# THE AGRICULTURE REVOLUTION, MILITARY TECHNOLOGIES AND THE FORMATION OF THE STATE †

Carles Boix ‡

October 17, 2011

† This paper is based on both the introduction and chapter 3 of the book manuscript “Political Order, Inequality and Growth”. Previous versions of the material employing to write this paper were presented at the University of Virginia, the New York meeting of the “September Group” Princeton University, Duke University, Yale University, Stanford University, the University of Chicago, Harvard University, Cornell University and the University of Maryland. I thank the comments of all their participants, in particular to those of Alícia Adserà, Sam Bowles, Dan Gingerich, Stathis Kalyvas, Carol Mershon, Thomas Romer and Milan Svolik. I am grateful to Teppei Yamamoto for his research assistance.

‡ Princeton University. E-mail: cboix@princeton.edu.

## INTRODUCTION

The political and economic history of mankind revolves around managing (and perhaps solving) three main issues: the construction and maintenance of political order, the generation of economic growth, and the social distribution of the latter. In fact, the specific responses given to each one of those problems, which, as develop in the book, turn out to be mutually connected, have defined the broad historical phases through which human societies have evolved. Until about 10,000 years ago mankind lived in small communities of foragers, which, according to existing archaeological and anthropological evidence, had no formal political institutions, produced at the margin of subsistence and presented relatively equal distributions of income and wealth. From 8,500 B.C. onward, however, several regions of the world transited to agriculture and saw the development of sedentary human communities as well as considerable population growth. In turn, the domestication of plants and animals led to or at least was correlated with two momentous events. On the one hand, it preceded or coincided with the formation of the state -- ranging from small urban polities to vast despotic monarchies. On the other hand, it was associated with the emergence of marked inequalities in the distribution of wealth (as well as in the access to food and health and therefore in the general welfare of individuals). The old agrarian order (what the French revolutionaries used to refer to as the *Ancien Régime*) remained in place (with all its internal variety of political forms, that is, from clan-based chiefdoms and feudal states to despotic monarchies) until the spread of industrial technologies in North Atlantic economies around 1800 A.D. generated a period of unprecedented growth and compressed the distribution of income within countries (with a few national exceptions and temporal reversions) in the following two centuries. The emergence of a capital-based economy (and the decline of inequality) then triggered a process of political democratization first in Western Europe and North America and then in growing parts of the world.

To shed light on those historical events and to understand the foundations of political societies, this book offers a theory of the conditions under which the state emerged as a solution to the problem of reducing violence and creating order. This theory of state formation, which comes together with an account of the ways through which political elites are materially rewarded (and the overall economy is regulated), allows us to examine two additional issues. It spells out the origins and evolution (particularly until the industrial revolution and contemporary democratization) of economic inequality. It provides a theory of growth and, more specifically, it defines the overall conditions that triggered and sustained modern (industrial) growth at a particular historical time.

**Equality as a Starting Condition.** To examine the foundations of political order, that is, to observe how political authority formed *ex nihilo*, I engage in a thought experiment, partially modeled after modern political or state-of-nature theory. I start by assuming a world characterized by the simplest, most sparse initial conditions: one where a set of individuals, endowed with identical resources (time and perhaps some innate abilities), interact among themselves in the absence of any political institutions or state, that is, without any organization having the monopoly of force over them. Under such a condition of anarchy, those individuals rely on two different strategies to survive and prosper. They may follow a productive strategy, which consists in the allocation of their resources to the production (and voluntary exchange) of goods and services. Alternatively, they may adopt an expropriatory or extractive strategy, that is, they may direct their resources to appropriate the assets or returns of other individuals in a forcible manner. Given those very sparse conditions, I show that, even when those individuals have incentives to follow an expropriatory strategy in independent, one-shot interactions, they may cooperate 'spontaneously', that is, without any permanent political institutions, over time, provided that their resources are similar, that is, if there are no changes in the initial condition of equality that characterizes the state of nature. Such a state of social cooperation takes place through two alternative forms: in the form of individuals (or, at most, households) living separately and avoiding conflict among themselves; or in the form of a community of people living together and sharing in the processes of production and consumption to either minimize risks or exploit some complementarities in the process of production. Either way, however, life under a situation of spontaneous cooperation is poor, nasty, brutish and short. Men and women live at the margin of subsistence, almost always exclusively preoccupied with satisfying their most elemental material needs, and their private behavior and conversations are strictly fettered by a community that punishes any deviation from the socially expected standard of behavior with ostracism and sometimes even with death.

