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ABSTRACT

This paper provides evidence of the long-run effects of a permanent increase in agricultural productivity on conflict. We construct a newly digitized and geo-referenced dataset of battles in Europe, the Near East and North Africa covering the period between 1400 and 1900 CE. For variation in permanent improvements in agricultural productivity, we exploit the introduction of potatoes from the Americas to the Old World after the Columbian Exchange. We find that the introduction of potatoes permanently reduced conflict for roughly two centuries. The results are driven by a reduction in civil conflicts.

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1 Introduction

Understanding the relationship between a permanent rise in agricultural productivity and conflict is a central question for political economy and development economics. A large body of literature provides important evidence that transitory productivity shocks reduce conflict.[1] However, there is much less evidence on the effect of a permanent rise in agricultural productivity. This is somewhat surprising given that economic development and change in the equilibrium level of conflict are both long-run processes, and economic growth has historically been characterized by permanent increases in agricultural productivity.

In agrarian economies typical to historical societies and low-income countries today, increasing agricultural productivity can affect conflict for several reasons. On the one hand, improved agricultural productivity can reduce conflict. For example, the increase in productivity could reduce the requirement for land, which can reduce the competition over its control.[2] Similarly, an increase in agricultural productivity could increase real wages and the opportunity cost of arming. On the other hand, the availability of cheap food could reduce the cost of maintaining large armies, which can increase conflict. Thus, the net effects are ambiguous *ex ante* and, whether or not improved agricultural productivity reduces conflicts is, ultimately, an empirical question.

The goal of this paper is to make progress on this important question by providing empirical evidence on the long-run relationship between a permanent increase in agricultural productivity and conflict. As with any study of the effect of a permanent change in agricultural productivity, we face two obstacles. First, to examine the long-run effects, researchers would need to observe conflict over a long time horizon. Second, to establish a causal relationship, one needs to find plausibly exogenous variation in a permanent change in agricultural productivity.[3]

[1] We discuss the literature in detail later in the Introduction.

[2] This assumes that the demand for food is price inelastic such that an increase in productivity is not fully offset by an increase in demand, which leads to a decline in food prices and the value of land that is used to produce food.

[3] To understand this problem, assume that we find a negative association between conflict and agricultural

The principal contribution of our study is to address these two difficulties. To deal with the lack of data, we construct a new dataset that includes all conflicts with more than 32 combat mortalities.[4] We combine information from two well-known sources in the historical conflict literature, Clodfelter (2008) and Brecke (1999, forthcoming). These sources provide information on wars and battles. Over a period of six years, we manually digitized the information and geo-referenced each conflict to construct a dataset that records the date and location of each conflict in Europe, North Africa and the Near East from 1400 to 2000 CE. To the best of our knowledge, these are the most comprehensive digitized and geocoded data of historical conflicts today. Our analysis examines the period from 1400 to 1900, when agriculture was economically more important than in the period after 1900.

To establish the causal link from agricultural productivity to violent conflicts, we adopt the strategy of Nunn and Qian (2011). This exploits the introduction of potatoes from the Americas to the Eastern Hemisphere as an exogenous increase in agricultural productivity in regions that are geographically and climatically suitable for potato cultivation.[5]

A third and related difficulty is the lack of continuity in polities over time. Studies of modern conflict (or other political economy outcomes), particularly studies of interstate warfare, typically examine a panel of polity pairs. This allows researchers to directly test theories of conflict that make predictions about country pairs, and to control for potentially confounding influences with polity fixed effects or polity-pair fixed effects. This is difficult to implement in the historical context because very few polities existed for much of the long time period that we study. Even for those polities that existed throughout (e.g., France), the numerous boundary changes make it conceptually difficult to define a polity over time. We address this difficulty by conducting our analysis at the geographic cell level – i.e., we

productivity in the data. This does not necessarily mean that increased productivity reduces conflict, since the association is also consistent with reverse causal channels – i.e., reduced conflict could increase agricultural productivity, or there may be a third factor which influences both variables – i.e., better institutions could both improve productivity and reduce conflict.

[4] Like all conflict datasets, the cutoff is arbitrary.

[5] The earlier study shows that the introduction of potatoes increased population density, urbanization and well-being (height), but it does not examine political economy outcomes.

construct a balanced panel of cells over time and compare outcomes across cells of varying levels of suitability for potato cultivation, before and after the introduction of potatoes.

Thus, our analysis relies on a *differences-in-differences* (DD) strategy and compares conflict in regions that are suitable for cultivating potatoes with regions that are less suitable before and after the introduction of potatoes. In order to capture spatial and temporal spillovers, our unit of observation is a 400km×400km grid-cell during a fifty-year time period. Since potatoes began to be adopted as a field crop in continental Europe in the late 1600s, we interpret 1700 as the effective date of introduction. Our baseline specification controls for grid-cell fixed effects, which accounts for all time-invariant differences across cells. It controls for time fixed effects, which isolates all changes over time that have similar effects across cells (e.g., other technological improvements, changes in European warfare technology). It also accounts for the interaction of suitability for the cultivation of staple crops that existed prior to the introduction of potatoes (e.g., wheat, barley, rye, rice) and time fixed effects. We interpret only the interaction of suitability for potatoes and post-introduction as plausibly exogenous.

Our results show that the increase in agricultural productivity brought about by the introduction of potatoes dramatically reduced conflict. The relative decline began soon after the introduction and persisted over time. On average, a one-standard deviation increase in potato cultivation reduced conflict by 0.26 standard deviations. Our results are qualitatively robust to a large number of controls, which we discuss later. We show that the decline persists through the end of our sample, 1900.

There are two important caveats for interpreting our results. The first is the concern of spatial spillovers, which is particularly important for long-range conflicts – i.e., what if the introduction of potatoes in a region suitable for its production, such as Russia, caused it to be belligerent elsewhere in a region that was less suitable for potatoes? This will cause the DD estimates to be negative, but the interpretation will be confounded. We provide several pieces of evidence that alleviate this concern. First, our results are similar when we extend the unit of analysis to larger grids, such as 800km×800km (roughly the size of France today). Second, we show that our findings are similar if we exclude conflicts that involve actors who are far apart. Finally, we show that our results are mainly driven by civil conflicts that do not involve any foreign entities.

The second caveat stems from the concern that suitability for potato cultivation is correlated with other factors which caused a reduction in conflict in the eighteenth and nineteenth centuries. To address this, we document the correlates of potato suitability and show that our results are robust to controlling for these factors as well. Specifically, we control for suitability to other staple crops introduced by the Colombian Exchange (e.g., maize, cassava and sweet potatoes), geographic characteristics (e.g., distance to nearest ice-free coastline, elevation, ruggedness, latitude, longitude, etc.) and weather shocks. To allow the influences of agricultural and geographical controls to vary over time in a flexible way, we interact each variable with time fixed effects. These controls address the potentially confounding influences of changes in military and agricultural technology to the extent that such changes are particularly beneficial to certain types of terrain or crops.

It is beyond the scope of our paper to be conclusive about the underlying mechanism. In the paper, we provide one internally consistent explanation of how an increase in agricultural productivity can reduce land prices and thus the contest for land. This explanation is consistent with all of our results and the model, which is based on the insights of Acemoglu et al. (2012), is formally presented in the Appendix. An important alternative mechanism to the one that we propose is insurance. Potatoes may have reduced conflict by helping to smooth consumption through particularly cold winters. This would be similar to the mechanism for how sweet potatoes reduced conflict in historical China by smoothing consumption during droughts (Jia, 2014). To investigate this, we construct an annual panel with historical winter-temperatures and estimate the interaction of cold temperature shocks and the introduction of potatoes. We find no effect, which goes against insurance as a main driver of our results. We are also open to other explanations, some of which we discuss in the paper.

Our findings make several contributions to the growing literature on the determinants of conflict. For example, the pioneering studies of Miguel et al. (2004) and Dube and Vargas (2013) link conflict to rainfall and commodity price shocks, which they interpret as evidence that increases in the opportunity cost of arming will reduce conflict. More generally, our study adds to the small but rapidly growing number of empirical studies that attempt to provide causal evidence on the determinants of conflict. These studies have found that conflict is, for instance, affected by foreign aid (Dube and Naidu, 2013; Crost et al., 2014; Nunn and Qian, 2014).

Our findings support these earlier works in showing that conflict is sensitive to resource shocks. However, we conceptually differ in examining the long-run effects of a permanent change in productivity as opposed to transitory shocks. Distinguishing between the effects of transitory shocks versus permanent shocks is important since responses to transitory shocks might reflect shifts in the timing of conflict, and it is not conceptually obvious how such shocks should affect the equilibrium levels of conflict. By contrast, the finding that increased agricultural productivity from the introduction of potatoes reduced the levels of conflict for the subsequent two hundred years is likely to reflect a reduction in the equilibrium levels of conflict. To the best of our knowledge, the only other study to examine the effect of a permanent change is (Jia, 2014), which focuses on the role of sweet potatoes as insurance in reducing rebellions in historical China.

Our findings also contribute to a prior literature that examines the determinants of historical conflict. For example, Onorato et al. (2014) estimate the relationship between military technology and army size among thirteen European powers from 1600 to 2000. Aghion et al. (2012) examine the relationship between military rivalry and subsequent educational improvements using global data from 1830 to 2001. Gennaioli and Voth (2015) study the importance of war finance for military success and how this affected state-building in Europe during the Early Modern period.

In looking at long-run effects, we ask a similar question as studies of how natural resource endowments affect conflict. For example, Caselli et al. (2013) provide cross-sectional evidence that the likelihood of inter-state conflict increases when at least one of the countries has mineral resources, especially if the resources are close to the border. Similarly, Acemoglu et al. (2012) provide a theoretical basis for how an increase in natural resources such as oil can increase conflict. Our results support the idea that natural resources are important for explaining conflict. We differ from most studies of resource-driven conflicts by providing empirical evidence that certain types of resource shocks, in this case agriculture, can *reduce* conflict.[6] In this sense, we add to the large literature on the effects of agricultural productivity, especially recent studies that find that the introduction of New World foods increased population density (Chen and Kung, 2011; Hersh and Voth, 2011; Nunn and Qian, 2011). We complement these studies by investigating the effects on conflict, which, as we discussed earlier, are not obvious ex ante.

This study is also related to a companion study, Iyigun et al. (2017), which shows that persistent cooling during the Little Ice Age increased conflict in the historical context. The two studies are interested in the determinants of historical conflict, but examine very different shocks. One positive and agricultural (potatoes) and the other negative and climatic (cooling). The two studies are complementary as they both investigate the same over-arching question of understanding the long-run relationship between permanent (or in the case of climate, indefinite) changes in agricultural productivity and conflict.

Finally, our study makes a general contribution to the conflict research literature by constructing a comprehensive digitized and geo-referenced dataset of conflicts. We hope that this dataset will facilitate future empirical research as we intend to make the dataset publicly available.

The rest of our paper is organized as follows. Section 2 discusses the historical background.

[6] For two other papers on the causality from resource shocks to the outbreak and incidence of civil wars, see Besley and Persson (2008) and Brückner and Ciccone (2010). Also, see Montalvo and Reynal-Querol (2005); Esteban and Ray (2011); Esteban et al. (2012) for empirical and theoretical evidence on the relationship between ethnic polarization and conflict. Our study is also related to the large body of studies in political science that documents relationships between a number of economic factors and the incidence of civil war (Collier and Hoeffler, 1998, 2001; Fearon and Laitin, 2003; Sambanis, 2002).

Section 3 summarizes the conceptual framework and discusses the empirical strategy. Section 4 describes the data. Section 5 presents the baseline estimates and robustness results. Section 6 provides additional findings. Section 7 offers concluding remarks.

2 Background

2.1 Conflicts

We now turn to a discussion of the historical features of conflict that are important for our empirical investigation. In the historical context, when the economy is largely agricultural, conflicts were often waged to gain control of land, a key input in agricultural production. The conflicts in our study include ones between many different types of actors. As Tilly (1992, pp. 68–71) explains, ordinary people had weapons at their disposal and nobles had a legal right to wage private wars in many parts of the Old World and throughout most of history. "Europeans followed a standard war-provoking logic: everyone who controlled substantial coercive means tried to maintain a secure area within which he could enjoy the returns from coercion" (Tilly, 1992, p. 70). In practice, this means that the conflicts that we examine include conflicts between peasants, the nobility and/or sovereign rulers in any combination. The conflicts often include two actors, but they can also include more than two. Since new polities emerge and existing polities disappear over time, the identities of the actors can change in an ongoing conflict.

Conflict scholars have long recognized that the difficulty in defining the onset and termination of wars is how to aggregate or disaggregate sequential or simultaneous wars.[7] Consider the extreme example of the Hundred Years' War, which lasted from 1337 to 1453, and included at least five large polities (England, France, Scotland, Bohemia, Burgundy) engaging in armed conflict on both sides of the English Channel. In our study, we follow the strategy of the empirical literature on modern conflicts and avoid such difficulties by using "battles"

[7]For a detailed discussion, see Levy (1983, pp. 63–69).

(defined as a location with conflict) rather than the larger war to which a battle may have belonged, as units of observation.

