Fractured-Land and the Puzzle of Political Unification and Fragmentation

Jesús Fernández-Villaverde, Mark Koyama, Youhong Lin, Tuan-Hwee Sng*

January 2019

Preliminary and not for circulation

Abstract

A prominent explanation for Europe’s long history of political fragmentation and China’s tendency towards political unification is the fractured land hypothesis made famous by Diamond (1997a). We build a model to explore the effects of geography on political fragmentation. We find that topography, or fractured land, is necessary but not sufficient to account for China’s early political centralization and Europe’s persistent political fragmentation. The existence, or lack thereof, of a dominant core region of high land productivity also plays a critical role in explaining the political divergence at the two ends of Eurasia.

Keywords: China; Europe; Great Divergence; State Capacity; Political Fragmentation; Political Centralization

JEL Codes: H56; N40; P48

* Jesús Fernández-Villaverde, Department of Economics, University of Pennsylvania. Email: jesusfv@econ.upenn.edu. Mark Koyama, Department of Economics, George Mason University. Email: mkoyama2@gmu.edu. Youhong Lin, Center for Cliometrics Studies of China, Guangdong University of Foreign Studies. Email: lin.youhong@foxmail.com. Tuan-Hwee Sng (corresponding author), Department of Economics, National University of Singapore. Email: tsng@muis.edu.sg. We are grateful for comments from seminar audiences at UC Irvine and from discussions with Lisa Blaydes, Jean-Paul Carvalho, Latika Chaudhary, Dan Bogart, Saum Jha, Nippe Lagerlóf, Gary Richardson, Mohamed Saleh, and Stergios Skaperdas.
1 Introduction

The economic rise of western Europe is often attributed to its political fragmentation (Jones, 1981, 2003; Lagerlof, 2014; Mokyr, 2016). Correspondingly, many explanations of China’s comparative failure to achieve sustained economic growth focus on its long history as a centralized empire. But what factors account for the prevalence of political fragmentation in Europe and the prominence of political centralization in China?

Numerous explanations have been proposed. A particularly popular one, offered by Jared Diamond (1997a, 1998), argues that “fractured land” such as mountain barriers, heavy forests, and rugged terrain impeded the development of a large empire in Europe in comparison to other parts of Eurasia. The hypothesis has been challenged by Hoffman (2015), who points out that China is in fact more mountainous than Europe.\textsuperscript{1} It is also criticized for being static and overly deterministic. Hui (2005) contests the idea that China was “destined to have authoritarian rule under a unified empire,” (p. 1) while arguing that Europe’s political fragmentation was also a highly contingent outcome.\textsuperscript{2}

This paper provides a systematic investigation of the fractured land hypothesis and the challenges that it has received. We explicitly model the process of state-building over time to explore if and how fractured land shaped and interacted with inter-state competition. Our model suggests that fractured land indeed provides a robust explanation for the political divergence observed at the two ends of Eurasia. However, topography alone was not sufficient. The nature of geopolitical competition was played a critical role too. The presence of a dominant core region of high land productivity in China—in the form of North China plain—and the lack thereof in Europe was also crucial for the emergence of political fragmentation in Europe and political unification in China.

Our incorporation of inter-state competition into the model is built upon Hoffman’s argument (2015) that early modern Europe was characterized by a political-military tournament in which

\textsuperscript{1}Similar arguments have been advanced by Peter Turchin and Tanner Greer in blog form. Turchin notes that it is not Europe’s fragmentation that needs explanation but China’s precocious and persistent. See http://peterturchin.com/cliodynamica/why-europe-is-not-china/ and http://scholars-stage.blogspot.com/2013/06/geography-and-chinese-history-fractured.html.

\textsuperscript{2}Other tests for various elements of Diamond’s hypothesis include Turchin, Adams, and Hall (2006) and Laitin, Moortgat, and Robinson (2012).
rulers had to investment in military technologies. According to Hoffman, this tournament eradicated polities that were unable to compete and led to an acceleration in military and political technologies which evolved comparatively rapidly as a result of intensive learning-by-doing. We provide a framework in which the existence of a political-military tournament is not an alternative hypothesis to the fractured land hypothesis but a complement to it.

One novel feature of our model is the role played by agricultural productivity in giving rise to conflict and thereby prompting larger states to coalesce. In this respect, our analysis shares some similarities with Acharya and Lee (2018), who develop a model in which economic development generates rents that lead to the formation of territorial states.

More broadly, our analysis contributes to several literatures in political economy and economic history. First, we complement a long-standing literature in political science and history that attributes the rise of western Europe to its multi-state system (Montesquieu, 1748, 1989; Pirenne, 1925; Hicks, 1969; Jones, 1981, 2003; Hall, 1985; Rosenberg and L.E. Birdzell, 1986; Baechler, 1975; Cowen, 1990; Tilly, 1990; Chaudhry and Garner, 2006; Mokyr, 2007; Karayalcin, 2008; Chu, 2010; Olsson and Hansson, 2011; Lagerlof, 2014) by investigating the causes of Europe’s political fragmentation.

Relatedly, a second strand of research we contribute to is the study of state formation in European and Chinese history. One element within this literature emphasizes the importance of the invasion threat from the steppe in shaping the development of the Chinese state (Lattimore, 1940; Grousset, 1970; Huang, 1988; Barfield, 1989; Gat, 2006; Chen, 2015; Ko, Koyama, and Sng, 2018). Another strand emphasizes the importance of war and military competition in shaping the formation of European states (Parker, 1988; Tilly, 1990; Downing, 1992; Voigtländer and Voth, 2013; Gennaioli and Voth, 2015).

Studying the formation of large empires in world history, Turchin (2009) focuses on the antagonistic relations between the nomadic steppe and settled agriculturalists. Turchin argues that the Eurasian steppe was a key factor in state formation in the Old World. Steppe nomads put pressure on premodern polities forcing them to strengthen and to invest in state capacity as a defensive response.

Turchin, Currie, Turner, and Gavrilets (2013) study how warfare with the steppe shaped
state formation and social evolution from 1500 BCE to 1500 CE. In their model, groups inhabit a 100km by 100 km cell and compete with each other through warfare. The intensification of warfare favors the evolution of ultrasocial traits and the rise of large-scale states. Group competition is affected by geographical conditions such as deserts, rivers, mountains and the Eurasian steppe. Successful polities conquer other polities and spread their cultural traits. Turchin, Currie, Turner, and Gavrilets (2013) match their stimulations to historical data on the distribution of large states and empires.

Among the papers that have compared political fragmentation in Europe to the relative unity experienced by China, Ko, Koyama, and Sng (2018) offer a complementary thesis to the framework outlined in this paper. We develop an argument that emphasizes a different set of factors: the roles played by geographical fractionalization, agricultural productivity, and military competition.