The state of spontaneous cooperation tends to break down over time. In the normal process of production, individuals develop, through a simple process of learning-by-doing, and perhaps spurred by growing demographic pressures, new abilities or tools to exploit the natural resources or territories they control. Their new know-how may be common to everyone (either because all individuals invent it at the same time or because, in the absence of state institutions, any innovation spreads around freely). But its effects become biased at some point in time: its marginal productivity varies with the territory (or, more generally, input factors) to which it is put to use. The agricultural revolution is a case in point. The techniques of plant domestication turned out to be available to everyone in the medium run. But not all soils are equally fertile. As a result, individuals, who were similar before the creation of new production techniques, sorted themselves into different types with different payoff functions and hence different strategies. The economically advantaged individuals or ‘natural producers’ continued to have a strong preference for a productive strategy and therefore for the collective outcome of cooperation. Those who did not benefit from the technological shock preferred, however, to loot the producer. In a world populated by some individuals whose dominant strategy is looting, the outcome of self-enforcing cooperation breaks down, giving way to a Hobbesian world of systematic conflict.

**The Emergence of Political Order.** The only solution to generalized disorder consists in the construction of an organization or structure that has both the incentives and the capacity to enforce order among both producers and looters. Political authority was born through two alternative paths. On the one hand, producers themselves can coordinate to defend themselves against plunderers. On the other hand, looters can set up a system in which they restrain themselves from looting the producers once and forever. Instead, they collect some permanent stream of income from the producers. To secure those rents, looters have to defend their producers (now turned into "taxpayers" of some sort) from other. The first type of solution leads to a republican compact. Republics generally preserve the existing distribution of wealth and income that results from the structure of ownership and the control of technology in the new political community in place. The second form of government is a monarchical regime. Monarchies lead to a substantial redistribution of income, from producers to looters, who have now become the lords of the former.

Warfare and war technology turn out to be the main driver behind the distribution of monarchies and republics across the world and over time, at least before the industrial revolution. The invention and spread of warfare techniques that give some comparative advantage to looters lead to the expansion of monarchical regimes. By contrast, those technologies of fighting that equalize resources across individuals or that confer some additional strength to producers (naval power in commercial republics is one such example) expand the number of republics while improving their chances of survival.

Dictatorships and monarchical states have been the dominant form of political organization across the world since the invention of metal weapons about six to five thousand years ago for two reasons. "Republican" political communities have appeared during rather circumscribed historical periods and in particular geographical areas (such as classical Greece, the system of Germanic tribes governed by councils of free men as described by Tacitus or parts of Western Europe in late medieval and early modern times). They have also tended to be small in size. The distribution of regime types is due to two factors. On the one hand, the introduction of new weapons such as the sword, or later the chariot or the horse with stirrups, which require spending considerable time and effort in training, led to the formation of a class of professional warriors with a strong comparative advantage in the control of violence and tipped the balance of power away from producers and in favor of predatory individuals. On the other hand, warfare itself imposes strong opportunity costs on republican forms of government. To defend itself, a republic may follow two alternative strategies. On the one hand, it can raise a citizens' militia. On the other hand, it may contract out the tasks of military defense (and offense) to a set of soldiers separate from the body politic. This latter solution reduces the opportunity costs of those producers that have to serve in a militia but it comes at a high political cost. A hired (including a "professional") army cannot credibly commit to preserve the terms of the contract made with the republican regime. Once in control of the production and management of violence, it will be tempted to subject the producers and establish a monarchy – this is what Italian medieval and modern thinkers, aware of its dangers, referred to as the problem of the "condottiero". As a result, most republican systems or city-states rationally tended to avoid territorial expansion.[1]