There are several additional aspects that are important to note about the context of our study. First, warfare in the medieval and pre-industrial eras was a highly seasonal activity, with hostilities typically coming to a halt during the winter months, only to be picked up again with the onset of warmer weather in the spring.[8] This suggests that the incentive to arm might have been highly sensitive to agricultural wages. This motivates us to include an opportunity cost mechanism in our framework, which we discuss in the next section. Second, as past studies have noted, changes in military technology made warfare more expensive over time (e.g., Tilly, 1992). This should not affect the validity of our empirical strategy, which compares conflict across regions with differing levels of productivity within the same time period, as well as conflict over time. We will discuss this more when we conduct our robustness exercises.

2.2 The Potato and Agricultural Productivity

Potatoes are native to South America and came to the Eastern Hemisphere via Europe during the Colombian Exchange. Upon arrival in the 16th Century, they were initially seen as an exotic curio rather than an edible crop. One of the first accounts of potatoes being widely cultivated is from England in the 1690s, where potatoes were used as a supplement to bread (Langer, 1963; McNeill, 1999). By the late-18th century, potatoes had become an important field crop in countries such as France, Austria, and Russia. Once Europeans began cultivating the potato, it spread fairly rapidly to other parts of the Old World by European mariners who carried it to ports across Asia and Africa (Langer, 1963; McNeill, 1999). Since there are no data on the time of adoption for each region and the actual date of adoption may be endogenous to factors that could influence conflict, we follow Nunn and Qian (2011) and interpret 1700 to be the date of the "introduction" of potatoes, by which we mean to be the

[8] See Iyigun (2008, 2015).

beginning of the cultivation of potatoes as a major staple crop in continental Europe.[9]

Potatoes provide many more calories per acre of land than pre-existing staple crops such as wheat, rice or barley. They are also rich in micronutrients and lack only vitamins A and D. In fact, humans can have a healthy diet from consuming only potatoes, supplemented with only dairy, which contains the two vitamins not provided by potatoes (Connell, 1962; Cook, n.d.; Davidson et al., 1975). Potatoes are also more resistant to cold weather than existing staple crops. Thus, the availability of potatoes allowed Europeans to increase the productivity of existing agricultural land as well as to bring in marginal pieces of land in colder climates into agricultural production (Davidson et al., 1975; Reader, 2008).

In support of the claim that the introduction of potatoes increased agricultural productivity, Nunn and Qian (2011) finds that the introduction of potatoes substantially increased height, population and urbanization. See this earlier paper for a longer discussion about the benefits of potatoes, and Salaman et al. (1985) for a detailed and comprehensive discussion of the history of the potato.

3 Conceptual Framework

3.1 A Simple Model

A rise in agricultural productivity can reduce conflict for many reasons. In this section, we develop a simple model to illustrate two of the most obvious channels through which the introduction of potatoes can reduce conflict. The goal of the model is to provide a framework for interpreting the cell-level empirical analysis and to provide an internally consistent example of mechanisms consistent with our empirical findings. We focus on narratives that explain a wide range of types of conflict (e.g., peasant rebellions, interstate conflict, etc.) since our data cannot clearly distinguish between the different types of conflict. Here we discuss the key insights of the model, which is formally presented in the Appendix. We discuss

[9]We discuss this more in subsection 3.3.

alternative explanations after we present the empirical results in Section 6.

We begin with the basic setup from Nunn and Qian (2011), which illustrates how the introduction of potatoes (and the resulting productivity increase) leads to a reduction in the value of land. The key mechanism is as follows. Suppose that (*i*) the demand for food is sufficiently inelastic, and (*ii*) the production function for food is Cobb-Douglas.[10] A positive TFP shock in agriculture increases the output of food. From (*i*), we obtain that the price of food falls by more than output increases. Based on (*ii*), we obtain that the value of land is proportional to the market price of agricultural output. Since agricultural prices fall by more than the increases in agricultural product, this implies that the value of land declines. Obviously, the positive TFP shock increases real wages.

There are many ways to introduce conflict in our model. We present a parsimonious model with one agent (e.g., political ruler or a local civic leader) with the means to organize and mobilize violent action in an attempt to exert sole property rights over the land in question. Our modeling choice is motivated by the empirical analysis, which examines geographical cells rather than polities.

In this model, the agricultural productivity shock reduces conflict through two channels. First, it reduces conflict by reducing rents from land. We assume that conflicts occur to gain control of land, and the primary value of land comes from agriculture. Following the recent work of Acemoglu et al. (2012), which focuses on the incentives to arm, we assume that the cost of arming and the probability of winning a violent contest are both increasing and concave functions of resources allocated to armament. On that basis, lowering the value of land will obviously reduce the incentives to arm and the probability of winning a war. Thus it follows that lower land values will reduce the probability of violent conflict. Second, increases in real wages due to improvements in agricultural productivity raise the opportunity cost to arm. This can reduce conflict by making it more expensive for peasants to partake in conflict. It can also reduce conflict decided by rulers, who obtain revenues from taxing labor.

[10]Studies typically estimate the price elasticity of food demand to be between -0.80 and -0.20 (e.g., Tobin, 1950; Tolley et al., 1969; Van Driel et al., 1997).

Our model differs from other recent studies of conflict in not relying on the characteristics of country pairs, which as we discussed earlier, is not practical for an empirical analysis in the very long-run historical context. But the key insights are similar: conflict declines when the value of the object being fought over declines or when it becomes too costly to fight.

3.2 Other Potential Channels

Another possible channel through which potatoes could have reduced conflict in the short run is by loosening the Malthusian checks and balances. For example, increased productivity could have reduced the incidence of local rioting and peasant uprisings. Since the introduction of potatoes occurred when Malthusian links were weakening in most of Europe, this mechanism is consistent with the persistent effects of the introduction of potatoes. If Malthusian links are strong such that productivity gains are soon offset by fertility increases, then the benefit of potatoes will be temporary.[11]

Another way in which potatoes may have affected conflict is by providing a better supply of food to both soldiers and citizens during war. For example, Salaman (1949, pp. 573–574) and Reader (2008, p. 119) argue that potatoes provided a source of food for foraging soldiers during wartime. The 'Kartoffel Kreig' or the 'Potato War' of 1778–1779 is a salient example of how a greater availability of potatoes could have instigated and prolonged conflicts. Potato beds could have been dug up and eaten by soldiers on active duty in the battlefields. This may have helped to at least partially alleviate one of the primary obstacles during war: how to feed soldiers. Similarly, potatoes also provided food for citizens and populations that were displaced during war. In addition, they were also more difficult to expropriate (Scott, 2009). Thus, scholars such as McNeill (1999, pp. 71–72) and Scott (2009, pp. 187–207) have argued that potatoes may have decreased the destructive impact of warfare because potatoes, which grew beneath the ground, were more difficult for soldiers to appropriate than traditional staples such as wheat and rye which grew above the ground.

[11]See, for example, Galor and Weil (2000) for a model of the Malthusian regime and the transition process when Malthusian links weaken.

3.3 Empirical Strategy

Our analysis uses a cell-level panel. The main analysis uses $400km \times 400km$ cells that are observed every fifty years from 1401 until 1900 CE. Our strategy is similar in spirit to a *differences-in-differences* (DD) estimate, except that we have a continuous measure of suitability. The baseline equation is the following:

$$y_{it} = \alpha\, Potato_i \times I_t^{Post} + \mathbf{X}_{it}\mathbf{\Gamma} + \delta_i + \rho_t + \varepsilon_{it}. \tag{3.1}$$

The number of battles in cell i during time period t, y_{it}, is a function of: the interaction of suitability for potatoes, $Potato_i$, and an indicator variable that equals one for the years 1700 and afterwards, I_t^{Post}; a vector of controls, $\mathbf{X}_{it}$; cell fixed effects, δ_i; and time-period fixed effects, ρ_t. We cluster the standard errors at the 400km×400km grid-cell level.[12]

As in Nunn and Qian (2011), we use the agro-climatic suitability of a region for potato cultivation instead of actual potato cultivation as our main explanatory variable. This is done for two reasons. First, there is limited historical data on cultivation. Second, the level of cultivation is endogenous to a host of factors, including conflict itself (Reader, 2008, pp. 177-178). There are well known examples of rulers discovering the benefits of the potato because of conflict. For instance, Frederick the Great of Prussia learned the value of the potato during the war of the Austrian succession, 1740–1748. He observed how potatoes kept peasants alive, despite the ravages of invading armies (Gentilcore, 2012, p. 43).[13]

In equation (3.1), we compare conflict in cells that are suitable for cultivation to conflict in cells that are less suitable, before and after the introduction of potatoes. Cell fixed effects

[12]We discuss alternative strategies for addressing spatially correlated standard errors when we present our main results in the next section.

[13]To further understand our reduced form estimates, consider the hypothetical case where we had data on historical potato cultivation and we estimated the 2SLS effect of potato cultivation on conflict to obtain an elasticity of conflict with respect to potato production. The first-stage regression would be similar to equation (3.1), except that the dependent variable would be the level of potato cultivation. Since the 2SLS estimate is approximately the quotient of the reduced form estimate and the first stage, this means that the instrumented effect of potato cultivation on conflict will be smaller or larger than our estimated reduced form effect of the suitability for potato cultivation on conflict, depending on whether the first stage interaction coefficient is larger or smaller than one.

control for time-invariant differences across cells such as geography. Time-period fixed effects control for changes over time that affect all regions similarly, such as climate change or general improvements in military technology. If the introduction of potatoes reduced conflict, then $\hat{\alpha} < 0$.

In addition, the baseline estimates control for the suitability of existing staple crops in the Old World. This is important since the benefit of the new crops, potatoes, will greatly depend on the productivity of alternatives. Since suitability is highly correlated across crops, we control for the first principal component of suitability for the five main pre-existing staples (wheat, wet rice, dry rice, barley and rice), which accounts for approximately 60% of the variation in suitability.[14] To allow the effects to vary over time in a flexible way, we control for its interaction with time fixed effects.

The main concern about our identification strategy is that, conditional on the baseline controls, suitability for potato cultivation is correlated with factors that may also have reduced conflict over time. We address this in two ways. First, we directly control for the correlates of potato suitability that are most likely to also affect conflict, $\mathbf{X}_{it}$. We will document and discuss these in the next section.

Second, we will examine the timing of the impact of potatoes. If there is no pre-trend and the levels of conflict began to diverge between regions of varying suitability for potato cultivation around the time when potatoes first came to be cultivated in the regions of our study, then we will be less concerned about spurious correlations. We will also present numerous additional robustness checks after we present the main results.

[14] Appendix Table A.2 panel A shows the factor loadings for the components. The eigenvalue for the first component is over three, while it is slightly less than one for the second component. A standard rule-of-thumb is to control only for principal components that have eigenvalues of more than one. Later, we will show that our results are almost unchanged with other ways of measuring suitability.

4 Data

4.1 Conflict and Suitability for Potato Cultivation

Our conflict dataset is the union of two well-known sources of historical conflict. The first is Michael Clodfelter's (2008) *Warfare and Armed Conflicts*, which is a statistical encyclopedia of global conflicts from 1494 to 2007. The second is Peter Brecke's *Conflict Catalogue*. The Catalogue is an effort to extend the *Correlates of War* to include older historical conflicts. It is an annual record of all violent conflicts with 32 or more combat deaths, starting in 1400 CE.[15] Although the locations of conflicts were not reported explicitly in Brecke, we obtained the locations from other sources such as Shaw (1976), Levy (1983) and Findlay and O'Rourke (2007).[16] Over a period of six years, we manually geo-referenced and digitized the location of each conflict. This proved challenging because many of the conflicts had location names that matched multiple places during the time period of the conflict. In these cases, we researched the conflict in question to pinpoint the correct location.[17]

The geographic coverage ranges from approximately eight to 78 degrees latitude and from -61 to 96 degrees longitude. This includes North Africa, the Near East, Europe, Greenland and Iceland. The region of interest is divided into equal-area square grid cells. We use a sample that includes the years from 1401 to 1900. We exclude the 20th century because agriculture was economically less important and conflicts were unlikely to be driven

[15]For each conflict recorded in the catalog, the primary information covers (*i*) the number and identities of the parties involved in the conflict; (*ii*) the common name for the confrontation, if it exists; and (*iii*) the date(s) of the conflict. On the basis of these data, there also exists derivative information on the duration of conflicts and the number of fatalities, although these are only available for less than a third of the sample.

[16]For the Brecke data, where we had to consult additional sources, we collected up to four different locations for the primary battles fought in each war. For the Clodfelter data we use all locations reported. Our strategy dictates that for observations prior to 1494, we rely solely on Brecke. In Appendix Table A.1, we show that our results are robust to using only the Clodfelter data.

[17]A number of other sources of data on conflict are available. However, we felt that Clodfelter (2008) provides better details on battles, and their locations, than other references that primarily provide information on wars only (e.g., Kohn, 2007), and relative to other resources that include detailed information on battles (e.g., Eggenberger, 1985; Dupuy and Dupuy, 1993), it has a more extensive coverage of battles. Gennaioli and Voth (2015) use data from Jaques (2007) to analyze 374 battles in Europe between 1500 and 1800. In our view, the quality and detail of the information provided by Jaques (2007) and Clodfelter (2008) are similar, with Clodfelter being slightly more comprehensive. For example, for our geographic area of interest and our time period of interest (1400–1900), Clodfelter records 115 more battles than Jaques.

by agricultural productivity during that period. Our analysis excludes naval battles as well. This exclusion was made for practical purposes: it is difficult to interpret the effect of potato suitability on naval conflicts since the sea/ocean is unsuitable for cultivation. Conceptually, we would need to consider the relationship between the average suitability of the actors in the conflict and the occurrence of the naval conflict. As we discussed earlier, such an analysis is difficult in the historical context because the identities of political actors and the boundaries of polities changed significantly over time. In practice, this exclusion is unlikely to affect our analysis since there are very few naval battles in our sample.[18]

The raw data for this analysis contain 2,477 battles that belong to 899 wars. The main analysis will focus on all battles/conflicts. Later in the paper, we will separately examine interstate and intra-state conflicts. Figure 1 shows that the majority of conflicts took place within the modern borders of Austria, France, Germany, Italy, Poland, Russia, Spain and Turkey. Appendix Figure A.1, which reports conflict by decade, shows that conflicts moved from northwest to southeast over time, a pattern originally identified by Parker (1995).

