimizing the AIC when the lag order is less than the largest number of lags, which is 2 in this case (the same results can be obtained by using the general-to-simple approach). The Durbin-Watson test results (the p-values are over 0.7 in both columns) suggest that residual serial correlation is not an issue of concern (H_0: no serial correlation). Because the roots of $A(\lambda) = 1 - \alpha_{11}^{1}\lambda - \alpha_{12}^{1}\lambda^{2} - \cdots - \alpha_{1r}^{1}\lambda^{r} = 0$ are all larger than 1, the stability condition is also satisfied.

These estimation results demonstrate a strong, positive relationship between negative rainfall shocks and Sino-nomadic conflict. For instance, the positive coefficient of the lower precipitation variable (drought) suggests that less rainfall significantly increases the frequency of nomadic invasions, whereas more rainfall reduces it. In terms of marginal effects, an additional year of drought in a particular decade increases the probability of nomadic invasions in that decade by 0.2600 times, and a much larger effect of about 0.576 times is seen over the longer term (0.2600/[1 − 0.348 − 0.201], column 2). In column 4, which includes attacks initiated by the sedentary agricultural regime with two lags, the magnitudes of both short- and long-run effects are about the same as those of the nomadic invasions: 0.2577 and 0.559 (0.2577/[1 − 0.341 − 0.198], column 4). In the case of floods, an additional year of levee breaches of the Yellow River in a particular decade reduces the likelihood of nomadic invasions by 0.3635 times in the short run and 0.806 times in the long run. Where the lagged effect of attacks by the sedentary agricultural regime is included (column 4), the corresponding reductions in nomadic invasions due to a favorable climate for the nomadic regime are, respectively, 0.3617 times in the short run and 0.785 times over the long run.

As with the key explanatory variables, the lags in nomadic attacks are all significant and positive, whereas snow and low temperature calamities are statistically insignificant. All three of the period variables of nomadic conquest have negative relationships with the dependent variable at varying degrees of statistical significance. The first period is significant at the 10% level, whereas the second is insignificant, and the third is significant at nearly the 1% level. The lags in attacks initiated by the sedentary agricultural regime are not significant, which implies that nomadic invasions were unlikely to be responses to such attacks. In any case, the inclusion of these control variables fails to change

TABLE 3.—BASELINE ESTIMATIONS WITH AUTOREGRESSIVE DISTRIBUTED LAGS

	Nomadic Attacks			
	(1)	(2)	(3)	(4)
Nomadic attacks: Lag 1	0.343***	0.348***	0.340***	0.341***
	[0.072]	[0.069]	[0.073]	[0.070]
Nomadic attacks: Lag 2	0.206***	0.201***	0.208***	0.198***
	[0.075]	[0.069]	[0.075]	[0.069]
Nomadic attacks: Lag 3	−0.007		−0.021	
	[0.071]		[0.074]	
Sedentary attacks: Lag 1			0.097	0.097
			[0.106]	[0.099]
Sedentary attacks: Lag 2			−0.034	−0.039
			[0.106]	[0.099]
Sedentary attacks: Lag 3			−0.005	
			[0.102]	
Lower precipitation	2.765**	2.600**	2.703**	2.577**
	[1.136]	[1.057]	[1.144]	[1.061]
Lower precipitation: Lag 1	−0.179		−0.207	
	[1.109]		[1.118]	
Higher precipitation	−3.244**	−3.635**	−3.312**	−3.617**
	[1.531]	[1.411]	[1.545]	[1.416]
Higher precipitation: Lag 1	−1.130		−0.908	
	[1.618]		[1.646]	
Snow disasters	1.871	1.833	1.817	1.824
	[1.728]	[1.696]	[1.743]	[1.705]
Low-temperature disasters	−0.746	−0.830	−0.890	−1.002
	[1.467]	[1.434]	[1.487]	[1.449]
Temperature	−0.463*	−0.399	−0.455	−0.400
	[0.278]	[0.259]	[0.280]	[0.260]
Nomadic conquest 1	−1.489**	−1.417**	−1.561**	−1.512**
	[0.683]	[0.658]	[0.729]	[0.694]
Nomadic conquest 2	−1.278	−1.174	−1.142	−1.075
	[0.820]	[0.784]	[0.840]	[0.795]
Nomadic conquest 3	−3.639***	−3.461***	−3.562***	−3.408***
	[1.095]	[1.026]	[1.105]	[1.031]
Time trend	0.011	0.009	0.011	0.009
	[0.007]	[0.006]	[0.007]	[0.006]
R^2	0.39	0.38	0.39	0.39
Observations	203	204	203	204
Lag order selection	2	2	2	2
AIC (*r*)[a]	5.010	4.978	5.035	4.993
Durbin's Test (*p*-value)	0.783	0.991	0.795	0.913
Stability condition:	Satisfies	Satisfies	Satisfies	Satisfies

Standard errors in brackets; constant terms are not reported. Significant at *10%, **5%, ***1%.
[a]AIC of equations with less than two lags are not reported.

the sign or significance of the key explanatory variables, which suggests the highly robust nature of our estimation.