[1] This does not mean that republics are peaceful or that, more to the point discussed here, they could not become large or even create some territorial imperial. Some republics became substantially large provided they met one of the following conditions. First, their war capabilities were embedded within the technologies of production: some trading cities (such as Athens and Venice) exploited their naval know-how, initially developed through their commercial activities, to create large empires overseas. Second, they established a larger state through some sort of federative arrangement that combined small republican cities or states within a broader institutional structure: that was probably one of the main contributions to political engineering made by the founders of the United States. Third, republics designed an institutional technology to control a professionalized army. Finally, they developed a (highly capital-intensive) technology of war that allowed them to defend themselves with very little opportunity costs to their productive activities.

**Structure of this paper.** To probe the theoretical argument developed so far, this paper offers several layers of empirical evidence. First, it uses systematic evidence collected across the world and over time to show that the agricultural revolution (the key technological shock that pushed most of mankind away from stateless communities and into state-governed societies) that started about 10,000 years ago was triggered by biogeographical conditions in each region in the world that were exogenous to any political or institutional factors. It then relates the timing of the birth of state institutions to the emergence of agriculture through two kinds of data: systematic data based on coding the whole world as well as more fine-grained archaeological evidence from the arguably two most researched regions of the world, Europe and the Middle East. It finally turns to assess the relationship between military conditions and the type of the state by looking at the impact of five key technological innovations in military weaponry: bronze weapons, the horse chariot, the invention of iron, the stirrup, and firepower arms. The point of that inquiry is to show that the balance of power among "producers" and "bandits" (in agricultural societies) and therefore on the nature of political institutions shifted with the war technology at hand.

## COMPLEX FORAGING SOCIETIES, THE AGRICULTURAL REVOLUTION AND INEQUALITY

As pointed out before, economic inequality came hand in hand with the introduction of new production technologies that changed the resource gradient of land. Although archaeological excavations seem to point to the presence of some material differentiation within a few Paleolithic communities in southern France about 30,000 years ago (Hayden 2001), inequality first appeared in a systematic manner following the formation of "complex" hunter-gathering societies in the Mesolithic period. In contrast to the simple, equal communities of hunter-gatherers [examined in Chapter 1 of the book manuscript], complex foraging communities are characterized by, among other things, a higher degree of technological complexity, greater sedentism, incipient forms of economic specialization, a stronger sense of territoriality and the presence of authority structures and status and wealth inequalities.[2]

Their origin can be traced back to the development of new tools and materials, such as boats, fishing apparel or pottery, that prompted the emergence of some highly productive patches generating predictable and accumulable resources such as fishing areas along a river or the coast (Kelly 1995; Gurven et al 2010).[3] A more effective exploitation of the environment translated into higher population densities. Looking at an ethnographic sample of about one hundred hunter-gatherer societies, Keeley (1985) shows that population densities averaged about 3.5 inhabitants per square mile in complex foraging societies (with a maximum value of 21.6 among the Chumash) versus 0.05 persons per square mile in simple foraging bands.[4] The higher and steady productivity of those territories increased the incentives of its occupants to defend those territories and spurred a more intense competition among individuals and bands to secure the control of those resource-rich areas.[5]

According to ethnographic work on contemporary complex foraging communities (Malinowski 1922; Earle (1997) on Hawaiian societies; Wiessner 2002), the need for defensive structures resulted in the emergence of political hierarchies led by "big men" or "chiefs". Those chiefs would then employ a mix of coercive and clientelistic practices (including the use of debt schemes) to aggrandize their position within their own community, therefore opening a process of social differentiation within the foraging community itself. Complex foraging communities emerged with the Natufian culture of the Mediterranean Levant around 12,000-10,000 B.C., which

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[2] For a definition of complex foraging communities, see Price and Brown (1985) .

[3] Keeley (1988) shows that complex foraging societies are correlated with much higher population densities than simple foraging societies.