The main outcome measure is the total number of *conflict incidents* in grid cell i during time period t. Our baseline specification uses 400km$\times$400km cells. Prior to settling on our baseline grid cell size, we undertake a series of tests to estimate the presence of potential spillover effects using different cell sizes (50km, 100km, 150km, and 200km cells). We find that 400km$\times$400km cells is the smallest size for which we do estimate spillover effects. The baseline conflict incidence results use 50-year time intervals.[19] When we discuss and present our results, the year will indicate the end of the interval. For example, 1450 includes battles during 1401-1450 and 1900 includes battles during 1851-1900.

We define conflict incidence as the sum of all of the conflict years in a cell and time period. The number of *conflict incidents* in our sample exceeds the number of *battles* in the raw data. This is because, if one battle spans two calendar years, it will count as two

[18]Naval battles comprise less than 6% of the full sample of battles.

[19]Our findings are similar when we use different intervals. We discuss grid cell sizes and time-period lengths more in the next section.

incidents. Consider that around 75% of the 2,477 battles lasted one year or less. Any battle that begins and ends within one calendar year will count as one incident.[20] The remainder of the roughly 25% of battles each lasted over one year. Each of these battles is counted for as many incidents as the number of calendar years that it spanned. We then add up all of the incidents in a 400km×400km cell over a 50-year period. For example, a battle that lasts from 1401-1410 in location A will contribute ten conflict incidents to the grid-cell which contains location A for the period 1401-1450. We count battles this way so that we capture not just the occurrence of a conflict but also the intensity (i.e., duration) of the conflict. This results in 4,916 conflicts in our baseline sample of 275 400km×400km grid-cells covering the period from 1400 to 1900.[21]

Figure 2 displays the geographic coverage of the 400km×400km grid cells. The figure shows that in places such as modern Italy, one such cell can span the entire width of the continental land. The grid cells are arbitrarily overlaid with the map and our results are not affected by shifting around the grid.[22]

Following Nunn and Qian (2011), we construct a measure of potato suitability using the *FAO*'s Global Agro-Ecological Zones (*GAEZ*) data base. We differ in using a more recent version than was available to Nunn and Qian (2011).[23] The data include information on 154 different crops and the physical environment of 2.2 million cells spanning the whole world, with each cell covering an area of 5 arc minutes by 5 arc minutes, or roughly 10km×10km. Using nine climate characteristics of each cell, such as frequency of wet days, precipitation, mean temperature, etc., the *FAO* calculated an estimate of the potential yield of each crop in each cell, given an assumed level of crop management and input use. With some additional data processing, the *FAO* then calculated the constraint-free crop yields and referenced the potential yield of each cell as a percent of this benchmark. The index ranges from 0 to 100.

[20]If there are two battles in the same location that began and ended within the same year, then we observe two conflict incidents.

[21]We have updated and expanded the sample since our earlier companion paper, Iyigun et al. (2017).

[22]These alternative results are available upon request.

[23]The results are robust to using the older dataset.

The suitability measures across the land area of interest are shown in Figure 3. In the map, more suitable locations are represented by a lighter shade. The most suitable locations in our sample are in Northern and Eastern Europe. However, there is significant local variation within regions due to differences in elevation and microclimates.

Since the 10km×10km *GAEZ* cells are finer than the cells used in our analysis, we measure suitability at the cell level as the average suitability measure of land within the cell. The potato suitability measure is an index ranging from 0 to 100. For presentation purposes, we converted this to a measure that ranges between zero and one (by dividing the index by 100). The mean value in our sample is 0.15. Other crop suitability measures used in our analysis come from the same source and are constructed in the same manner.

It is important for our study that the suitability measures we use proxy for historical conditions. The FAO GAEZ database has several features that make this possible. In calculating suitability, the FAO's agro-climatic model explicitly avoids taking into account factors that are easily manipulated by human intervention. For example, the fact that Europe has been significantly de-forested over time does not affect the suitability measure because the amount of forests does not factor into suitability. Instead, the model focuses on agricultural inputs that are difficult to manipulate such as climate and the average hours of sunshine in each season. Similarly, the GAEZ model allows us to choose inputs for factors such as mechanization and irrigation. We choose inputs to approximate for the level of technology available during our historical period of study, which is rain-fed and of low-input intensity.

5 Empirical Results

5.1 Baseline Estimates

Panel A of Table 1 presents the baseline estimates from equation (3.1). We present the results for all of the grid-cell sizes to be comprehensive, but focus on the 400km×400km cells that we use for the main analysis. Results in column (4) show that the introduction of potatoes reduced conflicts. The interaction coefficient is -11.31. It is statistically significant at the 1% level. To assess the magnitude, consider that the sample standard deviation of suitability measure is 0.156 and that the sample standard deviation of conflict incidence is 6.736. Thus, after the introduction of potatoes, a cell with one standard deviation higher suitability for potato cultivation experienced 1.76 fewer conflict incidents ($-11.31 \times 0.156 = -1.76$), which is 0.26 standard deviations of conflict ($-1.76/6.736 = -0.26$). This is a sizable, yet plausibly moderate magnitude. It shows that potatoes had a quantitatively important impact on reducing conflict in a context where we believe that there were many other drivers of changing patterns in conflict other than the introduction of potatoes.

5.2 Spatial Spillovers

To determine the correct grid-cell size, we have two main considerations. One the one hand, we would like the grid-cell to be small so that we have more granularity and variation in the data. On the other hand, we need the grid-cell to be large enough to capture spatial spillovers. Conflicts that a given group engages in do not always occur where the group produces food. For example, potatoes may increase agricultural productivity in a given 50km×50km grid, but the group which obtains food from that grid historically engages in conflict with a neighboring region 100 km away. To observe the influence of potatoes on conflict, we need to capture the spatial spillover across 50km×50km grids by making the unit of observation grid cells of approximately 150km×150km or larger. In practice, the correct size will vary by conflict. We can only aim to get the right size for the average battle.

To surmise the smallest grid-cell size that would allow us to capture the spillover effects, we re-estimate the baseline equation with the addition of the interaction of average potato suitability in the eight adjacent cells with the post-1700 indicator variable. The results are presented in panel B of Table 1. This exercise estimates the effect of introducing potatoes in one's own cell, as well as the introduction of potatoes in the adjacent cells. The latter can be interpreted as spillover effects – i.e., the effect of potatoes in adjacent cells on conflict in one's own cell. If a cell is large enough to capture local spillovers, then we should find that the own-grid-cell effect is statistically significant while the adjacent-grid-cell effect is (statistically) zero.

In columns (1) through (3), we use units of observation at the 50km $\times$ 50km, 100km $\times$ 100km and 200km $\times$ 200km grid cell levels. With the smallest 50km$\times$50km cells in column (1), neither interaction is significant. In column (2), when we use 100km$\times$100km cells, the own interaction is insignificant, while the adjacent interaction is twice as large in magnitude and significant at the 5% level. In column (3), when we use larger 200km$\times$200km cells, both estimates are imprecise, but the adjacent interaction is much larger in magnitude. These results show that the adjacent cell effects are similar or much larger than own-cell effects, which means that the three grid-cell sizes used so far are too small to capture spillover effects.[24]

In column (4), we use 400km$\times$400km cells. The own interaction is significant at the 5% level and the adjacent interaction is insignificant. Moreover, the own interaction is now three times as large in magnitude as the adjacent interaction. In other words, with the larger grid cells, we now capture the negative effect that the introduction of potatoes had on conflict in a grid cell, and find that the introduction in adjacent cells had statistically zero effect on conflict. In column (8), we expand to 800km$\times$800km cells. We find a similar pattern as with the 400km$\times$400km cells. The introduction of potatoes had a negative effect on conflict in the same grid cell, while the introduction in adjacent cells had no statistically significant effect. We conclude from this exercise that 400km$\times$400km cells are the smallest cells that allow us to capture spatial spillovers. Thus, we will use 400km$\times$400km cells for the rest of the analysis.

Later in the paper, we also show that our main results are not due to longer distance spatial spillovers – e.g., the relocation of conflict from Russia to Spain after potatoes are introduced to Russia – by excluding conflicts that are part of wars with distant actors and

[24]The magnitude of the interaction coefficients are not directly comparable across columns since the mean number of battles will be higher in larger grid cells.

by examining only conflicts which are part of intra-state wars.

5.3 Robustness

5.3.1 Different Time Periods

Table 2 investigates what happens with different time-periods: 50-years (baseline), 25-years and 100-years. The results are similar. The mean number of conflict incidents in a grid-cell-time-period observation doubles when the time-period increases from 25 to 50 years, and from 50 to 100 years. This causes the interaction coefficient to also roughly double.

5.3.2 Spatially Correlated Standard Errors

A final concern related to our geographic analysis is that the standard errors will be spatially correlated across 400km×400km cells. We address this concern by estimating Conley spatially correlated standard errors. They are presented in square brackets in Table 2 and are similar to the errors that are clustered at the 400km×400km grid-cell level, which means that the latter are not an artifact of spatial correlation.

5.3.3 Pre-trends and Timing

Next, we examine the timing of the effect of potato suitability on conflict. This is important for two reasons. First, to provide support for the parallel trends assumption, we would like to establish that there was no pre-trend. For example, if the difference in conflict between suitable and unsuitable areas was constant over time prior to the introduction of potatoes, we would be more likely to believe in the parallel trends assumption of the DD strategy – i.e., absent the introduction of potatoes, conflicts would have evolved along parallel trends between regions that are more or less suitable for potato cultivation. Second, we would like to see that the divergence began shortly after potatoes were first adopted as a staple crop on continental Europe in the late-seventeenth century. Given that potatoes were first cultivated as an important field crop in Europe around 1690, and it presumably took some time for the technology to gradually diffuse, we expect to see a trend-break around the early 1700s and that the reduction in conflict after the trend-break was gradual.

With these objectives in mind, we estimate the following equation:

$$y_{it} = \sum_{j=1500}^{1900} \beta_j (Potato_i \times I_t^j) + \mathbf{X}_{it}\mathbf{\Gamma} + \delta_i + \rho_t + \varepsilon_{it}, \tag{5.1}$$

where, as before, i indexes cells and t time periods. The incidence of conflicts in cell i during time period t, y_{it}, is a function ,of: the interaction of the suitability for potatoes, $Potato_i$, time-period fixed effects, ρ_t; grid-cell fixed effects, δ_i; and time-period fixed effects, ρ_t.

The estimated coefficients, $\hat{\beta}_j$'s, and their 90% confidence intervals are plotted in Figure 4. There is no trend prior to 1700. Recall that 1700 measures conflicts from 1651 to 1700. Areas that are suitable for potatoes and areas that are unsuitable are very similar prior to the introduction of potatoes (conditional on the baseline controls). These results support the parallel trends assumption. After 1700, the coefficients become gradually more negative.[25] Thus, the timing of the decrease in conflicts in places suitable for potato cultivation is consistent with our identification strategy. The confidence intervals, which reveal whether the point estimates are statistically different from zero, are not informative given that what one cares about is whether the interaction coefficients prior to 1700 are jointly different from those after 1700. This is what is established by our earlier baseline results.[26]

The estimates also show that our main differences-in-differences findings are not driven by any one time period. There is a persistent negative relationship between potato suitability and conflict in all time periods after 1700. This addresses the concern that our results are due to particular wars, which causes a spurious correlation in the DD estimates. Figure 4 shows that our results would be qualitatively similar with the exclusion of any particular time period.

[25] We note a slight uptick in the interaction coefficient for 1850. However, it is statistically similar to the other interaction coefficients for after 1700.

[26] The coefficients and standard errors for the flexible estimates are shown in Appendix Table A.3 column (1).

The analogous figure for alternative 800km×800km grid cells produce a similar pattern. There is no relationship between potato suitability and conflict prior to 1700. After 1700, as potato cultivation diffuses, the negative relationship between potato suitability and conflict emerges and become stronger over time. See column (2) of Appendix Table A.3 and Appendix Figure A.2.

5.3.4 The Correlates of Suitability for Potato Cultivation

Recall that the main concern with our empirical strategy is the possibility that the suitability for cultivating potatoes is correlated with factors that differentially affected the levels of conflict after 1700. To address this, we document the correlation of potato suitability and factors that could have reduced conflict after 1700. We examine variations using a cross-section of 400km×400km cells.