Our study also relates to the analysis of Kitamura and Lagerlof (2018) who explore the role geography plays in shaping political borders. Using data on political borders for Europe, North Africa and the Near East, they find that mountain ranges and rivers do help explain political boundaries but they are less important than other factors such as the number of borders in neighboring cells (an R-squared of 10% using only geographic variables compared to 60% when neighboring cells are included). They find that Europe’s geography cannot explain its high level of political fragmentation. Kitamura and Lagerlof (2018)’s data is from Europe, North Africa, and Near-East so it does not permit them to make a direct comparison between China and Europe.

Finally, we contribute to the literature on the relationship between geography and economic and political outcomes. Geography can shape economic outcomes directly (via access to trade routes or vulnerability to disease vectors) (i.e. Sachs, 2001) or indirectly via its effect on political institutions (e.g. Acemoglu, Johnson, and Robinson, 2001, 2002, 2005). We provide an example of the second phenomenon: geography mattered in Chinese and European history because it gave rise to a centralized state in China and resulted in fragmentation in Europe.

In the remainder of the paper, we first outline the main arguments advanced in favor of geographical explanations for Europe’s persistent fragmentation. Second, we motivate the analysis
by considering European and Chinese geography. The location of Europe’s mountain ranges ensured that there were several distinct geographical cores of equal size that could provide the nuclei for future European states whereas China is dominated by a single large northern plain between the Yangtze and the Yellow river. Third, and motivated by these facts, we build a simple model of interstate competition. The novel feature of our model is that we explicitly integrate geographical bounders into our analysis; this allows us to directly study the implications of the fragmented land hypothesis. Section 5 discusses some aspects of European and Chinese history in light of our model. We conclude in Section 6.

2 Motivation

Anthropologists, geographers, historians and sociologists have long suggested that early states could only form where there was a sufficiently large area of productive agricultural land. This land had to productive enough to generate a food surplus. It also tended to require geographical boundaries that made it possible for political authorities to coerce the population into transferring these surpluses to a political elite (e.g. Carneiro, 1970). Agrarian states struggled to project power into rugged, hilly, or mountainous lands (Scott, 2017). Geographers use the concept of a geographic core to describe the nucleus of successful states (Whittlesey, 1944; Pounds and Ball, 1964; Michael Hechter, 1980). They argued the core of most successful states were based around self-contained geographic regions characterized by areas of fertile agricultural land characterized by good transport connections and defensible from external invasion.³

The idea that Europe’s geography played an important role in giving rise to its political fragmentation has been explored by many authors (e.g. Jones, 1981, 2003; Kennedy, 1987).⁴ We

³Thus: “[t]he geographical pattern of the states of Europe had, in general, taken shape before the age of modern nationalism … However profoundly they may have been modified and their expansion influenced by the forces which make up modern nationalism, most European states grew in fact by a process of accretion from germinal areas which have come, after Derwent Whittlesey, to be called ‘core-areas’” (Pounds and Ball, 1964, 24).

⁴Jones noted that the “topographical structure of” Europe “its mountain chains, coasts and major marches, formed boundaries at which states expanding from the core-areas could meet and pause’ and that ‘these natural barriers helped to hold the ring between the varied ethnic and linguistic groups making up the European peoples” (Jones, 1981, 2003, 226). Kennedy similarly stated that Europe’s political diversity was ‘largely’ due to its geography: “There were no enormous plains over which an empire of horsemen could impose its swift dominion; nor were there broad and fertile river zones, like those around the Ganges, Nile, Tigris and Euphrates, Yellow and Yangtze, providing the food for masses of toiling and easily conquerable peasants. Europe’s landscape was
focus on Jared Diamond’s exposition because it is highly influential \cite{Diamond1997a, Diamond1998}. Diamond makes the following observations: (1) China was not threatened by the presence of large islands off the mainland of China (Taiwan is too small and Japan too far away); (2) The Chinese coastline was smooth compared to the European coastline; (3) Most importantly, unlike Europe China was not fractured by high mountains and dense forests.\footnote{In his own words, “[..] the ultimate reason for Europe’s political fragmentation emerges from a glance at a map of Europe […] Seas, a highly indented coastline, high mountains and dense forests divide Europe into many peninsulas, islands and geographical regions, each of which developed political, linguistic, ethnic and cultural autonomy. Each such region became one more natural experiment in the evolution of technology and scientific inquiry, competing against other regions. Conversely, China has a much less indented coastline, no islands large enough to achieve autonomy, and less formidable internal mountain barriers. (Even China’s two largest islands, Hainan and Taiwan are small: each has less than half the area of Ireland; neither was a major independent power until Taiwan’s emergence in recent decades; and, until recently, Japan’s geographical isolation kept it much more remote politically from the Asian mainland than Britain has been from mainland Europe.) China was linked from east to west by two parallel, long and navigable rivers, and was eventually linked from north to south by canals between those rivers. So once a unified Chinese state was founded, geography prevented any other state from gaining lasting autonomy in any part of China \cite{Diamond1998, 433}.”}

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure1.png}
\caption{Ruggedness in Europe and China Proper.}
\end{figure}

However, the claims of the fractured land hypothesis have come under criticism. Hoffman \citeyear{Hoffman2015, 109-112} observes that, in fact, China is significantly more mountainous than Europe. He notes that over 37\% of modern China is defined as mountainous in comparison to little more much more fractured, with mountain ranges and large forests separating the scattered population centers in the valleys; and its climate altered considerably from north to south and west to east” \cite{Kennedy1987, 17}.
than 10% of Europe. Even if one restricts attention to China proper (?), more than 33% was elevated above 1,000m compared to only around 6% in Europe. However one looks at the data, China is more mountainous than Europe.

What may be crucial, however, is the location of either continent’s mountainous regions. As Figure 1 illustrates, mountain ranges at or near the center of Western Europe play an important role in separating Italy and Spain from France and making core regions of central Europe (Switzerland, Austria) difficult to conquer.

Moreover, much of the northern European plain was historically covered with dense forest, which impeded conquest and the rapid movement of large armies. The Romans, historians note, “were forced to stop in their expansion and Empire building at the boundaries of the dense, virgin German forests whose inhospitable and somber nature was pictured in dark colors by such ancient writers as Tacitus, Pomponius Mella, and Marcellinus, who spoke of the forests as of something horrid and inaccessible and unsuited for human habitation” (Zon, 1920, 141).

Consequently, Europe comprises several cores: the British Isles, Scandinavia, the Iberian peninsular and the Italian peninsular all form distinctive and discontinuous “regions” that stand out from any simple visual inspection of a map of Europe. The modern counties of France, the Low Countries, Germany and Poland span what is known as the northern European plain. The eastern most region part of this plain borders the Russian forest in the north-east, the steppe in the east, and the Carpathian mountains in the south; it corresponds loosely to modern Poland and to the territory controlled by the Polish-Lithuanian Commonwealth in the early modern period. The central part of the plain corresponds to the modern country of Germany while the western part of the plain is in modern France.