[4] The classification of hunter-gatherer societies is mainly based on the presence of storage practices.

[5] For an empirical test of the correlation between resources concentration and an increase in the incentives to defend a circumscribed territory, Dyson-Hudson and Smith 1978.

seem to have enough burial remains pointing to some status differentiation within each human settlement (Hayden 2001). They were also prevalent among the Australian aboriginal societies in the resource-rich coastal areas of Arnhem Land and Tiwi –featuring a mostly gerontocratic authority structure and status-driven polygynous practices (Knauft 1991, Lourandos 1997). Finally, they also developed in rich-resources areas of North America, among the Riverton, the Chumash and the ethnographically well-researched communities in the Northwest Pacific, which had strongly stratified social structures that included slaves (Hayden 2001).[6]

The invention of agriculture starting in 9,000-8,000 B.C. generalized and accelerated the transition away from a world solely populated by primitive and equal societies. It did so in two steps. In the first place, the domestication of plants and animals increased the marginal productivity of land substantially. Population densities in the Neolithic Levant jumped to about 90 persons per square kilometer after the introduction of agriculture. Employing very intensive forms of land cultivation, such as those based on irrigation, a household may live with less than one hectare or a density of over 400 persons per square kilometer (Bellwood 2005: 14-19). Moreover, the growth of population and of production stimulated a process of economic specialization in agricultural societies that led to the development of a multiplicity of new tools and consumption goods. Hence, even though patterns of food consumption, health and life expectancy seemed to have been rather

[6] The existing literature has advanced other alternative explanations for the emergence of inequality. A first account sees population pressure as leading to the emergence of elites capable of resolving disputes, channeling information about available resources, etc. (Ames 1985). [However, such a functionalist explanation is hard to maintain in light of the discussion in Chapter 2 of the book manuscript]. A second school of work claims that resource abundance lifted the constraints of a nomadic life and "release[d] human nature" (Hayden 1981). Yet that assumes the highly debatable idea that some individuals naturally accept to be poorer than others. According to a third interpretation, resource abundance allows a set of self-aggrandizing individuals to manipulate the rest into obedience (Testart 1982) – a fact that fits well with the model of this book. Finally, some relate inequality to some symbolic or cultural transformations, a position that is difficult to maintain given the tight correlation between certain material changes (a technology-driven emergence of resource-rich areas) and inequality.

similar across simple foraging and agricultural societies, the latter were certainly much wealthier in material possessions (from furniture to jewelry and architectural construction) than the latter.[7]

In the second place, agricultural and pastoral practices raised land productivity in a non-uniform manner since not all territories are equally fertile. That gave way, in turn, to a pattern of sharp inequalities across individuals and human communities. Agriculture developed independently in several areas of the world: the Near East and Egypt, China, South Asia, Mesoamerica, Andean South America [West Africa and Ethiopia]. It then spread outwards, although only very gradually. For example, the westward expansion of agriculture from southwestern Europe to Ireland proceeded at a rate of 1 km per year over a span of 4,000 years. Such a slow expansion jointly with high variability of land fertility generated a clearly differentiated resource gradient ranging from a 'core' of rich lands to a 'periphery' of very marginal quality.

Such heterogeneity in land productivity together with a considerable temporal lag between the moments of planting and gathering a crop accentuated the territoriality of agricultural communities. Land property and the intergenerational transmission of land became central features in agrarian and pastoral societies. Summarizing a recent set of studies on the distribution of wealth in a twenty-one pre-modern societies, Smith et al. (2010) conclude that the intergenerational transmission of material wealth (land, livestock) in agrarian and pastoral societies, which shows a standardized coefficient for the relationship between parents' and children's assets averaging 0.61, equals or exceeds the level of transmission in modern industrial societies, where the standardized coefficient is 0.43 in the United States or Italy, and certainly in foraging communities, where the estimated coefficient is 0.13. As I examine in detail in the next two sections, the introduction of

[7] Moreover, their population growth sustained higher growth rates since the presence of some economic specialization (correlated with more population density) generally accelerates the rate of technological progress resulting from a process of learning-by-doing.