The first set of alternative factors that we consider is the suitability of grid-cells for the cultivation of other staple crops.[27] Table 3 presents pairwise correlation coefficients and their p-values. These show that suitability for potato cultivation is significantly associated with suitability for the cultivation of all of the other major staples except for dry rice and cassava. A grid-cell's suitability for the cultivation of potatoes is positively associated with its suitability for the cultivation of other staples that existed in the Old World prior to the introduction of potatoes, such as wet rice, wheat, barley and rye. The latter two crops, barley and rye, were particularly important in colder climates where wheat could not be cultivated. Suitability for potatoes is also positively associated with suitability for other staple crops that were introduced from the Americas: sweet potato, maize and cassava.[28]

[27]Suitability for the other staple crops is calculated the same way using the FAO's GAEZ model as for potatoes.

[28]In addition to addressing the omitted variable bias discussed earlier, controlling for the suitability for the cultivation of Old World staple crops is important because the increase in productivity due to the introduction of potatoes may differ depending on how productive a region was in cultivating pre-existing crops. This is why we already controlled for the suitability for cultivating Old World crops in our baseline specification. In contrast, the suitability for the cultivation of sweet potatoes and cassava are not important controls in practice since they never became important staples in our context. To be comprehensive, however, we will later include them as controls.

We next examine the correlation between potato suitability and other geographic characteristics that could affect conflict differentially over time. The first geographic characteristics we examine are elevation and ruggedness, since changes in military technology may have changed the cost of fighting in uneven terrain and mountainous regions. The data show that rugged and high elevation grid-cells tend to be less suitable for the cultivation of potatoes. Thus, one may be concerned that the introduction of potatoes may have been associated with changes in military technology – e.g., the introduction of a fast-moving professional army – that were more advantageous in flatter terrain.

The second geographic characteristic that we examine is distance to international trade, which may have altered the desirability of a location over time as trade became a more important source of revenue, or alternatively, as it waned in importance. We find that places that are further from international trade, proxied by (straight-line) distance to the coast, happen to also be more suitable for potato cultivation on average. The third geographic characteristic that we examine is (straight-line) distance to the nearest major river. Rivers, in addition to being important for trade, tended to also be the locations of early industrialization. We find that grid cells with rivers are more suitable for potato cultivation. This raises the concern that the introduction of potatoes benefitted areas that industrialized earlier.

The fourth set of geographic characteristics that we examine is a cell's cardinal location, measured using latitude and longitude. For each cell, these variables are measured based on the center of the grid cell. We find that more northern latitudes and more eastern longitudes are associated with greater suitability for potato cultivation. This reflects the fact that some of the most suitable regions shown in Figure 3 are in northeastern Europe. Thus, it will be important to control for the interaction of these variables with time fixed effects to address the possibility that there may have been geographic shifts in the patterns of conflict for geo-political reasons that are independent of the introduction of potatoes.

Finally, we investigate the correlation between potato suitability and political and economic characteristics during the base period, 1401-1450. We find that areas suitable for cultivating potatoes were typically further away from urban areas and experienced more conflict during this period. Thus, if the occurrence of conflicts increased in inland regions relative to coastal regions, or if conflict increased more in places with higher levels of historical conflicts, then our baseline will be confounded. We also find that there were more conflicts in the baseline period in areas suitable for cultivating potatoes. This raises the concern that our main results may partly be driven by mean reversion or other factors that would have caused conflicts to evolve differentially depending on the base level.

In summary, the correlations examined in this section show that the suitability for potato cultivation is correlated with several variables that could potentially affect conflicts over time. Although the effects of many of these correlates on conflict are ambiguous *ex ante*, it is important for us to examine whether our main results are robust to controlling for these additional influences. To be as rigorous as possible, we will allow the influence of the characteristics to be as general as possible by flexibly interacting each with time period fixed effects.

Controlling for the Suitability for Other Staple Crops The baseline controls for the first principal component of pre-existing Old World Crops. In column (2) of Table 4, we show that our estimates are robust to also controlling for the second component.[29] In column (3) of Table 4, we control for the first principal component of Old World Crops and the first component of the three other staple crops that were introduced from the Americas: maize, cassava and sweet potato. Column (4) measures suitability to Old World Crops as the average across crops instead of using Principal Components. The interaction effect is similar to the baseline. In column (5), we follow Nunn and Qian (2011) and control for the average suitability of the three Old World staple crops of wheat, dry rice and wet rice. The estimate is similar to the baseline. These results show that our results are robust to alternative measures of suitability for Old World and New World staples.

[29] Panel A of Appendix Table A.2 reports the factor loadings of the principal components.

Controlling for Geographic Characteristics Estimates accounting for these additional factors are reported in Table 5. Column (1) restates the baseline estimate for comparison. We then gradually introduce additional controls for geographic characteristics to illustrate their influence. In column (2), we add controls for ruggedness and elevation. In column (3), we introduce latitude, longitude, as well as latitude $\times$ longitude. In column (4), we control for an indicator variable for the presence of a navigable river, the distance to the nearest ice-free coastline, and the average distance to the nearest urban area during 1401-1450. In column (5), we control for the number of battles during 1401-1450. We interact each control with time fixed effects to allow conflict levels to evolve differentially over time according to each measure in a way that is flexible over time. In column (6), we control for the lagged dependent variable. Our main results are almost identical. We do not control for the lagged dependent variable in the baseline because of potential concerns of the Nickell bias (Nickell, 1981).

The main interaction coefficient remains robust and changes very slightly with the addition of the different sets of controls. The impact of potatoes on conflict is always negative, statistically significant, and quantitatively similar to the baseline estimate.

Omitting Large Wars Our analysis is at the battle level. However, there are some large wars which contain numerous battles. This raises the concern that our results are spuriously driven by one very large war. To address this, we alternatively omit individual wars and find that the results are very similar with the omission of any given war. The smallest wars in our sample have one battle, while the largest war has 72 battles. Several of the wars that historians categorize as independent wars are part of the larger "Napoleonic Wars" (209 conflicts in all). Appendix Table A.4 shows the results for when we alternatively omit each of the 25 largest wars, as well as when we exclude all battles that are part of Napoleonic Wars. The interaction effect is always negative, statistically significant and statistically similar to the baseline.

6 Additional Results

6.1 Onset vs. Duration

Thus far, we have focused on the number of conflict incidents as the outcome variable. As we discussed earlier, our measure of incidence takes into account both the onset and the duration of a conflict. In this section, we conduct a complementary analysis by examining whether our main results are driven by effects on the extensive margin (potatoes reduced the probability of any conflict) or the intensive margin (potatoes reduced the number of conflicts conditional on there being at least one). Our data allow us to investigate this question in two ways.

First, we consider whether agricultural productivity reduced the start of new wars (conflict onset) or if it made wars shorter by increasing the likelihood of conflict offset conditional on a war occurring. For this analysis, we exploit the granularity of our data to construct an annual panel and estimate a hazard model. In the hazard models, the event of interest is either the onset of conflict during an episode of peace or the offset of conflict during an episode of war. Let t index years, i index periods of peace (or conflict) and $T_i \geq 0$ denote the duration, in years, of the episode of interest. The sample includes all grid-cells and years that are "at risk" for transition into conflict or peace, e.g., for the onset regressions, all of the observations for which there was no conflict in the previous period. The estimation uses the discrete hazard $h_{it} = \Pr(T_i = t \mid T_i \geq t)$, where it is assumed that h_{it} follows a logistic distribution. Our regressions control for a third-order polynomial in the duration of the peace or conflict episode up until year $t-1$. It also includes our interaction of interest, potato suitability interacted with the post-adoption indicator variable, as well as the following additional controls: the first principal component of Old World staple crops, the post-adoption indicator variable, and the interaction between the first principal component of Old World crops and the post-adoption indicator variable.

For the analysis of onset and duration, it becomes particularly important that we measure wars and battles precisely. Wars will appear to continue in our data if a war ends, but another war begins within the same grid cell. This false-continuation is more likely with larger grid cell. For our onset and duration estimates, we use grid-cells that are at a finer level than 400km×400km and check the robustness of our findings to the use of grid cells of different sizes. Thus, we report estimates where the analysis is at the 50km, 100km, and 200km grid cell levels.

The estimates are reported in Table 6. The coefficients report marginal effects evaluated at means. Our estimates provide suggestive evidence that the agricultural productivity increase from the introduction of potatoes reduced the onset of conflict. The coefficients from columns (1) to (3) are negative and statistically significant. By contrast, the interaction coefficients from the offset regressions, reported in in columns (4) to (6), are insignificant. The interaction coefficients are negative, large in magnitude, and very imprecisely estimated. The lack of precision may be due to the much smaller sample size. Thus, the evidence indicates that the introduction of potatoes decreased the probability of conflict onset, but it did not reduce the probability of conflict offset and the duration of conflicts once they start.

6.2 Long-Range Conflicts

Earlier, we showed that the main results capture spatial spillovers within 400km×400km grid cells. One may still be concerned that there are longer distance "global" spatial spillovers. For example, what if the introduction of potatoes in Russia caused Russia to relocate its conflicts to southern Spain? Then, our differences-in-differences strategy will show that potatoes reduced conflict, but will partly be driven by long-range relocation effects. This is unlikely to drive our results because there are very few conflicts in our sample where the involved parties were very distant. Table 7 shows that the results are statistically similar when we exclude conflicts where the two nearest actors were more than 1200 kilometers apart (column 2) or more than 800 kilometers apart (column 3).

These results show that our main finding that the introduction of potatoes reduced conflict is not driven by the introduction of potatoes causing a party to relocate their belligerence to distant locations. In the next section, we will provide additional evidence on this point by examining conflicts that are part of intra-state wars.

6.3 Heterogeneous Effects

6.3.1 Types and Sizes of Wars

In our data, we are able to identify whether a battle was part of a war that involves more than one sovereignty (i.e., an inter-state war) or not (i.e., an intra-state war). With this information, we examine whether the introduction of the potato had different effects on the different types of battles. Columns (1) and (2) of Table 8 report estimates of equation (3.1) with either the number of conflicts belonging to inter-state wars as the dependent variable or the number of conflicts belonging to intra-state wars as the dependent variable, respectively. The means at the top of the table show that unlike modern contexts, there were many more inter-state than intra-state conflicts in our sample. The estimates show that the introduction of potatoes reduced the number of conflicts for both types of wars. The coefficient is larger in magnitude and more precisely estimated for intra-state wars. To compare the magnitudes of the coefficients, we also estimate the normalized coefficients in units of standard deviations. These are presented in square brackets in the table. The normalized interaction coefficient is -0.08 for conflicts that are part of inter-state wars and -0.22 for conflicts that are part of intra-state conflicts. This suggests that the introduction of potatoes had a larger effect in reducing intra-state, i.e., civil, conflicts.

The finding that potatoes had, if anything, a larger and more precisely estimated impact on intrastate wars is important for interpreting our results since it goes against the concern that our results are driven by the long-distance relocation effects discussed in the previous section.

6.3.2 Sizes of Wars

In columns (3) to (5) of Table 8, we categorize battles according to the size of the war to which they belonged. Using information on the number of battles fought in each war, we categorized wars into three equally sized groups: small, medium and large. The interaction coefficients are all negative, similar in magnitude and imprecise when we divide the conflicts this way.

6.3.3 Political Fractionalization

We next turn to an examination of heterogeneity depending on pre-existing political fragmentation. Given the endogeneity of state boundaries with respect to conflict, we measure political fragmentation as whether there was a political boundary in a given grid-cell in any year during the base period, 1401-1450.[30] A comparison of the dependent variable means at the top of the table shows that, perhaps unsurprisingly, conflicts were more likely to occur in cells that contained a border in the baseline period. This is consistent with the fact that many conflicts were border disputes over territory. We re-estimate equation (3.1) with each sub-sample. The estimates are reported in columns (6) and (7) of Table 8. The estimates show that the introduction of potatoes reduced the number of battles in both types of cells. The interaction coefficients are negative and statistically significant in both cases. The magnitudes of the standardized coefficients are similar.

6.4 Coastal Regions and Cities

Finally, for interest, we examine whether the introduction of potatoes reduced conflict similarly for coast regions (versus interior regions) and for urban areas (versus areas that were not urbanized). Ex ante, the predicted differences are ambiguous in both cases.

First, consider access to a coastline. On the one hand, coastal areas have access to trade and rely less on agriculture, which suggests that changes in agricultural productivity should

[30] We digitized boundaries for every ten years from historical maps provided by euratlas.com.

have a smaller effect on conflict in such regions. On the other hand, our unit of observations are geographically large. This means that the benefits of increased agricultural productivity in the region may be magnified by trade within the cell, which suggests that changes in agricultural productivity could have a larger effect on conflict in such regions.

Lacking systematic historical data on trade volumes, we proxy for the importance of trade with access to an ice-free coastline. Coastlines were particularly relevant for many northern European countries that were suitable for potato production, such as the Baltic countries. We measure access as an indicator variable that equals one if there is a coastline within the 400km×400km grid cell. We allow for heterogeneous effects by including the triple interaction of potato suitability, the post-adoption indicator variable, and our measure of access to international trade in equation (3.1). The augmented specification also controls for all of the baseline variables in equation (3.1), as well as the interaction of the trade-access variable and the time fixed effects.[31]

The estimates reported in columns (1) of Table 9 show that the main interaction term is large, negative and statistically significant. The triple interaction with the inland indicator is smaller in magnitude, positive and statistically significant. This means that the introduction of potatoes greatly reduced conflict in cells which contain a coastline, and the effect is mitigated for cells that do not contain a coast line. The sum of the double and triple interaction coefficients shown at the bottom of the table yields the effect of the average introduction of potatoes for cells that do not contain a coast line. It is negative and statistically significant, though smaller in magnitude than the double interaction effect at the top of the table. Thus, the introduction of potatoes reduced conflict everywhere, but the reduction was larger in regions with access to trade.