Meanwhile, the most mountainous regions in China are in the south and west, and they do not intersect the central plain in North China that historically played a crucial role in China’s early unification (Figure 1). The central Chinese plain, which forms around the delta of the Yellow and Yangtze rivers, is blocked from Korea in the north east by the Changbai Mountains and the Taihang Mountains in the west. The plain itself is flat with the exception of the Taishan mountains in Shandong and Dabie Mountains of Anhui. Southern China is more mountainous than the central Chinese plain. The Yunnan-Guizhou Plateau has particularly
high elevation. Mountains and then dense forest divided Lingnan and Yunnan from Vietnam and Burma respectively. Diamond (1997a, 414) himself emphasizes the existence of a large core region capable of dominating the other regions in China:

“China’s heartland is bound together from east to west by two long navigable river systems in rich alluvial valleys (the Yangtze and Yellow Rivers), and it is joined from north to south by relatively easy connections between these two river systems (eventually linked by canals). As a result, China very early became dominated by two huge geographic core areas of high productivity, themselves only weakly separated from each other and eventually fused into a single core”.

In the next Section, we introduce a simple model of state formation and competition. This model allows to separate the role of geography from that of political competition.

3 Model

We now discuss our model. First, we describe the geographical setup and the interpretation of the different variables that characterize the environment. Second, we discuss how the size of polities evolves through conflict and secession.

3.1 The Geographical Setup

Our area of study includes Europe (except the northern parts of Scandinavia and Russia), North Africa, the Middle East (except the interior of the Arabian Peninsula), most of Continental Asia (except parts of Northern Siberia), and Japan. This area, plotted in Figure 2, is sometimes called—with different degrees of precision— the “Old World,” Eurasia, and the Afro-Eurasian ecumene. As the renowned historian Marshall Hodgson put it, this area corresponds to:

“...the various lands of urbanized, literate, civilization in the Eastern Hemisphere, in a continuous zone from the Atlantic to the Pacific, [that] have been in commercial and commonly in intellectual contact with each other, mediately or immediately” (Hodgson, 1954, 716).
By the middle Bronze Ages, there were intense political, trade, and cultural contacts across the area that justify considering it as a unit of study for our purposes. For instance, the Roman Empire and Han China knew of each other’s existence and traded indirectly. Roman commerce with the Indian subcontinent was considerable, with the tariffs on it accounting perhaps for as much as one-third of the Empire’s revenue (McLaughlin, 2010). Roman coins made their way to Japan and Buddhism had a presence in Rome. The regions from the Afro-Eurasian landmass that we ignore (northern parts of Scandinavia and Russia, Sub-Saharan Africa, the interior of the Arabian Peninsula, etc.) were either excluded from the above-referenced networks of exchange due to geographical barriers or too thinly populated due to environmental constraints. And beyond minor interactions (the Mali Empire, Arab seamen in the East Coast of Africa, the Vikings in North America), Sub-Saharan Africa, the Americas and Oceania developed in an independent way from our area of study until the start of the Voyages Age of Exploration beginning in the 15th century.

![Figure 2: Study Area.](image)

Importantly for our purposes, the area of study in Figure 2 has accumulated, for most of
history, the majority of world human population and has been the origin of much the developments in technology and social forms (Kremer, 1993; Diamond, 1997b). For instance, by the year 1500 around 85 percent of the world population lived in the area.\(^6\) Understanding the dynamics of its political forms is, therefore, particularly important.

We divide the area of study in Figure 2 into 4439 cells of 100 kilometers by 100 kilometers in length, each capable of sustaining a polity and allowing armies to pass through it. Of these cell, 286 cells cover “China,” defined as south of the Great Wall, and 282 are in “(Western) Europe,” defined as the lands west of the Hajnal line running from Saint Petersburg to Trieste and delimiting the region of the so-called European marriage pattern (Hajnal, 1965). Figure 2 represents China and Europe’s cells with green and red borders, respectively.

Each cell \( i \) is indexed by seven characteristics, four binary and three continuous. The four binary variables are: i) whether the cell comprises a narrow sea channel; ii) whether its weather was below 0 degree celsius for 6 months or more per year in 8,000 BC (the Holocene epoch, which was relatively warm in historical context); iii) whether the cell is in the tropics, \( x_{\text{tropics}} \); and iv) whether the cell is a part of the Eurasian steppe. The three continuous variables are: i) terrain “ruggedness”; ii) elevation; and iii) agricultural productivity.

We label agricultural productivity as \( y \) and group the first six variables, which constitute barriers to conquest, in the vector \( x \):

\[
x = \{ x_{\text{sea}}, x_{\text{cold}}, x_{\text{tropics}}, x_{\text{steppe}}, x_{\text{elevation}}, x_{\text{ruggedness}} \}. \tag{1}
\]

The binary variables are easy to explain. \( x_{\text{sea}} \) incorporates the “stopping power of water” (Mearscheimer, 2001, 84). Seas constitute major barriers that impede the spread and expansion of states. An invasion across a sea channel is militarily risky and logistically challenging. In Figure 2, we represent the narrow sea channels as dark blue cells (\( x_{\text{sea}} = 1 \)). These cells include, for instance, the English Channel, the Sound, the Bosporus, and the Taiwan Strait. In the same figure, the cold climate variable is depicted as light blue cells where \( x_{\text{cold}} = 1 \). Most of these cells

\(^6\)We build this estimate from Table B-12 in Maddison (2001). The data does not exactly fit with our area. For example, Africa is not divided between North and Sub-Saharan Africa. However, Africa’s total population in 1500 CE was 10.5 percent of the world population and any reasonable imputation of it between North and Sub-Saharan shares will give us roughly equivalent total shares for the area with which we are concerned with.
are in the northern frontier of our area of study or in mountainous regions (the Himalayas, the Alps, the Caucasus). Similarly, $x_{tropics}$ appears as pink cells that are mostly clustered in the Indian Subcontinent and in Southeast Asia. $x_{steppe}$ is a binary variable that captures the fact that this terrain was unsuitable for the expansion of agrarian empires because they could be outflanked and attacked by nomads from the steppe (Barfield, 1989; Gat, 2006).

Figures 3 and 4 depict $x_{ruggedness}$ and $x_{elevation}$, the “ruggedness” and “elevation” of the cells, respectively. We measure “ruggedness” by the standard deviation of elevation of each cell, an indicator of the speed at which terrain changes. Both plains and plateaus will low in this measure, while mountain rages and valleys score high (Nunn and Puga, 2012).