agriculture prompted the construction of formal political institutions, culminating in the state as an organization with the monopoly of violence. In this new economic and political context, social inequalities became much sharper. For instance, Smith et al. (2010) again report a Gini index around 0.4-0.5 for agrarian and pastoral societies versus less than 0.2 among hunter-gatherers for the twenty-one societies they have examined.[8]

### BIOGEOGRAPHY AND THE INTRODUCTION OF AGRICULTURE

Even though the domestication of plants and animals was not a necessary condition to disrupt the world of relatively equal communities prevailing in primitive societies, as attested by the preceding discussion on the origins and features of complex foraging societies, I turn now to employ the initial introduction of agricultural techniques across the world to test the political predictions contained in the model developed in Chapters 1 and 2.[9]

This strategy seems appropriate for reasons of measurement, coverage, temporal variance and econometric identification. First, although there is an important debate, which I tackle later, on the meaning of the agricultural revolution, agriculture as an economic practice is a relatively well defined concept in the literature. As a result, its introduction has been measured in a consistent way by employing broadly similar criteria across the world. Second, examining the introduction of agriculture (or its lack thereof) gives us maximum geographical breadth: agricultural practices

[8] Although suggestive, those results suffer from two important limitations. First, they are based on a small sample that probably underestimates the variance in Gini figures among agricultural societies. Second, they do not disentangle the economic from the political causes of inequality. I consider all these issues in Chapter 4.

[9] From a theoretical point of view, the adoption of agriculture is not a sufficient condition either to generate economic differentiation and to trigger the formation of state institutions. A simultaneous technological shock in an equally fertile territory would maintain the same level of equality across individuals. The creation of defensive structures and state institutions required, instead, the emergence of territorial discontinuities that produced conflict.

eventually traveled to all the corners of the globe. Third, since they did at a relatively slow pace, the timing of their introduction can be exploited for empirical purposes. Finally, as shown shortly, the nature of the biological and climatic characteristics of each territory strongly determined the timing of the introduction of agrarian practices. At the same time, agriculture led, with some temporal lag, to the emergence of state structures. Since it is hard to claim both that the introduction of political institutions was the direct result of strict biogeographical features, such as latitude or type of climate, and that climate and geography were shaped by states, it seems reasonable to conclude that the agricultural revolution made the state and not viceversa.

Although the literature on the causes behind the adoption of agriculture is very extensive, it may be classified into three broad positions. According to the first one, agriculture resulted from a long, perhaps unintended, process of learning derived from the constant interaction between plants, animals and mankind (Rindos 1980, 1984; Diamond 1997). A second strand of research has claimed, instead, that a declining marginal productivity of hunting and the related Malthusian constraints faced by growing populations of hunters and gatherers pushed mankind to invest in the domestication of plants and animals (Flannery 1965; Binford 1968; Higgs and Jarman 1969; Cohen 1977). In a related explanation, Gordon Childe (1951) attributed that shift to a process of desertification that, by depleting the number of available wild animals and plants, led human communities sheltered in some oases to develop agricultural techniques. Finally, a third school of thought traces the invention of agriculture back to some momentous shift in the cultural and symbolic norms of foraging societies (Bender 1978).[10]

Independently of whether the domestication of plants and animals took place as a result of a process of learning-by-doing or as an outcome of population pressures or as a result of an ideational shift – there is simply not enough evidence to refute one of them, it is obvious that the

[10] For general reviews, see Watson (1995), Bar-Yosef and Meadow (1995), Bellwood (2005), Barker (2006, chapter 1).

transition to agriculture only took place in those areas that were characterized by favorable biological, climatic and geographical conditions.[11] As reminded most recently by Diamond (1997), the agricultural revolution materialized in those regions of the world that had enough plants and animals suitable for domestication. Similarly, the introduction of agricultural techniques must have taken place in those world regions endowed with an appropriate climate and soil.