Second, consider urbanization. Again, the predicted effects are ambiguous ex-ante. On the one hand, urban areas are less involved in agricultural production, which suggests that a change in agricultural productivity may affect conflict in cells with cities less. On the other

[31]The interaction of the trade-access variable and potato suitability is time-invariant and absorbed by the grid-cell fixed effects.

hand, urban areas in our historical context mostly relied on locally/regionally produced food, and in times of famines, farmers will reserve food for themselves before selling it to cities – i.e., urban populations could be more likely to experience food deprivation and increased prices during bad harvests.[32] This means that an increase in regional agricultural productivity may have larger effects in reducing conflict in cells with cities.

We measure urbanization using an indicator variable that equals one if there was a city (with more than 40,000 inhabitants) in the cell. We only look at cities in 1401 to avoid endogeneity.[33] As with distance from the coast, we estimate the triple interaction effects while controlling for all of the double interactions. Column (2) shows that the introduction of potatoes reduced conflict everywhere. However, the reduction was larger in magnitude for cells that contained a city in 1401.

6.5 An Alternative Mechanism – Insurance Against Cold Winters

The results thus far are consistent with agricultural productivity having reduced conflict. However, they do not preclude the role of other mechanisms which may have been at play. Here, we discuss two that were likely to have mattered in the historical context.

First, we turn to the possibility that the introduction of potatoes may have improved peasants' ability to smooth consumption during adverse shocks by diversifying cultivation. For China, Jia (2014) finds that the cultivation of sweet potatoes – another crop that was introduced from the Americas to the Old World – allowed peasants to better survive droughts due to the fact that sweet potatoes are drought resistant. She shows that this, in turn, resulted in a reduction in peasant revolts during periods of drought. Along similar lines, potatoes are known to be particularly hardy through cold winters. Thus, in the European setting, it is natural to ask whether the introduction of potatoes reduced the incidence of

[32]See, for example, O Grada (2007) and Meng et al. (2015), for a discussion of historical famines.

[33]Data on the populations of cities is most complete from Chandler (1987). We therefore use the city measures from Chandler (1987), supplemented by Bairoch (1988) and Modelski (2003) if a city's population is missing from Chandler (1987) but exists in either of the other sources. Nunn and Qian (2011) showed that the introduction of potatoes increased urbanization.

conflict, especially during cold-weather shocks.

We investigate this possibility by using data on historical seasonal (winter, spring, summer and autumn) temperatures reported by Luterbacher et al. (2004).[34] These data are at the annual and 0.5×0.5 degree levels for the years 1500 to 1900 and cover a geographic subsample of our main sample.[35]

We consider three measures of cold weather shocks based on the following: We construct cold-weather indicator variables that vary at the grid-cell and year levels. The variables equal one if the winter temperature in that grid-cell and year was below a percentile threshold of the winter temperature in the same grid-cell over the period spanning 1500 to 1900. Next, we construct our three different measures using the 5th, 10th and 20th percentile thresholds. Having constructed our measure of cold-weather shocks, we then test whether the impact of potatoes on conflict was greater in grid-cells and years with cold winters. In practice, we do this by first estimating a version of equation (3.1) where the time period is a year. Given the persistence of conflicts over time in the annual panel, we also include a one-year lag of the dependent variable. Given that we are using an annual panel, the Nickell (1981) bias is very unlikely to be a problem. We then test for the heterogeneous effect of interest by embedding into equation (3.1) a triple interaction of potato suitability, a post-adoption indicator and a cold-winter indicator variable. We also include the relevant double interactions.

The effect that cold temperatures during winters might have on conflict is ambiguous. On the one hand, it could have resulted in an agricultural productivity decline which, in turn, could have encouraged peasant rebellions. This could have been due to the lack of food having been viewed as a failure of government policy, or because peasants in search of

[34]Another historical climate data source used in empirical studies today, such as our companion study (Iyigun et al., 2017), is the dataset constructed by Mann et al. (2009). These data have larger geographic coverage, but less precision both spatially and temporally. Thus, while Mann et al. (2009) is better suited for examining longer-run climate change, which is the focus of (Iyigun et al., 2017), Luterbacher et al. (2004) is better suited for examining shorter-run weather shocks, which is the object of interest here.

[35]See Appendix Figure A.3 for a map showing the coverage and size of grid-cells of the original data. The climate data are constructed using instrumental readings (when available), geological climate proxies (e.g., soil sediment, tree rings, ice cores, etc.) as well as documentary evidence. See the data appendix provided by Luterbacher et al. (2004) for a detailed discussion.

food might have migrated and caused conflicts with the local population of the new region, or because the opportunity cost of arming may have declined with agricultural productivity. On the other hand, cold winter temperatures could have made it physically more difficult to engage in conflict. Thus, the coefficient for winter temperatures would capture the net of these opposing forces.

The results are reported in Table 10. In columns (1) to (3), we first report estimates of equation (3.1) using the annual panel, including the cold-winter-shock indicator variables as controls. Column (1) uses the 5th, column (2) the 10th, and column (3) the 20th percentile thresholds. The coefficient on a very cold shock (winter temperatures below the 5th percentile of the grid cell) has a negative and significant coefficient – i.e., cold shocks result in fewer conflicts. However, the coefficients for the less extreme shocks in columns (2) and (3) are statistically zero.

In columns (4) through (6), we report estimates that include the triple interaction of suitability for potato cultivation, an indicator variable for post-adoption, and an indicator for winters that were very cold. If our main finding reflects the role of potatoes as an insurance mechanism, then the double interaction of suitability for potato cultivation and an indicator variable for post-adoption should be close to zero, since this coefficient captures the effects of the introduction of potatoes in years without a cold shock.

We find that the double interaction of the suitability for the cultivation of potatoes and the post-adoption indicator variable is always statistically significant and similar in magnitude to those in columns (1) to (3). This means that the introduction of potatoes reduced conflict even during years with good weather and the magnitude of this reduction is very similar to the baseline average estimated reduction. The triple interaction estimates are all statistically zero. Thus, we find no evidence that our results are driven by better insurance against cold winters.

7 Conclusion

This paper provides evidence of the long-run relationship between a permanent increase in agricultural productivity and conflict. To do so, we overcome several challenges. First, we construct a new comprehensive dataset which digitizes the name, date and location of battles, as well as the participants (at the war level). Second, we exploit variations in agricultural productivity caused by the introduction of potatoes to establish causal relationships. Third, we conduct our analysis at the grid-cell level to address the difficulty caused by changing political boundaries over time.

The results show that the introduction of potatoes led to a significant reduction in the incidence of conflict. The effect is particularly prominent for civil conflicts. To help interpret the results, we use a simple model to show that they are consistent with the introduction of potatoes increasing agricultural productivity which, in turn, reduced conflict through a number of possible channels, such as reducing the value of land, increasing the opportunity cost of arming and loosening Malthusian links. We are open to other interpretations. At the same time, our empirical results show that potatoes had similar effects during very cold and normal winters. Thus, it is unlikely that our main results are due to potatoes providing insurance through cold winters.

Our findings show that understanding the long-run effects of a permanent change in agricultural productivity and/or the determinants of a persistent change in conflict are important and feasible avenues of future empirical study. Specifically, our results naturally beg the question of what other outcomes are affected by a permanent increase in agricultural productivity. For example, Friedman (1977) argues that the consolidation of states in Europe in the 18th century was largely due to a rise in productivity. Another question that naturally follows from this study is whether a permanent decline in productivity increases conflict. We address this in our companion study, Iyigun et al. (2017), which shows that persistent cooling increased conflict in the historical context. However, this is only a small first step in understanding the long-run process of the co-evolution of economic growth and conflict. To this end, we hope that the conflict database that we have constructed will allow researchers to make more progress by conducting in-depth and rigorous quantitative analyses.

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Table 1: The Effect of the Introduction of Potatoes on Conflict for Varying Grid Sizes, Spatial Spillover Effects

	Dependent Variable: Number of Conflicts				
	Grids that are too small to capture spillover effects				
	(1)	(2)	(3)	(4)	(5)
Grid Cell Size:	50km × 50km	100km × 100km	200km × 200km	400km × 400km	800km × 800km
	A. Baseline Specification				
Dependent Variable Mean	**0.0366**	**0.138**	**0.509**	**1.788**	**5.586**
Potato Suitability x Post	-0.105	-0.448	-2.035	-11.31	-64.91
	(0.0708)	(0.252)	(1.079)	(4.674)	(24.71)
Observations	133980	35560	9660	2750	880
R-squared	0.164	0.194	0.302	0.484	0.595
# Clusters	13398	3556	966	275	88
	B. Control for Neighbor Suitability x Post				
Potato Suitability x Post	0.0826	0.461	-0.329	-9.037	-67.48
	(0.140)	(0.469)	(1.685)	(5.817)	(24.52)
Potato Suitability in Neighboring Cells x Post	-0.214	-1.034	-2.078	-3.124	-15.45
	(0.144)	(0.515)	(1.532)	(5.005)	(9.200)
Observations	133950	35550	9660	2750	870
R-squared	0.164	0.194	0.302	0.485	0.596
# Clusters	13395	3555	966	275	87

Notes: The table reports regressions where an observations is a 50-year time period and a grid cell. The sizes of the grid cells are in the column headings. All regressions control for the full set of baseline controls: grid-cell FE, year FE, and year FE x the first principal component of suitability for Old World Crops (wheat, wet rice, dry rice, barley and rye). Standard errors are clustered at the grid-cell level.

Table 2: The Effect of the Introduction of Potatoes on Conflict – Various Time Intervals, Spatially Correlated Standard Errors

	Dependent Variable: Number of Conflicts		
	(1)	(2)	(3)
Time period:	50-years	25-years	100-years
Dependent Variable Mean	**1.788**	**0.894**	**3.575**
Potato Suitability x Post	-11.31	-5.653	-22.61
	(4.674)	(2.275)	(9.916)
Conley SE	[4.13]	[2.54]	[10.01]
Observations	2750	5500	1375
R-squared	0.484	0.333	0.661
# Clusters	275	275	275

Notes: Grid cells are 400km × 400km and the lengths of the time periods are reported in the panel headings. All regressions control for the full set of baseline controls: grid-cell FE, year FE, and year FE x the first principal component of suitability for Old World Crops (wheat, wet rice, dry rice, barley and rye). Standard errors in parentheses are clustered at the grid-cell level. Conley standard errors are shown in brackets.

Table 3: The Correlates of Suitability for Potato Cultivation

Correlation with Suitability for Potato Cultivation		
	Correlation Coef.	p-value
Suitability for the cultivation of		
Dry Rice	-0.0735	0.2244
Wet Rice	0.1853	0.002
Wheat	0.958	0.000
Barley	0.939	0.000
Rye	0.9414	0.000
Sweet Potato	0.1833	0.0023
Maize	0.6936	0.000
Cassava	0.0184	0.7608
Geographic Characteristics		
Ruggedness	-0.0706	0.2431
Elevation	-0.1921	0.0014
Distance to Nearest Ice-Free Coast	0.2007	0.0008
Indicator for Presence of Navigable River	0.6205	0.000
Latitude	0.2898	0.000
Longitude	0.1692	0.0049
Base-Period Characteristics		
Distance to Nearest City in 1401-1450	-0.2936	0.000
Number of Conflicts in 1401-1450	0.2276	0.0001

Notes: The table reports the correlation coefficients of the stated variables and suitability for potato cultivation. The sample is a cross-section of 400km × 400km grid cells. There are 275 observations.

Table 4: The Effect of Potatoes on Conflict – Robustness to Controlling for the Suitability for Other Staple Crops

	Dependent Variable: Number of Conflicts				
	(1)	(2)	(3)	(4)	(5)
	Baseline				Nunn-Qian (2011)
Potato x Post	-11.31	-11.34	-8.068	-10.02	-9.387
	(4.674)	(4.718)	(4.866)	(4.479)	(4.657)
Controls: Time FE ×					
Suitability of Old World Crops (1st Prin Comp)	Y	Y	Y	N	N
Suitability of Old World Crops (2nd Prin Comp)	N	Y	N	N	N
Suitability of New World Crops (1st Prin Comp)	N	Y	Y	N	N
Old World Avg Suitability	N	N	N	Y	N
Old World (3 crops) Avg Suitability	N	N	N	N	Y
Observations	2750	2750	2750	2750	2750
R-squared	0.484	0.484	0.489	0.483	0.483
# Clusters	275	275	275	275	275

Notes: The sample is a balanced panel for 1401-1900. The observations are at the 50-year and 400km × 400km grid-cell level. All regressions control for grid-cell FE and year FE. The standard errors are clustered at the cell level.