Figure 5 plots the agricultural productivity $y$ of each cell. Productivity will determine the ability of the polity that controls it to mobilize resources from it for military purposes. Before the Industrial Revolution, agricultural productivity was the main determinant for the income level of an area and a strong predictor of its population density. In our benchmark simulations, data on agricultural productivity is from Ramankutty, Foley, Norman, and McSweeney (2002).
Figure 4: Elevation.

For robustness, we report results using measures of potential caloric yield from Galor and Ömer Özak (2016) (Appendix A.7).

### 3.2 The Evolution of Polities

Time $t$ is discrete in our model: $t = 0, 1, 2, \ldots$. At the initial period $t = 0$, each cell begins as an independent polity. Over time, some polities may expand so that each comes to rule a a block of cells. We can think of each period as corresponding to 10 years. Therefore, a 100 year period can be thought of as reflecting 1000 years of history.

Each cell $i$ has four borders, denoted by $l, r, u, d$. In each period, there is some probability that cell $i$ encounters border conflict:

$$p \cdot y_i^\alpha,$$

where the parameters $p, \alpha > 0$. The dependence of the probability of conflict on productivity
indicates that more productive cells are tempting to neighbors as source to loot and exploit. Also, for simplicity we assume that when a cell experiences a border conflict, only one of its four borders is affected (relaxing this assumption is straightforward, but it makes the model less transparent at the benefit of little additional insight).

Conditional on having a border conflict, the probability that it occurs along border \( m \in \{ l, r, u, d \} \) is given by:

\[
y_m = \frac{y_m^\beta}{y_l^\beta + y_r^\beta + y_u^\beta + y_d^\beta},
\]

where \( \beta > 0 \) and \( y_l, y_r, y_u, \) and \( y_d \) are the productivities of the four cells sharing a border with cell \( i \). Figure 6 illustrates this.

If there is conflict along a border between two cells controlled by the same polity, nothing happens. The unified government solves the unrest by reallocating resources or exercising other policies to resolve the conflict in a manner that is inconsequential for our model. However, if the conflict is between two cells controlled by two different polities, fighting occurs and the victor annexes its neighbor’s cell in conflict.
Victory depends on the productivity of the cells controlled by each polity and the geographical characteristics of the cell. These characteristics included ruggedness, elevation, where the cell is a sea channel, whether it is frozen for more than 5 months of the year, and whether it is in the tropics. More concretely, if a war between regimes $j$ and $k$ takes place at the border between cells $i$ and $\bar{i}$, $j$ wins with probability:

$$Pr_{j,\text{win}} = \frac{Y_{j,t}}{(Y_{j,t} + Y_{k,t}) \times (1 + \max \{\Theta \cdot x_i, \Theta \cdot x_{\bar{i}}\})}$$

where $x_i$ and $x_{\bar{i}}$ denote the characteristics of cell $i$ and $\bar{i}$, respectively, and $\Theta$ is the corresponding parameter vector. Given this contest function, the probability of the war ending with neither side annexing its neighbor’s cell is $1 - \frac{1}{1 + \max \{\Theta \cdot x_i, \Theta \cdot x_{\bar{i}}\}}$, which is strictly positive and is increasing in $\max \{\Theta \cdot x_i, \Theta \cdot x_{\bar{i}}\}$.

To reflect the historical tendency for border regions in large states to seek secession, we allow border cells to secede from the larger state they belong to with strictly positive probability. We assume that cell $i$’s probability of secession is higher if (a) cell $i$ has natural obstacles (a high $\Theta \cdot x_i$ make rebellions harder to suppress), (b) if the parent regime $j$ controls a large number of cells (and is therefore more heterogenous), (b) if regime $j$ has a long frontier relative to its interior (which increases the difficulty of monitoring and controlling the population). The probability of cell $i$ seceding from regime $j$ is therefore given by

$$\pi \times \Theta \cdot x_i \times \frac{\sum_{s=1}^{4439} (1_{j}(s) \cap 1_{B}(s))}{\sum_{s=1}^{4439} 1_{j}(s)} \cdot \sum_{s=1}^{4439} 1_{j}(s)$$

$$\pi \times \Theta \cdot x_i \times \sum_{s=1}^{4439} (1_{j}(s) \cap 1_{B}(s))$$

**Figure 6:** An illustration of the four borders of cell $y_i$. 
where \( \mathbb{1}_j(s) = 1 \) if cell \( s \) is ruled by regime \( j \) and \( \mathbb{1}_j(s) = 0 \) otherwise, and \( \mathbb{1}_B(s) = 1 \) if cell \( s \) is a border cell and \( \mathbb{1}_B(s) = 0 \) otherwise. A border cell is defined as one that borders one or more than one cell ruled by another regime. If a regime is cut into multiple disjoint parts due to war or succession, each part becomes a separate regime.

To summarize, the timing of events is as follows:

1. Time is discrete. At \( t = 0 \), each cell is a regime (i.e., 4439 regimes).

2. At each time period, the probability of conflict breaking out in cell \( i \) is \( p \cdot y_i^\alpha \), where \( p, \alpha > 0 \).

3. If conflict breaks out in cell \( i \), only one of its four borders is affected. The probability of conflict taking place along border \( m \in \{l, r, u, d\} \) conditional on conflict breaking out in cell \( i \) is \( \frac{y_m^\beta}{y_l + y_r + y_u + y_d} \), where \( \beta > 0 \) and \( y_l, y_r, y_u, \) and \( y_d \) are the productivities of the four cells bordering cell \( i \).

4. If there is conflict along a border between two cells controlled by different regimes, a war takes place.

5. If there is a war between between cells \( i \) and \( \tilde{i} \), controlled respectively by regimes \( j \) and \( k \), regime \( j \) wins (i.e., captures cell \( \tilde{i} \)) with probability given by Equation 2.

6. A regime may fight no war, one war, or multiple wars at any period. If it fights multiple \((n)\) wars, it splits its resources evenly (available resources are divide by \( n \)).

7. Cell \( i \) secedes with probability given by Equation 3.

We summarize the model’s variables in Table 1.

The setup allows state consolidation to take place over time as conflicts occur.

As unrest and conflicts occur, state consolidation takes place over time. Larger and more consolidated states have access to more resources, and hence are likely to consolidate further. However, some cells are more difficult to conquer than other cells due to their geographical characteristics. Mountainous cells and seas such as the English Channel constitute potential barriers that can impede state consolidation.
Variable

\( p \) Probability of conflict when \( y = 1 \).

\( y \) Agricultural productivity in a cell.

\( \alpha \) Relates the productivity of a cell to its probability of conflict (default \( \alpha = 1 \)).

\( \beta \) Relates the probability of conflict occurring on a given border to productivity of the bordering cells (default \( \beta = 1 \)).

\( \theta_{rugged} \) Terrain ruggedness.