B. Robustness Checks

As nomadic invasions into the Han hinterland may be correlated with attacks on the nomads initiated by the sedentary agricultural regime, we include this variable in some of our baseline estimations. Due to the possible simultaneity bias, however, we need to check the robustness of our results using VAR estimations. Table 4 presents the results. As with our baseline results, we perform all of the necessary procedures required of a dynamic regression model and satisfy the attendant conditions accordingly (for example, order of lags, residual autocorrelation, stability). The results of the first equation (of nomadic attacks) in estimation 2 (in which only two lag orders are included; column 2.1 of Table 4) are trivially different from those in column 4 of table 3, which suggests that there is no serious simultaneity bias of invasions by both sides and helps to reaffirm the robustness of our baseline estimates.

As the historical climate data used in this study are taken from the Han agricultural region, it is also of interest to examine the effects of climatic shocks on Han decisions to invade the nomadic territories. We find that of the four different climatic events, only floods (columns 1.2 and 2.2, table 4) and "snow disasters" (column 1.2, table 4) significantly reduce the frequency of such attacks. The lag effects of invasions initiated by the Han are strikingly similar to those initiated by the nomads; for instance, the pertinent coefficients of the first and second lags of Han-initiated invasions are, respectively, 0.325 and 0.182 (column 2.1, table 4), which are strikingly similar to those of the first (0.341) and second (0.198) lags of the nomad-initiated invasions (column 2.2, table 4). A more interesting finding is that although the first lag of nomad-initiated invasions is

Table 4.—Robustness Check – Vector Autoregression Model

	(1)		(2)	
	(1.1)	(1.2)	(2.1)	(2.2)
	Nomadic Attacks	Sedentary Attacks	Nomadic Attacks	Sedentary Attacks
Nomadic attacks: Lag 1	0.345***	−0.019	0.341***	−0.029
	[0.069]	[0.048]	[0.067]	[0.047]
Nomadic attacks: Lag 2	0.206***	0.146***	0.198***	0.121**
	[0.072]	[0.050]	[0.067]	[0.047]
Nomadic attacks: Lag 3	−0.022	−0.062		
	[0.070]	[0.049]		
Sedentary attacks: Lag 1	0.104	0.354***	0.097	0.325***
	[0.100]	[0.070]	[0.096]	[0.067]
Sedentary attacks: Lag 2	−0.040	0.198***	−0.039	0.182***
	[0.101]	[0.071]	[0.095]	[0.067]
Sedentary attacks: Lag 3	−0.003	−0.057		
	[0.097]	[0.068]		
Lower precipitation	2.540**	0.911	2.577**	1.041
	[1.034]	[0.725]	[1.024]	[0.722]
Higher precipitation	−3.642***	−1.661*	−3.617***	−1.623*
	[1.374]	[0.963]	[1.366]	[0.964]
Snow disasters	1.764	−1.958*	1.824	−1.739
	[1.663]	[1.166]	[1.645]	[1.160]
Low-temperature disasters	−0.960	−0.420	−1.002	−0.490
	[1.410]	[0.989]	[1.398]	[0.986]
Temperature	−0.405	−0.052	−0.400	−0.040
	[0.253]	[0.177]	[0.251]	[0.177]
Nomadic conquest 1	−1.509**	0.673	−1.512**	0.632
	[0.683]	[0.479]	[0.670]	[0.473]
Nomadic conquest 2	−1.056	−0.284	−1.075	−0.360
	[0.773]	[0.542]	[0.767]	[0.541]
Nomadic conquest 3	−3.441***	−0.091	−3.408***	−0.038
	[1.001]	[0.702]	[0.995]	[0.701]
Time trend	0.009	0.001	0.009	0.000
	[0.006]	[0.004]	[0.006]	[0.004]
R^2	0.387	0.334	0.387	0.327
Observation	203		204	
Lag order selection:	2		2	
Test for residual autocorrelation (H_0: No serial correlation):				
Lag 1 (*p*-value)	0.732		0.917	
Lag 2 (*p*-value)	0.463		0.355	
Stability condition	Satisfies		Satisfies	

Standard errors in brackets. Constant terms are not reported. Significant at *10%, **5%, ***1%.

not significant, the second is, which implies that the Han's delayed response may have been retaliatory; that is, the sedentary regime may have required time to reorganize its military resources and retaliate.