Table 5: The Effect of Potatoes on Conflict – Robustness to Controlling for Geographical Characteristics and the Lagged Dependent Variable

	Dependent Variable: Number of Conflicts					
	(1) Baseline	(2)	(3)	(4)	(5)	(6)
Potato Suitability x Post	-11.31	-10.78	-12.00	-12.95	-12.93	-12.58
	(4.674)	(4.457)	(4.811)	(5.59)	(4.093)	(4.685)
Number of Conflicts$_{t-50}$						0.00277
						(0.0721)
Controls:						
Time FE, Grid-Cell FE	Y	Y	Y	Y	Y	Y
Time FE ×						
Ruggedness, Elevation	N	Y	N	N	N	N
Latitude, Longitude, Latitude x Longitude	N	N	Y	N	N	N
River, Coast, and Urbanization	N	N	N	Y	N	N
Number of Battles in 1401-1450	N	N	N	N	Y	N
Observations	2750	2750	2750	2750	2750	2475
R-squared	0.484	0.490	0.489	0.492	0.581	0.487
# Clusters	275	275	275	275	275	275

Notes: The sample is a balanced panel for 1401-1900. The observations are at the 50-year and 400km × 400km grid-cell level. All regressions control for the full set of baseline controls: grid-cell FE, year FE, and year FE x the first principal component of suitability for Old World Crops (wheat, wet rice, dry rice, barley and rye). The standard errors are clustered at the grid-cell level.

Table 6: The Effect of Potatoes on Conflict Onset and Duration

	Hazard Models. Dependent Variable:					
	Conflict Onset			Conflict Offset		
	(1)	(2)	(3)	(4)	(5)	(6)
	50km × 50km	100km × 100km	200km × 200km	50km × 50km	100km × 100km	200km × 200km
Dependent Variable Mean	**0.000325**	**0.00112**	**0.00352**	**0.279**	**0.287**	**0.325**
Potato Suitability x Post	-0.000261	-0.000960	-0.00266	-0.337	-0.507	-0.190
	(0.000109)	(0.000378)	(0.00104)	(0.374)	(0.452)	(0.543)
Duration (third order polynomial)	Y	Y	Y	Y	Y	Y
Baseline controls	Y	Y	Y	Y	Y	Y
Observations	6,796,917	2,193,091	479,840	2,522	2,467	2,447
# Clusters	976	976	976	198	199	203

Notes: The table estimates of hazard models, where the unit of observation is a 50km × 50km, 100km × 100km and 200km × 200km grid-cell and a calendar year. Columns (1)-(3) report estimates form a hazard model that estimates conflict onset. Columns (4)-(6) report estimates from a hazard model that estimates conflict offset. The reported coefficients are marginal effects evaluated at the means from a logit regression. These estimates control for: a third-order polynomial of duration (either conflict or peace), the first principal component of suitability for Old World Crops (wheat, wet rice, dry rice, barley and rye), a post-potato-adoption indicator varable, and the interaction of the Old World Crop first principal component and the post-adoption indicator variable. All standard errors are clustered at the 200km × 200km grid-cell level.

Table 7: The Effect of the Introduction of Potatoes on Conflict – Excluding Conflicts (from Wars) with Distant Actors

Dependent Variable: Number of Conflicts			
		Exclude conflicts (wars) if nearest two actors are > X km apart	
	(1)	(2)	(3)
	All Conflicts	X=1200km	X=800km
Dependent Variable Mean	**1.788**	**1.522**	**1.331**
Potato Suitability x Post	-11.31	-10.54	-7.916
	(4.674)	(4.158)	(3.422)
Observations	2750	2690	2690
R-squared	0.484	0.497	0.490
# Clusters	275	275	275

Notes: The sample is a balanced panel for 1401-1900. The observations are at the 50-year and 400km × 400km grid-cell level. All regressions control for the full set of baseline controls: grid-cell FE, year FE, and year FE x the first principal component of suitability for Old World Crops (wheat, wet rice, dry rice, barley and rye). The standard errors are clustered at the grid-cell level. The column headings state the sample restrictions.

Table 8: The Effect of Potatoes on Conflict – According to the Type and Size of Wars, Political Fractionalization

	Dependent Variable: Number of Conflicts						
	War Actors		War Size (by Number of Battles)			Border in Cell, 1401-1450	
	Interstate	Intrastate	Small	Medium	Large	None	Border
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dependent Var. Mean	**1.115**	**0.544**	**0.553**	**0.790**	**0.315**	**0.174**	**3.445**
Potato Suitability x Post	-3.033	-4.982	-2.353	-2.955	-2.708	-3.327	-14.19
	(3.035)	(1.932)	(2.511)	(3.345)	(2.492)	(1.651)	(5.902)
Standardized Coef.	[-0.0795]	[-0.217]	[-0.0851]	[-0.0976]	[-0.161]	[-0.236]	[-0.209]
Observations	2750	2750	2750	2750	2750	1250	1500
R-squared	0.494	0.303	0.280	0.317	0.376	0.186	0.463
# Clusters	275	275	275	275	275	125	150

Notes: The sample is a balanced panel for 1401-1900. The observations are at the 50-year and 400km × 400km grid-cell level. All regressions control for the full set of baseline controls: grid-cell FE, year FE, and year FE x the first principal component of suitability for Old World Crops (wheat, wet rice, dry rice, barley and rye). The standard errors are clustered at the grid-cell level. The column headings state the sample restrictions.

Table 9: The Effect of Potatoes on Conflict – Heterogeneous effects for coastal and urban areas

Dependent Variable: Number of Conflicts		
	(1)	(2)
Potato Suitability x Post	-29.60	-20.42
	(9.124)	(7.183)
Potato Suitability x Post		
x Inland Dummy	13.13	
	(5.299)	
x Rural Dummy		11.87
		(4.440)
Observations	2750	2750
R-squared	0.491	0.494
# Clusters	275	275
Sum of double and triple interactions	-16.47	-8.55
Std. Error	(5.23)	(4.29)

Notes: The sample is a balanced panel for 1401-1900. The observations are at the 50-year and 400km × 400km grid-cell level. All regressions control for the relevant double interaction terms, the full set of baseline controls: grid-cell FE, year FE, and year FE x the first principal component of suitability for Old World Crops (wheat, wet rice, dry rice, barley and rye). Standard errors are clustered at the grid-cell level.

Table 10: The Effect of Potatoes on Conflict – Interaction with Annual Weather Shocks

	Dependent Variable: Number of Conflicts					
	(1)	(2)	(3)	(4)	(5)	(6)
	< 5th Percentile	< 10th Percentile	< 20th Percentile	< 5th Percentile	< 10th Percentile	< 20th Percentile
Potato Suitability x Post	-0.202	-0.201	-0.199	-0.202	-0.2	-0.189
	(0.0795)	(0.0791)	(0.0792)	(0.0793)	(0.0804)	(0.0809)
Cold Shock	-0.023	-0.00459	0.00329	0.0248	0.0211	-0.000414
	(0.0111)	(0.00880)	(0.00548)	(0.0194)	(0.0157)	(0.0111)
Potato x Post x Cold Shock				-0.0271	-0.0277	-0.0631
				(0.144)	(0.123)	(0.0781)
One-Year Lag of Number of Conflicts	0.458	0.458	0.458	0.458	0.458	0.458
	(0.0289)	(0.0289)	(0.0289)	(0.0289)	(0.0289)	(0.0289)
Observations	39200	39200	39200	39200	39200	39200
R-squared	0.271	0.271	0.271	0.271	0.271	0.271

Notes: An observation is a year and a 400km × 400km grid-cell. The sample is a balanced panel. The shocks used in columns (1) and (4) are defined as indicator variables that take the value of one if annual temperatures in grid cell i and year t are lower than the 5th percentile of temperature during the entire sample period for the grid cell. In columns (2) and (5), shocks are constructed using the 10th percentile, while in columns (3) and (6), they are constructed using the 20th percentile. All regressions control for the full set of baseline controls: grid-cell FE, year FE, and year FE x the first principal component of suitability for Old World Crops (wheat, wet rice, dry rice, barley and rye). Columns (4)-(6) also control for all relevant double interactions from the triple interaction. Standard errors are clustered at the grid-cell level.