To examine the transition to an agrarian economy across the world and to determine the extent to which it was shaped by a specific set of biological and environmental constraints, I have proceeded to divide the globe in regular geographic quadrants defined by 10 degrees in latitude and longitude (starting at the intersection of the Equator with the Greenwich meridian) for which there is some land mass. There are 234 such units – 203 if we exclude the Antarctica. For each quadrant I then code the variable "*Years to Agriculture*", that is, the years it took agriculture to appear in the geographical center of the quadrant since the beginning of the Holocene (9,500 BC).[12] The data is built employing the information gathered in the surveys written by Bellwood (2005), Pinhasi (2005) and Barker (2006) on the first existing evidence of plant (and animal) domestication. For those areas where agriculture has yet to develop I assign a value of 11,500 years (9,500 plus 2,000 years). The data ranges from 1,000 years (that is, the introduction to agriculture took place around

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[11] The third model, which relies on a process of cultural change, seems farfetched since it does contain an explanation of the ideational shift itself that triggered the adoption of agriculture and it cannot account for the strong covariation between material conditions (in the form of climate, geography and availability of domesticable species) and the timing of the agricultural revolution. Recent archaeological work has recently refuted Gordon Childe's theory, which for a while became highly influential because it instantly overcame old unilineal developmental theories.

[12] In those case where the geographical center coincides with the sea, the coding is done for the closest land area to the geometrical center of the quadrant.

8,500 B.C.) in the Middle East to 11,500 years (in places which still have no agriculture today) in Antarctica.[13]

The codification of the agricultural transition by geographical quadrant expands previous work done by Hibbs and Olsson (2004), Olsson and Hibbs (2005) and Putterman (2008) in a very substantial way. Hibbs and Olsson date the years since the transition to agriculture in eight regions of the world, following the information presented by Diamond (1997). They then regressed the time to agriculture on a vector of biogeographical conditions (which is a first principal component of climate, latitude, continental axis and continental size). Putterman codes the transition to agriculture in 112 countries (defined according to their contemporary borders) and again regresses that measure on the same composite vector. Although Putterman's data set is larger, its geographical coverage is still partial (the number of sovereign countries is close to 200) and the coding must come with considerable measurement error since certain countries, such as Russia, China, the United States, Australia or Chile contain rather diverse climates and geographies.

To measure the environmental and biological conditions that fostered (or constrained) the introduction of agriculture, I have considered the following variables:

1. *Number of Domesticable Species.* The number of species suitable for domestication are taken from Olsson and Hibbs (2005) and come for ten separate regions of the world.[14] The number

[13] An alternative approach prefers to date the introduction of agriculture in a particular territory as the moment in which agriculture becomes the dominant mode of subsistence there (Kenneth & Winterhalder 2006) or even when human communities followed a strategy of agricultural intensification (Thurston and Fischer 2007; Shenk et al. 2010). Following this second strategy postpones the timing of the introduction of agriculture substantially – from about 4,000 years in the Middle East (from ca. 8,000 B.C. to 4,000 B.C.) to 1,200 year in the Andean region (from 2,500 B.C. to 1,300 B.C.). This approach has two main drawbacks: the available data has a narrower geographical coverage; and measurement has a highly subjective component because it implies making arbitrary decisions about the extent to which daily food supplies came from agriculture and it seems to rely on other parameters such as the existence of complex social institutions.

of domesticable animals ranges from 9 in the Middle East to 0 in Iceland. The number of plants goes from 33 to 0.

2. *Climate.* The measure follows Köppen's system of climatic classification. It ranges from 1 (worst climate for agriculture) to 4 (Mediterranean and West Coast climate). [15] I code each unit of observation by looking at the geometrical center of the quadrant.

3. *Latitude* of the geometrical center of each observation. I also add the square of latitude to capture any potential non-linearities in the effects of latitude.

Finally, I consider two additional variables to approximate the costs of diffusion of agricultural techniques from those regions than transited to agriculture first:

1. Major *axis* of continent, that is, longitudinal degrees between the extreme eastern and western points of the continent divided by the distance in latitudinal degrees between the extreme northern and southern points of the continent. The axis ratio goes from 0.1 (in the Pacific Ocean) to 3 (for Asia). The axis ratio measures the fact that, as emphasized in Diamond (1997), a predominant East-West orientation speeds up the diffusion of agricultural techniques within continents since new agriculturalists do not need to modify the received plants to new climatic conditions.