\( \theta_{elevation} \) Terrain elevation.

\( \theta_{sea} \) if cell is a coastal sea lane.

\( \theta_{cold} \) if average temperature was below 0 degree celsius for > 6 months per year in 8,000 BC.

\( \theta_{tropics} \) if cell is in the tropics.

\( \theta_{forest} \) if cell is covered by forests.

\( \theta_{steppe} \) if cell is part of the Eurasian steppe.

| Table 1: Parameters of the model |

4 Implementation & Results

For our benchmark analysis, we choose parameter values that approximate the relative importance of land and sea barriers in the preindustrial world. We set \( \alpha = 1, \beta = 1 \). We set \( \theta_{cold} = \theta_{tropics} = \theta_{forest} = \theta_{steppe} = 2 \). To capture the importance of sea and mountain barriers, we set \( \theta_{sea} = 3 \) and choose the values of \( \theta_{rugged} \) and \( \theta_{elevation} \) so that \( \theta_{rugged} x_{rugged} = 3 \) for the cell at the 10th percentile of ruggedness and \( \theta_{elevation} x_{elevation} = 2 \) for the cell at the 10th percentile of elevation.

We simulate this model using R.\(^7\) Our model is extremely simple. Nonetheless, it generates patterns of political consolidation and fragmentation that resemble those that we observe in history. The most important of which is that larger polities emerged first in historical China and that this part of the world tends to become unified under a single state whereas political fragmentation is persistent in Europe.

Figures 7 and 8 show results for 49 simulations of the benchmark specification. Across simulations, not only does political centralization occur in China, rather than Europe, but political centralization in China emerges relatively quickly.

\(^7\)Appendix Figure 10 depicts a representative simulation from in period 1 in our benchmark setup. Each cell is an independent polity. Appendix Figure 11 depicts the same simulation after 121 periods.
4.1 Sensitivity

We now consider the sensitivity of our results to the key assumptions of the model. We consider eight variations of the main analysis (Figure 9). Row 1(a) in Figure 9 depicts the path of political centralization for China and Europe in our benchmark simulation. In row 1(b) we shut down the effect of geographical obstacles on conflict success. The basic result remains intact: China unifies more rapidly than Europe.

In row 1(c), in addition to shutting down the effects of geographical obstacles, we make all cells equally likely to engage in conflict regardless of their productivity. Now both China and Europe unify at a comparable rate. In 1(d), we reinstate the role of geographical obstacles, while allowing all cells to be equally likely to engage in conflict. We recover our main result.

In row 2 we explore sensitivity with respect to the possibility of splintering. Rows 2(a)-2(d) replicate 1(a)-1(d) but with the possibility of cells seceding removed. The only specification in which political unification in Europe takes place faster than in China is row 2(d). In this specification, political centralization is initially higher in China than in Europe. But over time, Europe overtakes China and unifies first.

Geographical obstacles alone do not explain the differences we observe in patterns of political centralization between China and Europe. If we remove geographic barriers, we still observe more rapid unification in China. Only removing both geographical barriers and the relationship between productivity and conflict onset ensures that China and Europe unify at a comparable
Figure 9: Sensitivity Analysis We use the “median” simulations for China and Europe respectively. How we define median: for each of the 49 simulations, we compute its average Herfindahl index over 500 periods. The median simulation is the one whose score is 25th out of 49.

We now consider different values of our main parameters. First we allow for higher values of $\alpha$. This makes more productive cells more likely to undergo unrest. Next we vary $\beta$. $\beta$ connects the probability of unrest along each border to the productivity of bordering cells. Our results are also robust when we employ a range of values of $\theta$.

We consider a number of additional robustness checks in the Online Appendix. We summarize them briefly here.

The Eurasian steppe The role of the Eurasian steppe is highlighted by Turchin, Currie, Turner, and Gavrilets (2013) who note that it influenced state building both directly, because steppe nomads eliminated weaker and less cohesive polities; and indirectly by developing and spreading technologies that intensified warfare. Another factor that made the steppe critical historically is that until the modern period, agrarian states were unable to subdue it and extend their authority across it. One reason for this was that steppe nomads were not dependent on holding land. In the face of attack from nomads could simply retreat as the undifferentiated “highway of grass” allowed them to reach the Black Sea from Mongolia in a matter of weeks (Frachetti, 2008, 7).

In Appendix A.4 we outline an extension to our model where we explicitly give an advantage to cells located close to the steppe. This extension enhances the realism of our analysis as it
impedes the formation of empires that encompass agrarian land in Europe, the Middle East or China and conqueror the steppe. But it does not qualitatively impact on main reasons with respect to the number of states in Europe or China.

Dynastic cycles  Premodern states often rose and fell. This phenomenon in Chinese history is viewed through the lens of dynastic cycles (Usher, 1989; Chu and Lee, 1994); but it was a universal one. Recently scholars have pointed to climate change as a possible cause of China’s dynastic cycles (see Zhang, Jim, Lin, He, Wang, and Lee, 2006; Fan, 2010). Climatic factors have also been adduced as important in the rise and fall of the Roman empire (see Section 5.2). Exogenous climate change also brought the High Middle Ages to close and help usher in the “Calamitous Fourteenth Century” (Tuchman, 1978).\textsuperscript{8}

In general, we can distinguish between such general system-wide crises such as the collapse of Bronze Age empires c 1177 BCE. (Cline, 2014) or the “general crisis of the 17th century” (Trevor-Roper, 1959; Hobsbawm, 1965; Parker and Smith, 1978; Parker, 2008, 2013) and regime specific crises which affect a single polity.

We incorporate the role of shocks in generating political instability as follows. To study the role of shocks such as natural disasters or the ascension of a particularly weak ruler, we allow for the probability of a general or a specific shock occurring each period and we extend the model to 4000 periods. We allow a 0.001 probability of a general shock occurring and a 0.004 probability of a regime specific shock occurring per period. If a general shock occurs, all regimes \(>25\) cells will break up (25 cells is roughly the size of mainland Italy. For regimes controlling 25 cells or less, one-third of them will break up into its constituent cells. Under regime specific shock, it is just the regime in question that breaks up. Under this specification there is a regime specific shock on average once every 250 years and a general shock on average once every 1000 years. Figure 12 depicts the Herfindhal index from a single (representative) simulation for both China and Europe.

For China, Figure 12 reveals a pattern of periods of sustained unification interrupted by periods of disunity, resembling the successive dynasties of Chinese history. Some periods of unified rule short-lived, others survive for many periods. In contrast, Europe never achieves full

\textsuperscript{8}See Lamb (1982). For a more up-to-date discussion see Campbell (2016).
unification in this realization of the model. There are periods of state-building that rest on one state becoming hegemonic in Europe but these are always transitory; political fragmentation remains persistent.