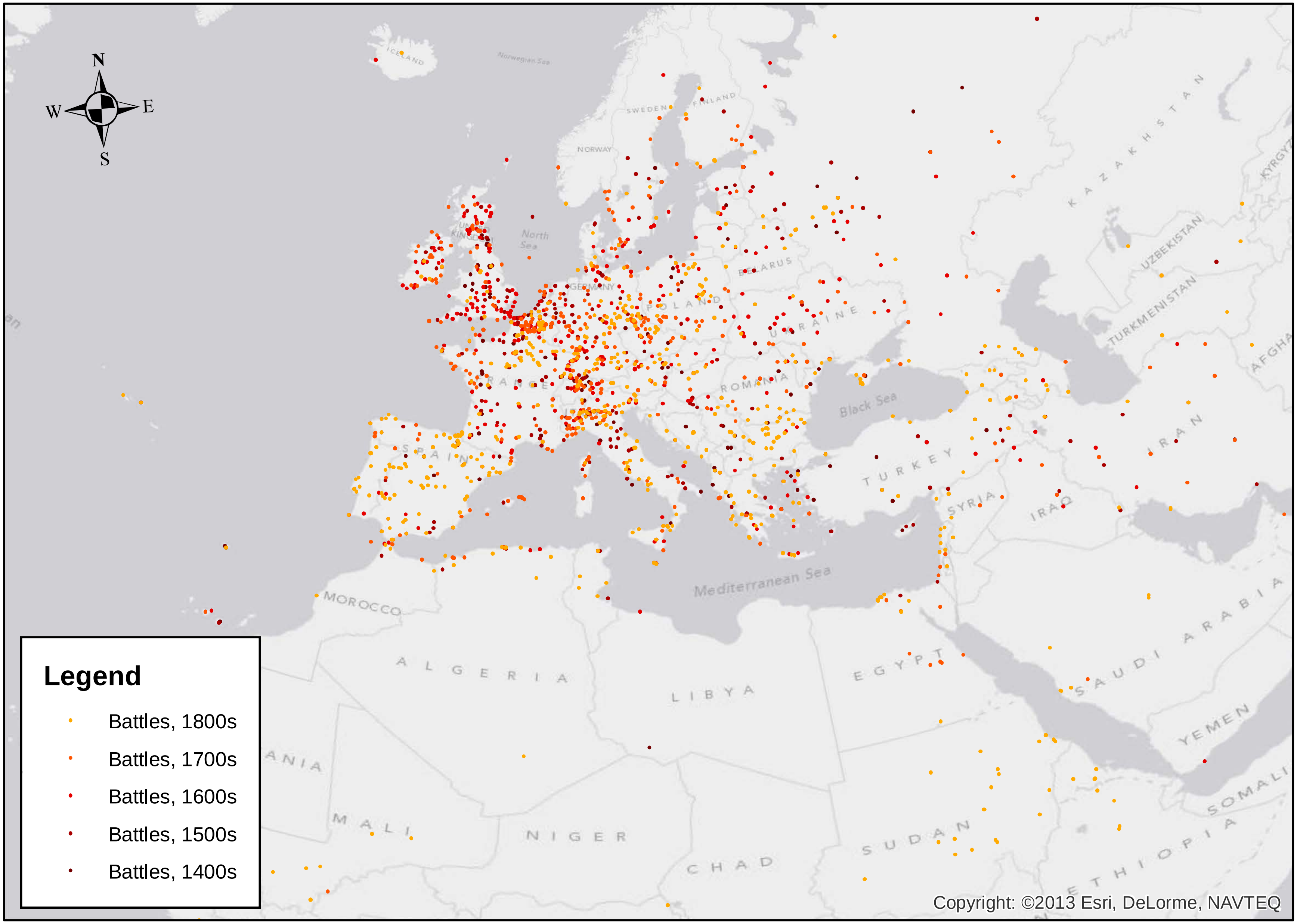


Figure 1: Conflicts, 1401-1900

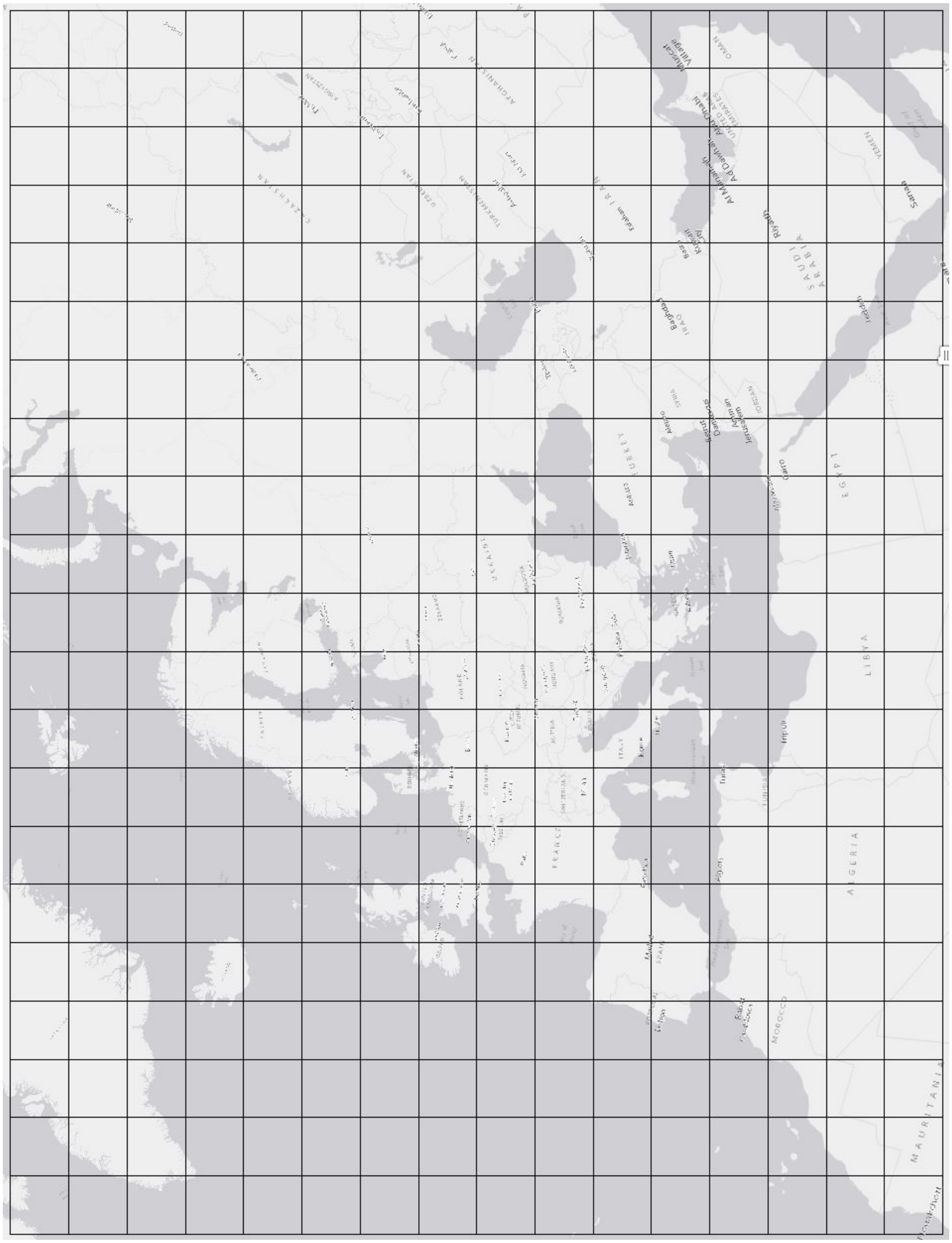


Figure 2: 400km × 400km Grid Cells

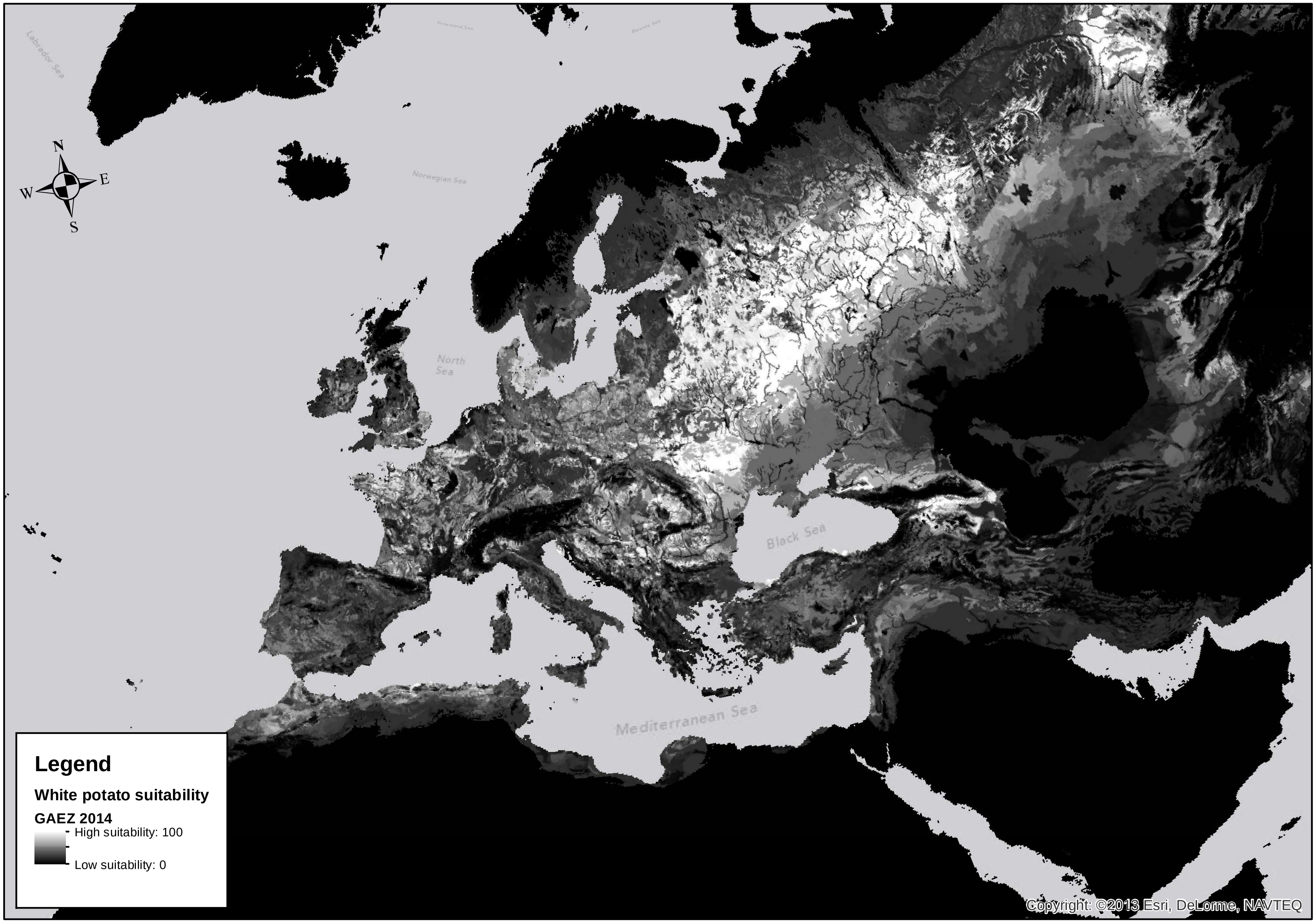


Figure 3: Potato Suitability

Figure 4: The Effect of Potatoes on Conflict for each 50-year Time Period, 400km × 400km Grid Cells

ONLINE APPENDIX – Not for Publication

A Theoretical Framework

A.1 Agricultural TFP and Land Values

The key mechanism is as follows: Suppose that (i) the demand for food is sufficiently inelastic, and (ii) the production function for food is Cobb-Douglas. A TFP shock in agriculture increases the output of food. From (i), we obtain that the price of food falls by more than output increases. Based on (ii), we obtain that the value of land is proportional to the market price of agricultural output. Since agricultural prices fall by more than the increases in agricultural product, this implies that the value of land declines.

Specifically, let there be two sectors, agriculture (A) and manufacturing (M). Production of both goods requires labor. We assume that land is in fixed supply and is only used in agriculture. Thus, because of the fixed factor land, agriculture has a decreasing marginal product of labor while, in manufacturing, the marginal product of labor is constant. More precisely, we assume the following production functions:

$$\begin{aligned} Y_A &= \widetilde{A_A} L_A^{\alpha} \qquad \text{where} \quad \widetilde{A_A} \equiv A_A N^{1-\alpha}, \\ Y_M &= A_M L_M, \end{aligned} \tag{A.1}$$

where L_A and L_M respectively denote labor allocated to agriculture and manufacturing. Total labor supply is normalized to one so that $L_A + L_M = 1$. We assume free mobility of labor across the two sectors.

By definition, A_A and A_M are productivity parameters for agriculture and manufacturing, and N is the total amount of arable land in the economy. $\widetilde{A_A}$ is aggregate productivity in agriculture taking into account not only the level of technology in this sector A_A, but also the amount of arable land available N. Historically, the introduction of the potato increased the productivity of arable land, since it had higher caloric yields per acre, and it increased the amount of arable land, due to the fact that potatoes could be cultivated on land that was not suitable for other crops.

The wage rate is denoted by w, the price of the manufacturing good is normalized to one, and the price of the agricultural good is given by p_A. We assume that all households hold equal shares of land (alternatively, we can assume that all land is being held by a landlord).

In the competitive equilibrium, the wage rate w is determined by the marginal productivity of labor in manufacturing:

$$w = A_M. \tag{A.2}$$

The value of land, which we denote by Π, is given by the solution to the following problem:

$$\Pi = \max_{L_A} p_A \widetilde{A_A} L_A^{\alpha} - w L_A. \tag{A.3}$$

The first-order condition for L_A gives:

$$\alpha p_A \widetilde{A_A} L_A^{\alpha-1} = w. \tag{A.4}$$

Combining equations (A.2) and (A.4) gives equilibrium labor in agriculture as a function of the relative price of the agricultural commodity, $L_A(p_A)$:

$$L_A(p_A) = \left(\frac{\alpha p_A \widetilde{A_A}}{A_M} \right),^{\frac{1}{1-\alpha}} \tag{A.5}$$

and output as function of the agricultural-good price is:

$$Y_A(p_A) = \left[\left(\frac{\alpha p_A}{A_M} \right)^{\alpha} \widetilde{A_A} \right].^{\frac{1}{1-\alpha}} \tag{A.6}$$

We now consider consumer demand to derive equilibrium prices. The consumer's problem is given by:

$$\max_{c_A, c_M} c_A^{1-1/\sigma} + c_M \text{ subject to } p_A c_A + c_M = w + \Pi. \tag{A.7}$$

The first-order condition for c_A gives

$$c_A^{-1/\sigma} = p_A. \tag{A.8}$$

In the goods market equilibrium, aggregate production equals aggregate consumption:

$$c_A = Y_A. \tag{A.9}$$

Taken together, (A.6), (A.8), and (A.9) give the equilibrium price of the agricultural good, p_A^*:

$$p_A^* \; = \; \left[\left(\frac{A_M}{\alpha} \right)^{\alpha} \frac{1}{\widetilde{A_A}} \right]^{\frac{1}{\sigma(1-\alpha)+\alpha}} . \tag{A.10}$$

Using (A.3), (A.5), and (A.10), we can now derive the equilibrium value of land:

$$\Pi^* = (1-\alpha) A_M^{\frac{\alpha(1-\sigma)}{\sigma(1-\alpha)+\alpha}} \widetilde{A_A}^{\frac{-(1-\sigma)}{\sigma(1-\alpha)+\alpha}} \tag{A.11}$$

In our setting, the elasticity of demand for food with respect to price is $-\sigma$.[36] Therefore, as long as the demand for food is inelastic (i.e., $\sigma < 1$), increases in A_A lower land values, Π.

The existing empirical evidence finds that the demand for agricultural goods is indeed price inelastic. Studies typically estimate the price elasticity of food demand to be between -0.80 and -0.20 (e.g., Tobin, 1950; Tolley et al., 1969; Van Driel et al., 1997). We therefore take the case in which an increase in agricultural productivity $\widetilde{A_A}$ decreases the value of land to be the empirically relevant scenario.

[36] Note that $c_A = p_A^{-\sigma}$. Therefore, $\frac{\partial c_A}{\partial p_A} \cdot \frac{p_A}{c_A} = -\sigma$.

A.2 Land Values and Conflict

Assume that, in each period, each country draws a random fixed cost of fighting. Countries fight over land, so they start conflict if the fixed cost of aggression is less than Π. Obviously, if Π decreases, conflict occurs less frequently.

Following the recent work of Acemoglu et al. (2012), which focuses on the incentives to arm more explicitly, we make the following assumptions: there is an armament decision m, the cost of which is given by $l(m)$. The function $l(.)$ is an increasing and convex function and the probability of winning a violent contest is $p(m)$, which is also an increasing and concave function. The aggressor solves

$$\max_{m} p(m)\Pi - l(m). \tag{A.12}$$

In this model, the introduction of potatoes increases the cost of arming, m, because it increases real wages; and it lowers Π since it decreases the value of land. Both forces obviously reduce the probability of armed conflict.

Table A.1: The Effect of Potato Suitability on Conflict – Using only Clodfelter's data

Dependent Variable: Number of Conflicts		
	(1)	(2)
	Full Sample	Clodfelter
Dependent Variable Mean	**1.788**	**0.710**
Potato Suitability x Post	-11.31	-7.425
	(4.674)	(3.132)
Observations	2750	2475
R-squared	0.484	0.399
# Clusters	275	275

Notes: The sample is a balanced panel for 1401-1900. The sample comprise only of conflicts reported by Clodfelter (2008). The observations are at the 50-year and 400km × 400km grid-cell level. All regressions control for the full set of baseline controls: grid-cell FE, year FE, and year FE x the first principal component of suitability for Old World Crops (wheat, wet rice, dry rice, barley and rye). Standard errors are clustered at the grid-cell level.