In light of the 700-year occupation of the agricultural lands by the nomads (out of the 2,060 years under study), one final robustness check is to drop the years in which the nomads directly controlled these lands. We do so by replicating the ARDL and VAR estimations using the smaller sample.[11] Consistent with our previous findings, the estimation results based on the ARDL method also show that lower precipitation increases the frequency of nomadic attacks, whereas higher precipitation reduces it (column 1, table 5). The results of the VAR estimation (column 2.1, table 5) are trivially different from those in column 1 of the same table.

[11] Because of the possible endogeneity of nomadic control of the agricultural lands, we correct for this potential sample selection bias. The results, shown in table A2, remain robustly consistent with the general results.

V. Conclusion

Throughout history, many settled civilizations have been invaded and conquered by what some historians refer to as "barbaric tribes," leading eventually to the downfall of one of the two groups. For more than two thousand years, the Han Chinese were subject to the bullying of their northern nomadic neighbors, the longest and most enduring clash in the history of ethnic conflict. The clash of civilizations is an important subject, but one to which the field of economics has made few contributions. A paucity of data is, in our view, the major impediment to such studies. By constructing a time-series data set from a few rich historical Chinese sources and following the approach pioneered by Miguel et al. (2004) and others in exploiting the effects of exogenous variations in rainfall on the probability of conflicts, we provide evidence of a reduced-form relationship between negative rainfall shocks and violent invasions in a temporal and geographical context that is very different from that of sub-Saharan Africa, and one that persisted for more than two millennia.

TABLE 5.—ROBUSTNESS CHECK—DROPPING PERIODS WHEN THE AGRICULTURAL LANDS WERE CONTROLLED BY THE NOMADS

	ARDL	VAR	
	(1)	(2.1)	(2.2)
	Nomadic Attacks	Nomadic Attacks	Sedentary Attacks
Nomadic attacks: Lag 1	0.397***	0.397***	−0.040
	[0.091]	[0.087]	[0.064]
Nomadic attacks: Lag 2	−0.036	−0.036	0.162**
	[0.092]	[0.088]	[0.065]
Han attacks: Lag 1	0.177	0.177	0.278***
	[0.122]	[0.117]	[0.086]
Han attacks: Lag 2	−0.014	−0.014	0.152*
	[0.118]	[0.112]	[0.083]
Lower precipitation	2.767**	2.767**	1.335
	[1.178]	[1.126]	[0.828]
Higher precipitation	−3.671**	−3.671**	−0.546
	[1.790]	[1.711]	[1.258]
Snow disasters	−0.344	−0.344	−2.409
	[2.313]	[2.212]	[1.626]
Low-temperature disasters	0.962	0.962	−1.442
	[1.990]	[1.902]	[1.399]
Temperature	−0.786***	−0.786***	0.168
	[0.269]	[0.257]	[0.189]
Time trend	0.010	0.010*	−0.003
	[0.006]	[0.006]	[0.004]
R^2	0.41	0.41	0.26
Observation	128	128	128

Standard errors in brackets. Constant terms are not reported. Significant at *10%, **5%, ***1% level.

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APPENDIX A

Weather Correlations between the Agricultural and Nomadic Regions

Our primary goal here is to identify whether there are any significant correlations in weather between the agricultural (region 1, figure 1) and nomadic regions (region 2, figure 1) using contemporary data. To achieve this goal, we employ a fixed-effects model

$$P_{2ij} = \rho P_{1ij} + \alpha_i + \varepsilon_{ij},$$

where P_{1ij} and P_{2ij} denote monthly precipitation in regions 1 and 2, respectively, in the ith month of the jth year. To check the robustness of this estimation, we replace P_{rij} with $\frac{P_{rij}}{|P_{ri}|}$ $(r = 1,2)$, given that the weather distribution ranges in the two regions are likely to be different. This check allows us to test whether deviations from normal weather in region 1 are correlated with those in region 2. Premised on the underlying assumption that abnormal precipitation can cause floods or droughts, the significant correlation between P_1 and P_2 supports the notion that a flood in region 1 is correlated with higher precipitation in region 2 and, conversely, that a drought in region 1 is correlated with lower precipitation in region 2.