**The Mediterranean Sea** In our benchmark analysis, sea cells that are adjacent to land cells are traversable but across seas or other large bodies of water are barriers across which conflicts cannot take place. This assumption is consistent with the difficulties of large-scale maritime invasions in the premodern period and the nature of most naval technology. However, as we discuss in Appendix A.5, this may not the best way to model the Mediterranean sea, which due to its geography is significantly calmer and less dangerous to traverse than other major seas. Indeed, as scholars such as Braudel (1972, 1949) and Horden and Purcell (2000) have pointed out, the Mediterranean facilitated the spread of shared cultural values and institutions throughout history and states throughout the pre-industrial period were able to launch military campaigns across the Mediterranean.

The most notable European empire in the premodern period, the Roman empire, was based on control of “Mare Nostrom” (*Our Sea*). We discuss the Roman empire in Section 5.2.

**Military technology** What about changes in military technology? Military innovations such as the invention of iron weapons, stirrups, and the invention of gunpowder shaped patterns of state building throughout history.\(^9\) To capture changing military technology we can modify our setup with a parameter \(d\) such that \(Pr_{i,\text{win}} = \frac{Y_{j,t}}{Y_{j,t} + Y_{k,t} + d\Theta(i,j)}\) [to update]. Equating a change in cell control as an aggressor emerging and winning the war and no change in cell control as successful defending, then \(d\) is a measure of the defender’s advantage. Hence once can think of higher values of \(d\) as an improvement in defensive technology. We report the effects of increasing \(d\) in the Appendix.

**Different values of \(\lambda\)** In our benchmark analysis we set \(\lambda = 1\). This ensures that the probability of a conflict ending in either one polity annexing a cell or failing to annex a cell is constant. We can also allow \(\lambda > 1\). In this case, the probability of war ending in no conquest

\(^9\)As discussed in Laichen (2003).
increases over time. This could reflect the formation of distinct national identities or cultures that make conquest harder to sustain. In this extension the probability of a sustained military tournament as discussed by Hoffman (2015) in Europe is increased as we discuss in Section 5.2;

5 Historical Discussion Informed by the Model

Our model generates several insights that help us understand patterns of state formation across Eurasia.

5.1 China

Why did China tend towards unification throughout its history? The simulations we run suggest that the geographical characteristics of the northern Chinese plain made it possible for a single powerful state to overcome its rivals and to build a centralized state. This is consistent with what we observe historically. Control of the key central plains of northern China was crucial to the unification of China under the Qin and to subsequent unifications under the Sui and Song dynasties.

Importantly, these geographical characteristics did not make the existence of a centralized empire inevitable. Historically, there were long periods of political fragmentation in China: the Warring States period (475 BCE-221 BCE), the Three Kingdoms period (220-280), the Five Dynasties and Ten Kingdoms period (907-960) and the Southern Song period (1127-1279). However, if a powerful Chinese state did arise like the Qin or the Ming it was possible for them to subdue rival kingdoms. Our model is consistent with this as we observe episodes of fragmentation interspersing periods of unification.

In contrast, to the situation in Europe, the Qin dynasty was able to unify China despite attempts at “balancing” by the other states. The historical literature points to the reforms enacted by the Qin state, notably by Shang Yang. These included conscription, large-scale irrigation projects, and a system of land registration (Hui, 2005). This reforms were partially, but not fully, emulated by the other warring states.

Our model adds an emphasis on the potential for cumulative conquests in the core regions
of historical China. Scholars note that “When Qin swept through the Chinese continent, it could readily incorporate conquered territories as prefectures and counties” (Wohlforth, Little, Kaufman, Kang, Jones, Hui, Eckstein, Deudney, and Brenner, 2007, 171). Historically, the majority of unifications came from the north. This pattern is generated in our model.

5.2 Europe

Our model sheds light on the conditions which ensured that Europe remained politically fragmented for much of its history. The closest that Europe came to being ruled by a single polity was during the Roman empire. Recent work by historians such as Harper (2017) have pointed to the confluence of favorable climatic conditions that facilitated the rise and longevity of the Roman empire. In terms of our model, the Roman warm period that Harper identifies would have increased the agricultural productivity of southern Europe and North Africa favoring the expansion of a Mediterranean based empire into the rest of Europe and the Near East. Section A.5 in the Appendix considers various extensions that allow for the Mediterranean sea to be traversable and for enhanced agricultural productivity in North Africa.

Nevertheless, despite remarkable successes, the Romans were not able to permanently incorporate Germany and Eastern Europe into the Empire. Our model points to one reason why Rome did not permanently expand beyond the Rhine. This is that the dense northern Europe forest played a crucial role in impeded the consolidation of a single European hegemonic state. We discuss this point more in Appendix Section A.6. In Figure 22 we provide an illustrative snapshot of the simulation where we remove the northern European forest. In this case, the probability of Europe unifying under a hegemonic state is slightly higher than in our baseline. The critical role of the northern Europe forest in deterring Roman expansion is attested to in the historical sources including Julius Caesar, Pliny the Elder, and Tacitus.

10 This is true of the formation of the First Chinese Empire under the Qin Dynasty in 221 BCE. The Sui dynasty unified China from the north. The Tang dynasty also originated in the North. Taizu, the first Song emperor, was a general from the Later Zhou, the most northern state in China. Including the Yuan and Qing dynasties also originated in north.


12 See Begle (1900); Howorth (1909). Tacitus describes Germania as a land that ‘bristles with forests or reeks with swamps’. He describes various German tribes, the ‘Reudignians, and Aviones, and Angles, and Varinians, and Eudoses, and Suardones and Nuithones’ as ‘all defended by rivers or forests’ (Tacitus, 1877, 90 and 116).
In this way, our model elucidates the role played by mountain and forest barriers in European history. Mountains and forests did not pose an insurmountable impediment to European armies. Hannibal famously crossed the Pyrenees and Alps in 218 BCE. Frederick Barbarossa was able to invade Italy on numerous occasions from Germany in the 1150s through to the 1170s. Spanish armies crossed into southern France on numerous occasions. Nevertheless, these barriers did substantially raise the cost of military interventions between polities in modern day Spain, France, Germany, and Italy.

After the fall of the Roman empire, the closest Europe came to being unified by a single ruler was during the sixteenth century under the Habsburg Charles V. Importantly, for our purposes, however. Charles V did not acquire this empire by conquest but by marriage. He also did not create a unified state but ruled his disparate kingdoms as separately entities. As such, our model does not directly speak to how the Habsburgs chanced on a European-wide empire. It does, however, speak to the difficulties Charles V had in managing his domains.