Table A.2: Factor Loading of Principal Components

A. Old World Staples: Dry Rice, Wet Rice, Wheat, Barley and Rye					
Component	**Eigenvalue**	**Difference**	**Proportion**	**Cumulative**	
Comp1	3.089	2.097	0.618	0.618	
Comp2	0.992	0.084	0.198	0.816	
Comp3	0.908	0.900	0.182	0.998	
Comp4	0.008	0.004	0.002	0.999	
Comp5	0.004	.	0.001	1.000	
Variable	**Comp1**	**Comp2**	**Comp3**	**Comp4**	**Comp5**
Dry Rice	-0.0635	0.9979	0.008	0.0005	-0.0002
Wet Rice	0.2056	0.0052	0.9786	0.0025	0.0079
Wheat	0.5636	0.0373	-0.1217	-0.5903	0.5636
Barley	0.5646	0.0368	-0.1119	-0.1934	-0.7937
Rye	0.5633	0.0364	-0.1224	0.7836	0.2287

B. New World Staples: Sweet Potato, Maize and Cassava				
Component	**Eigenvalue**	**Difference**	**Proportion**	**Cumulative**
Comp1	1.239	0.248	0.413	0.413
Comp2	0.991	0.221	0.330	0.743
Comp3	0.770	.	0.257	1.000
Variable	**Comp1**	**Comp2**	**Comp3**	
Sweet Potato	0.6962	-0.1087	-0.7096	
Maize	0.6906	-0.1683	0.7034	
Cassava	0.1959	0.9797	0.0421	

Table A.3: The Effect of Potato Suitability on Conflict for Each Year since Its Introduction

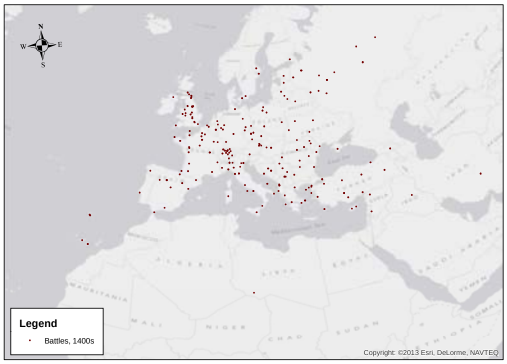
Dependent Variable: Number of Conflicts		
	(1)	(2)
Potato Suitability ×		
1500	1.591	10.86
	(14.68)	(43.32)
1550	3.474	19.24
	(12.39)	(34.57)
1600	21.28	77.76
	(17.62)	(58.07)
1650	5.535	40.38
	(8.410)	(33.13)
1700	11.98	79.29
	(15.96)	(68.88)
1750	0.603	8.959
	(14.10)	(35.88)
1800	-2.491	-34.84
	(11.94)	(55.56)
1850	-14.90	-65.46
	(12.38)	(44.18)
1900	-0.154	
	(14.60)	
Observations	2750	880
R-squared	0.486	0.602
# Clusters	275	88

Notes: The sample is a balanced panel for 1401-1900. The observations are at the 50-year and 400km × 400km (column 1) or 800km × 800km (column 2) grid-cell levels. All regressions control for the full set of baseline controls: grid-cell FE, year FE, and year FE x the first principal component of suitability for Old World Crops (wheat, wet rice, dry rice, barley and rye).

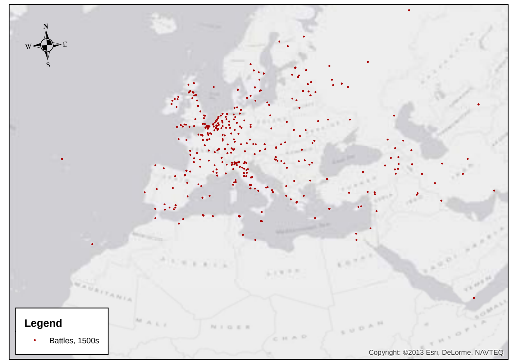
Table A.4: The Effect of Potato Suitability on Conflict for Each Year – Omit large wars

			Dependent Variable: # of Conflicts_t					
				Potato Suitability x Post				
Omit Largest Wars (In Descending Order)	War Common Name	# Battles in War	Dep. Var Mean	Coef.	Std. Err.	Obs.	R-squared	# Clusters
(1)	Napoleonic War (Peninsular War)	73	1.632	-7.183	(3.866)	2750	0.516	275
(2)	French Revolutionary War of the First Coalition	63	1.635	-7.478	(4.155)	2750	0.498	275
(3)	Seven Years' War	60	1.637	-8.294	(4.022)	2750	0.509	275
(4)	War of the Second Coalition	54	1.639	-6.860	(4.395)	2750	0.501	275
(5)	War of Spanish Succession	51	1.638	-7.523	(4.095)	2750	0.495	275
(6)	Thirty Years' War	45	1.636	-8.162	(3.877)	2750	0.506	275
(7)	Napoleonic War of Liberation	42	1.643	-8.165	(4.014)	2750	0.506	275
(8)	Napoleonic War of the Third Coalition	31	1.647	-8.266	(4.000)	2750	0.512	275
(9)	Second Northern War/Great Northern War	31	1.647	-8.219	(4.028)	2750	0.512	275
(10)	War of Austrian Succession	30	1.647	-7.731	(4.023)	2750	0.508	275
(11)	Franco-Prussian War	28	1.647	-7.946	(4.024)	2750	0.503	275
(12)	Egyptian and Syrian Campaign (Battle of the Pyramids)	27	1.649	-7.881	(3.943)	2750	0.514	275
(13)	Crimean War	25	1.649	-7.579	(3.917)	2750	0.513	275
(14)	Fourth Franco-Prussian War (Napoleonic Wars)	22	1.651	-7.806	(3.986)	2750	0.512	275
(15)	Napoleonic War (Russian Expedition)	20	1.651	-8.987	(4.121)	2750	0.513	275
(16)	Dutch War of Independence	18	1.651	-7.962	(3.932)	2750	0.517	275
(17)	First English Civil War	17	1.652	-7.941	(3.937)	2750	0.514	275
(18)	Dutch War of Louis XIV	16	1.653	-8.027	(3.929)	2750	0.510	275
(19)	Russo-Turkish War	15	1.653	-7.714	(3.950)	2750	0.515	275
(20)	Catherine the Great's First War with Turkey	14	1.653	-8.323	(3.979)	2750	0.513	275
(21)	United Irishmen Revolt (Wexford rebellion)	14	1.653	-8.240	(3.926)	2750	0.514	275
(22)	Habsburg-Ottoman War	14	1.654	-7.806	(3.959)	2750	0.513	275
(23)	n/a	14	1.653	-8.099	(3.964)	2750	0.513	275
(24)	n/a	13	1.653	-7.842	(3.937)	2750	0.514	275
(25)	First Northern War	13	1.653	-7.934	(3.964)	2750	0.513	275
(26)	*All* Napoleanic Wars	209	1.582	-8.293	(4.230)	2750	0.497	275

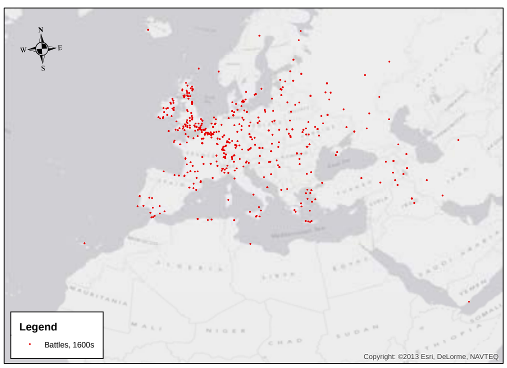
Notes: The sample is a balanced panel for 1401-1900. The observations are at the 50-year and 400km × 400km grid-cell level. All regressions control for the full set of baseline controls: grid-cell FE, year FE, and year FE x the first principal component of suitability for Old World Crops (wheat, wet rice, dry rice, barley and rye). Standard errors are clustered at the grid-cell level.



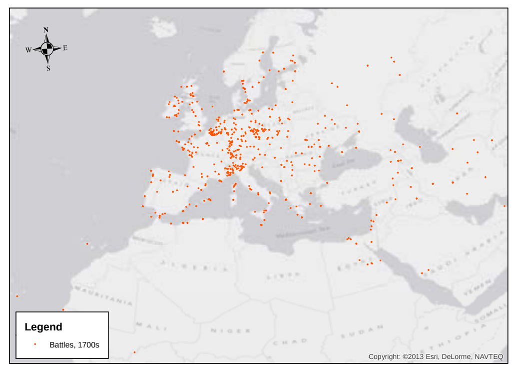
(a) 1401-1500



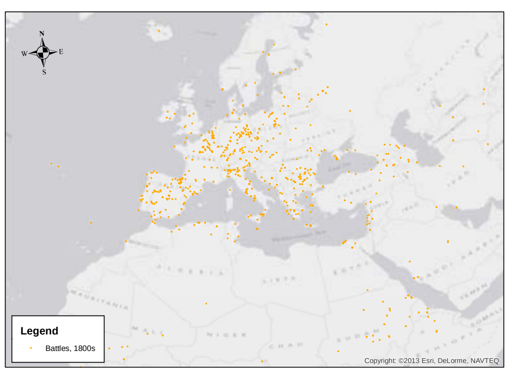
(b) 1501-1600



(c) 1601-1700



(d) 1701-1800



(e) 1801-1900

Figure A.1: Conflicts, 1401-1900 by Century

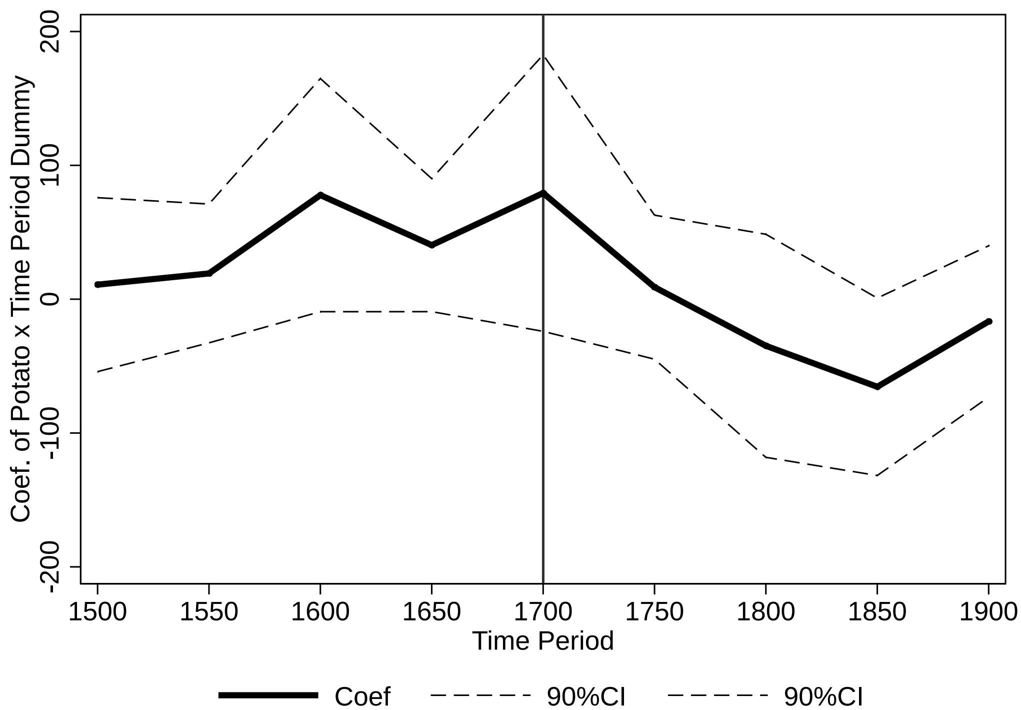


Figure A.2: The Effect of Potatoes on Conflict for each 50-year Time Period, 800km $\times$ 800km Grid Cells

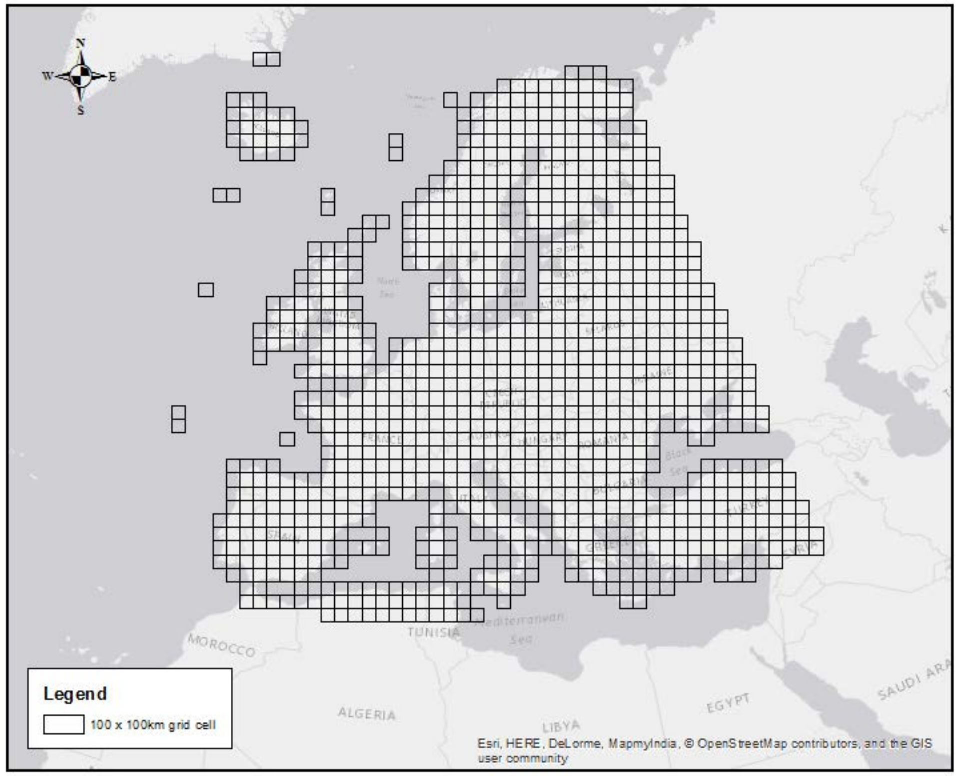


Figure A.3: Coverage of Luterbacher Weather Data, 50km × 50km Grid Cells