Table A1.—Correlations in Climate between Regions (Fixed-Effects Model)

	P_2		$\frac{P_2}{\lvert P_2 \rvert}$	
	(1.1) Random Effect	(1.2) Fixed Effect	(2.1) Random Effect	(2.2) Fixed Effect
P_1	0.229***	0.122***		
	(0.016)	(0.016)		
$\frac{P_1}{\lvert P_1 \rvert}$			0.141***	0.141***
			(0.023)	(0.023)
Observations	408	408	408	408
Number of months	12	12	12	12
R^2	0.83	0.83	0.09	0.09

Standard errors in brackets. Constant terms are not reported. Significant at *10%, **5%, ***1%.

With about 160 monitoring stations located in the two regions, the U.S. National Climate Data Center collected and houses data on monthly precipitation and temperature (both average and minimum) for the 1957–1990 period. Climate analysis typically entails dividing the global surface into grids based on a region's latitudes and longitudes. For the entire world, 2,592 grids are drawn over a 5 × 5 degree basis (72 longitude × 36 latitude grid boxes). Region 1 occupies about three grids, whereas region 2 occupies 20. Based on the weather data provided by the pertinent monitoring stations, we are able to generate the weather for each grid, including those of regions 1 and 2.

The results of these regressions (columns 1 and 2, table A1) strongly support our claim that the precipitation characteristics of regions 1 and 2 are highly correlated. Although there have been dramatic climatic changes in the past several thousand years, the climatic relationship between these two regions has remained relatively stable; after all, East and North Asia share similar monsoon characteristics—as much now as in ancient times (Zhang & Lin, 1992).

APPENDIX B

Validity Check of the War Data, 1677–1759

(1) Year	(2) Warfare Data used in This Paper	(3) Warfare Description in *China Marches West*	(4) Page
Period 1: Manchus, Mongols, and Russians in conflict, 1670–1690			
1677	Galdan attacked Ochirtu	In 1676 or 1677 Galdan defeated and killed Ochirtu Khan. Major attacks were reported in the Ordos region.	p. 139
1688	Galdan attacked Khalkha	On August 28, 1688, the Tusiyetu Khan and Galdan fought a pitched battle for three days.	p. 150
Period 2: End of Galdan, 1690–1697			
1690	Qing attacked Galdan at Ulan Butong	Qing ordered an attack on September 3, 1690, at Ulan Butong.	p. 155
1696	Qing attacked Galdan at Jao Modo	On June 12, 1696, the two armies met in a battle at Jao Modo.	p. 188
Period 3: Imperial overreach and Zunghar survival, 1700–1731			
1715	Tsewang Rabdan attacked Hami in 1715	Tsewang Rabdan attempted invasion of Hami in 1715.	p. 222
1717	Zunghars Tsewang Rabdan occupied Tibet	In the summer of 1717, Tsewang Rabdan sent his best general, Tsering Dondub. . . . Tsering Dondub led his troops into Lhasa.	p. 234
1717	Qing attacked Zunghars	By April 1717, 8,500 troops . . . prepared to advance to capture Turfan. . . . Far enough to run into Zunghar patrols.	p. 231
1718	Qing aided Tibet at the Kara-Usu River	There was a battle of the Manchu commanders Seleng and Elunte with Tsewang Rabdan's forces at the Kara-Usu River on Oct. 5, 1718.	p. 223
1718	Qing aided Tibet and attacked Zunghars	Kangxi ordered the Manchu general Erentei to march on Lhasa with seven thousand men.	p. 234
1718	Qing defeated Zunghars at Tibet	The Qing destroyed the entire force in September 1718.	p. 235
1723	Qing army defeated Lobzang Danjin in Qinghai, in 1723	On Nov. 16, 1723, the Qing army battled with Lobzang outside the Taersi.	p. 245
1724	Qing defeated Alabutansubatai	Not found.	
1727	Qing depressed the rebellion in Tibet in 1727	There were disturbances in Tibet in 1727.	p. 248
1730	Qing attacked Zunghars at Keshetu	A great review of the troops was held in Beijing in June 1729; [they] returned to the capital in January 1731.	p. 252
1731	Qing and Zunghars battled at Hoton Nor	On July 23 the Zunghars poured in, . . . surrounded the Qing army at Hoton Nor.	p. 254
1731	Qing and Zunghars battled at Urumchi	Yue Zhongqi's successful raid on Urumchi.	p. 254
1731	Qing attacked Zunghars at Erchudeng River	Furdan was routed too quickly for this feint to have any effect.	p. 254
Period 4: The final Blows, 1734–1771			
1748	Qing suppressed the Jinchuan rebellion	In early 1748, . . . establish a connection between Tibet and the Jinchuan rebels. . . .	p. 267
1750	Qing suppressed the chaos in Tibet	Chaos in both Tibet and Zungharia in the 1750s put an end to these connections.	p. 267
1755	Qing defeated Zunghars Dawaci	By the middle of 1755, . . . hearing of the Qing approach, Dawaci fled to Gedengshan.	p. 274
1756	Qing defeated Amursana	By October 1756, Qing troops had fought and defeated . . . Amursana. Amursana fled farther west.	p. 287
1757	Qing succeeded in defeating Amursana and his supporters	In early 1757 . . . the Qing emperor thought that now was the perfect opportunity to capture Amursana . . . settled for an inconclusive victory.	p. 288
1758	Qing suppressed the rebellion of Turki at Kucha	The Turki army then burst out of Kucha on the evening of July 28, 1758, and fled west.	p. 290
1759	Qing suppressed the rebellion of Turki at Blackwater Camp	Qianlong sent his best frontier general to besiege the rebels . . . Battled at Blackwater Camp . . . On December 13, 1759, the Qianlong emperor proclaimed the completion of the Zunghar campaigns.	p. 290