The limitations imposed by geography prevented Charles V from focusing attention on either facing the Ottomans in the Mediterranean, driving France out of Italy, or subduing rebellious German princes in the Holy Roman Empire. Consistent with our model, the viability of Habsburg hegemony depended on possession of the rich and densely populated Low Countries and the North Italian plain. Thus Habsburg dominance began to unravel once they lost control of the Netherlands as a result of the Dutch Revolt. Following this defeat, and the consolidation of the Reformation in Germany, the Habsburg’s lost their preeminence among European powers.

The simulations of our model is consistent with the findings of Abramson (2017) who highlights the ability of numerous small states to survive in Europe until 1800. Contrary to the arguments of Tilly (1990), the size of European states did not increase over time; during the period of the Military Revolution, average state size remained small and in fact fell.

Our model also speaks to the failure of Charles V, Louis XIV or Napoleon to successfully build a hegemonic state in Europe. The emergence of several medium sized states in Europe is

---

13Peter II of Aragon crossed the Pyrenees to confront the army of Simon de Montfort in 1213 dying during the Battle of Muret.

14Charles V ruled ‘a greater number of realms than had ever before been accumulated by any European ruler’ and his territories spanned much of Europe with the result that ‘his duties took him everywhere’. It is estimated that he spent 25% of his reign traveling. He himself described his life one long journey (Kamen, 2002, 50).
a common feature of our model. This captures the argument that “balancing powers” powers was crucial to preventing either Spain or later France from building a long-lasting continent spanning empire.\textsuperscript{15} The prominence of several medium-size states in our model is driven by Europe’s geography. It reflects not only mountain barriers, stressed by Diamond (1997a, 1998), but also the fact that the most productive agricultural land in Europe is dispersed, rather than concentrated, as is the case in China.

Finally, our model can be adapted to discuss the significance of a political-military tournament in late medieval and early modern Europe discussed by Hoffman (2015). According to Hoffman:

\textit{“...repeatedly pitted the continent’s rulers and leaders against one another in warfare that affected the lives of people around the globe. The prize for the rulers engaged in this grim contest was financial gain, territorial expansion, defense of the faith, or the glory of victory. To snatch the prize, they raised taxes and lavished resources on armies and navies that used the gunpowder technology and advanced it by learning from their mistakes or, especially in the nineteenth century, by doing research. The flood of resources channeled into warfare continued unabated up into the nineteenth century, even when it harmed the rest of the economy. In Europe, political conditions made it possible to mobilize gigantic sums for armies and navies, and military conditions favored the gunpowder technology, which, because it was new, had enormous potential for improvement by the sort of learning by doing that was going on in Europe before 1800”} (Hoffman, 2015, 16).

To answer the question why such an intense and prolonged political-military contest emerged in Europe but not in other continents, Hoffman relies on an argument based on political history rather than geography.\textsuperscript{16} Geography, in contrast, according to Hoffman cannot be the ultimate explanation of why interstate competition in Europe was fierce and persistent. Our extension,

\textsuperscript{15}The concept of balancing is the subject of an extensive literature in International Relations, see Waltz (1979); Mearsheimer (2001).

\textsuperscript{16}And in Hoffman’s argument “political history here is outside the model (in the language of economics, the political history is exogenous)” (Hoffman, 2015, 66).
laid out in the Appendix shows how it is possible for a more intense political-military tournament to emergence endogenously. By setting $\lambda > 1$, regions that do not part of a single regime early on become harder to conquer. This can be interpreted as reflecting the formation of national identities or cultures. This additional feature can to explain why over time, military competition in Europe became more intense and the prospects of a single European state weaker over time.

5.3 India

Unlike China, India was fragmented for most of its history. It was only united into a single polity under the British Raj. Previous Indian empires, the Maurya and Gupta empires, the Dehli Sultanate and the Vijayanagara empire, and the Mughal and Maratha empires only controlled part of the Indian subcontinent. Our model sheds light on why a single powerful empire did not take over the entire Indian subcontinent in the premodern period.

First, the Himalayas and the Hindu Kush represented a barrier to the north. The fact that the Himalayas posed a barrier to state expansion in our model is the product of both terrain ruggedness and low agricultural productivity. The mountains were not an insurmountable barrier to armies—the Mughals did conduct mountainous expeditions into places like Kashmir (1561, 1585, 1588), Garhwal (1635, 1656), Baltistan (1637), Ladakh and Tibet (1679–84)—but the lack of forage and food impeded all attempts to extend political authority permanently north of India. Gommans notes that ‘Indian armies were faced by tremendous logistical problems. One mid-eighteenth-century source considered the Kabul area a land of snow: “Men and cattle from India are not able to withstand the icy cold winds of that area. That is why it is difficult for the people of India to capture and occupy the Muslim countries of that area” (Gommans, 2002, 23).

Second, in the East, the thick jungles of Burma and Gondwana created unbridgeable, outer limits to Mughal expansion (Gommans, 2002, 198). Third, the Deccan Plateau in Southern India provided a formidable barrier to empire building. It rises to over 1000 meters in Southern India. It was the site of numerous conflicts between states from northern India and those from southern India. As a result, numerous Hindu states in the Deccan were able to resist the expansion of Muslim empires such as the Mughals.

Fourth, our assumption that productivity is low in the tropics is important in explaining
why India does not become unified in our model. This assumption is in keeping with historical
evidence which documents the difficulties involved in keeping together large armies in tropical
conditions in the premodern period (see Lieberman, 2003, 2009).17

6 Concluding Comments

In this paper we develop a model that allows us to adjudicate between competing explanations
of Europe’s political fragmentation and China’s political centralization.

Our analysis takes seriously Jared Diamond’s argument that Europe’s mountain barriers and
the shape of its coastline was responsible for its political fragmentation whereas Chinese geography
encouraged political centralization. We show that indeed the location of geographical boundaries
in Europe and China were of critical importance in shaping patterns of state formation.

But to fully account for patterns of state formation in Eurasia we need to go beyond Diamond’s
original hypothesis. Our analysis explicitly incorporates the productivity of land into a tractable
framework. This is inline with the argument of Abramson (2017, 3) that the “economic capacity
of states best explains their ability to produce force”. Both geographical barriers and land
productivity were critical in explaining Europe’s persistent fragmentation and China’s tendency
towards unification.

References

Organization, 71(1), 97–130.
1369–1401.
——— (2002): “Reversal Of Fortune: Geography And Institutions In The Making Of The

17These factors also can account for the transient nature of states in South-East Asia discussed by historians
(see Colombijn, 2003).


A Online Appendices (For Web Publication Only)

A.1 Example Simulation

Figure 10: Example simulation: period 10

Figure 11: Example simulation: period 120
A.2 Shocks and Cycles

To study the role of shocks such as natural disasters or the ascension of a particularly weak ruler, we allow for the probability of a general or a specific shock occurring each period. To better understand the dynamics of how polities rise and fall we extend the model to 4000 periods. We allow a 0.01 probability of a general shock occurring and a 0.5 probability of a regime specific shock occurring. Figure 12 depicts the Herfindhal index from a single simulation for both China and Europe.