Columns (1) and (2) are from China's Military History Editorial Committee (2003); columns 3 and 4 are from Perdue (2005).

APPENDIX C:

Conflicts between the Nomads and the Han—Correction of Selection Bias

In our robustness check, we drop the three periods in which nomadic conquest of the Han led to the nomads becoming sedentary themselves. However, whether the agricultural lands were controlled by the nomads is a possibly endogenous issue. To avoid the problem of sample selection bias, we use the following model:

$$y'_{1t} = \mu_1 + \sum_{i=1}^{r} \alpha^1_{1i} y'_{1t-i} + \beta^1_1 x_{1t} + \beta^1_2 x_{2t} + \pi^1 W_t + \varepsilon^1_t,$$

$$I_i = 1(B' x_t + \delta^{1'} w_{1t} + \delta^{2'} w_{2t} + \delta^{6'} w_{6t} + \gamma' z_{3t} > 0).$$

which means that the central plain was ruled by the ethnic Han.

The second equation determines the sample selection; y'_{1t} is observed when

$$B' x_t + \delta^{1'} w_{1t} + \delta^{2'} w_{2t} + \delta^{6'} w_{6t} + \gamma' z_{3t} > 0 \; and \; I_i = 1.$$

The maximum likelihood estimation in table A2 (column 2.1) shows that lower precipitation increases the frequency of nomadic attacks, whereas higher precipitation reduces it. This robustness check supports our baseline results.

Table A2.—Conflicts between the Han and the Nomads

	ARDL-Selection Bias Corrected			
	Two-Step Estimation		Maximum Likelihood Estimation	
	(1.1)	(1.2)	(2.1)	(2.2)
	Ruled by Han	Nomadic Attacks	Ruled by Han	Nomadic Attacks
Nomadic attacks: Lag 1		0.382***		0.380***
		[0.086]		[0.086]
Nomadic attacks: Lag 2		−0.016		−0.021
		[0.086]		[0.085]
Han attacks: Lag 1		0.153		0.171
		[0.113]		[0.110]
Han attacks: Lag 2		−0.014		−0.018
		[0.111]		[0.110]
Lower precipitation	−1.897***	3.072***	−1.886***	3.190***
	[0.615]	[1.472]	[0.618]	[1.173]
Higher precipitation	3.951***	−3.488	3.953***	−3.571*
	[0.850]	[2.703]	[0.851]	[1.834]
Snow disasters	−2.753***	−0.747	−2.736***	
	[0.944]	[2.849]	[0.951]	
Low-temperature disasters	−2.376***	1.143	−2.386***	
	[0.816]	[2.496]	[0.818]	
Temperature	0.700***	−0.740*	0.701***	−0.748***
	[0.174]	[0.450]	[0.174]	[0.277]
Time trend	−0.004	0.009	−0.004	0.009
	[0.003]	[0.007]	[0.003]	[0.006]
Observation	204	132	204	132

Standard errors in brackets. Constant terms are not reported. Significant at *10%, **5%, ***1%.