Figure 12: This figure depicts one realization of a simulation where we allow for both regime-specific shocks (prob. 0.5) and general shocks (prob. 0.01) occurring and allow the simulation to run for 4000 periods.

A.3 Sensitivity
Figure 13: Fan chart: the benchmark model.

Figure 14: Fan chart: shutting down geographical obstacles.

Figure 15: Fan chart: shutting down geographical obstacles and productivity.

Figure 16: Fan chart: reinstating geographical obstacles; shutting down productivity.
A.4 The Eurasian Steppe

To capture the role played by the Eurasian steppe include Steppe in our benchmark analysis. Steppe captures the fact that this terrain was unsuitable land for the expansion of agrarian empires because they could be outflanked and attacked by nomads from the steppe.

\[
Pr_{j, \text{win}} = \frac{Y_{j,t}}{Y_{j,t} + Y_{k,t} + \theta + \theta_{\text{rugged}}x_{\text{rugged}} + \theta_{\text{steppe}}x_{\text{steppe}} + \cdots + \theta_{\text{forest}}x_{\text{forest}}} \tag{4}
\]

\[
= \frac{Y_{j,t}}{Y_{j,t} + Y_{k,t} + \Theta(i, i)}. \tag{5}
\]

As a further extension we create a binary variable SteppeBorder that takes the value 1 if a cell is on the fringe of the steppe (within 300 kilometers of the steppe) and freeze = 0. In this extension, in the event of war between regimes \( j \) and \( k \) takes place at the border between cells \( i \) and \( \tilde{i} \), \( j \) wins with probability:

\[
Pr_{j, \text{win}} = \frac{\psi_j \cdot Y_{j,t}}{\psi_j \cdot Y_{j,t} + \psi_k \cdot Y_{k,t} + \theta + \theta_{\text{rugged}}x_{\text{rugged}} + \theta_{\text{steppe}}x_{\text{steppe}} + \cdots + \theta_{\text{forest}}x_{\text{forest}}} \tag{6}
\]

\[
= \frac{\psi_j \cdot Y_{j,t}}{\psi_j \cdot Y_{j,t} + \psi_k \cdot Y_{k,t} + \Theta(i, i)}. \tag{7}
\]

where \( \psi_j > 1 \) if regime \( j \) originates as a border cell and \( \psi_j = 1 \) otherwise.

Note that steppe border cells are agrarian, they are on the fringe of the steppe but are not part of it. We assume that a border cell is more proficient in war than the average agrarian cell/regime as invaders because (for example) they have better access to horses.

We plot the results of 100 stimulations of this extension in figures Figure 17 and 18.
**Figure 17:** Fan chart for 49 simulations of the benchmark model with the Steppe extension. Results for China.

**Figure 18:** Fan chart for 49 simulations of the benchmark model with the Steppe extension. Results for Europe.
A.5 Varying Assumptions about the Mediterranean Sea

In our benchmark model, we do not allow conflicts to take place across large bodies of water. Cells which are adjacent to a land cell are traversable. This ensures that conflicts can take place between polities in the British Isles and mainland Europe and across the Korea Strait. But it prevents polities separated by large bodies of water from coming into direct conflict. In general, this is a realistic depiction of the world before 1500.

However, it may not be the best way to model the Mediterranean Sea. As the Mediterranean is nearly landlocked, its tides are comparatively weak and it is much easier to transport ships and bodies of troops across the Mediterranean than across other equivalent seas.

This is a potentially a concern for our analysis because at least one European empire, the Roman Empire, was built upon control of the Mediterranean. To address this concern we modify the model to allow the Mediterranean to be traversable. First, we divide the Mediterranean Sea into 4 parts: east, central, west, and the Adriatic Sea. Each part is a cell, capable of launching attacks and being attacked. The results are displayed in Figure 19. We do not detect a perceptible difference in the pace of unification in Europe.

Figure 19: “Median” Simulations for China, Europe, and the Mediterranean Region, assuming that the Mediterranean Sea is traversable.

Figure 20: “Median” Simulations for China, Europe, and the Mediterranean Region, assuming that the Mediterranean Sea is traversable and North Africa is highly productive.

Ancient historians suggest that the Roman economy was built on controlling the Mediterranean and access to the extremely productive agriculture of North Africa. Climatic conditions during the Classical period ensure that North Africa was wetter than today (Murphey, 1951; Reale and Dirmeyer, 2000). As a consequence, the provinces of Egypt and Africa (modern day Algeria,
Morocco, Tunisia) were the “bread baskets” of the empire.\textsuperscript{18}

To capture this, on top of allowing the Mediterranean to be traversable, we increase the agriculture suitability of Northwest Africa (Algeria, Morocco, Tunisia) to 1 (maximum value). Now, we still do not see (Western) Europe unifying faster than China, but we do see an increased likelihood of empire formation around the Mediterranean. Polities in cells bordering the Mediterranean can come into conflict with one another.

Making the Mediterranean Sea traversable does not increase the likelihood of a single hegemonic state unifying Europe.

\textsuperscript{18}See Rickman (1980). According to Linn (2012, 305-306), “[S]ince the first century bCE, whenever Rome was shut off from North African grain, a shortage typically had ensued ... All these instances demonstrate two facts about the relationship between North Africa and the city of Rome: (1) North Africa was the lifeline for the city of Rome; (2) warfare commonly led to a food crisis in Rome because of transport blockages”.

39
A.6 Varying Assumptions about the Central European Forest

Central Europe prior to the modern period was covered by an extensive forest.

For additional robustness purposes, we remove the Central European forest from the model. Figures 21 and 22 depict the results of 49 simulations for China and Europe respectively. In general we observe greater variation in outcomes and somewhat larger European states. In general, however, removing the Central European forest does not lead to Europe becoming unifying.
A.7 Potential Crop Yield

For further robustness, we report results using a measures of potential caloric yield from Galor and Ömer Özak (2016) (Appendix A.7). Galor and Ömer Özak (2016) provide estimates of potential agricultural output using pre-Columbian exchange crops. Building on the Global Agro-Ecological Zones (GAEZ) project of the Food and Agricultural Organization, Galor and Ömer Özak (2016) assess the most suitable crop for each $5' \times 5'$ cell under the assumptions of low level inputs and rain-fed agriculture, and convert this potential yield into caloric equivalents.\(^{19}\)

As shown in Figures 23 and 24 we obtain very similar results using this alternative dataset.

---

\(^{19}\)Note that this data measures potential caloric yield under the assumption of rain-fed agriculture. To the extent that rice agriculture could have benefited disproportionately from irrigation technology, then this data may understand agricultural productivity in East Asia.