2. *Island*, that is, whether the unit of observation (or most of it) belongs to an island or not. It is a proxy for the role oceans play as a barrier to the adoption of agriculture.

[Figure 1 about here]

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[14] Those regions are: Near East-Europe-North Africa, East Asia, Southeast Asia, Sub-Saharan Africa, North America, Central America, South America, Australia, Pacific Islands and Iceland.

[15] The coding is as follows: 1 for tundra and ice (climates of type E in Köppen's classification), dry tropical climates (climates of type B) and subarctic climates (Dc and Dd in Köppen's); 2 for wet tropical (climates of type A); 3 for temperate humid subtropical and continental areas (types Caf, Caw, Da and Db in Köppen's system); and 4 for dry hot summers and wet winters (types Cb, Cc and Cs).

Figure 1 displays the correlation between the time at each agriculture was introduced and a composite index of biogeographical conditions. The latter is the equally weighted average of climate, latitude, axis and island, where each variable is set at its relative value in the corresponding quadrant with respect to the maximum value in the world. The abbreviations in Figure 1 correspond to the contemporary country that matches the geometrical median of the area—hence there may be more than one observation represented by the same abbreviation, such as Russia or the United States. Figure 1 is certainly indicative of the role that environmental and geographical factors played in the transition to agriculture: scoring high in climate conditions and having the geographical conditions that facilitate the diffusion of domesticated plants (being located in a continent with a high latitude to longitude axis) resulted in much earlier domestication dates.

Models 1 through 3 in Table 1 estimate the separate effects of the environmental and geographical variables on the years it took each quadrant to transit to agriculture.[16] Model 2 excludes the cases of Antarctica. Model 3 excludes those units where agriculture was introduced after the great explorations of the modern area, that is, from 1,500 A.D. onwards. All the variables are strongly significant in the three models. The r-squared is 0.54 in Models 1 and 2. It falls slightly to 0.45 in Model 3. A shift in the climate index from the worst to the best conditions leads to the introduction of agriculture about 2,400 to 2,800 years earlier. The size of the coefficients for axis ratio and island underscore, in turn, the importance of geographical barriers to explain the agricultural revolution. All other thing equal, agriculture spread 2,000 to 2,500 years earlier in Asia than in America. The sea delayed the process of diffusion by 1,700 to 2,300 years.

[Table 1 about here]

[16] As pointed out above, the estimations both of Hibbs and Olsson and of Putterman simply regress timing to agriculture on a single index of biogeographical conditions.

According to Diamond (1997) and Hibbs and Olsson (2004), the impact of those environmental and geographical conditions on the timing of agriculture took place through the number of domesticable species available to each human community. Accordingly, Models 4 and 5 in Table 1 test the covariation between the number of domesticable animals and plants and climate, latitude, continental axis and island. The estimations capture about 56 and 47 percent of the variance respectively. A two-point shift in the climate variable is associated with a change of 1 animal and 3 plants. The axis ratio covaries strongly with the number of species that can be domesticated: the maximum value of 3 implies about 11 animals and 24 plants. Being an island reduces the number of domesticable plants and animals by 3 and 10 respectively. Finally, latitude has some small effect on the number of plants. Given those results, Model 6 turns to explore the impact of the number of domesticable species directly on the timing of agriculture. The effect is positive for plants but strongly negative for animals. Moreover, the explained variance is low at about 17 percent. These results may be just a function of the considerable imprecision of the estimates: the data for domesticable species comes at a very level of aggregation (10 regions). But they probably point to the fact that although the number of available species may have mattered to explain the transitions to agriculture in the first place, the territorial expansion of agriculture was ultimately determined processes of learning-by-doing and diffusion mostly shaped by environmental and geographical constraints.[17]

## THE FORMATION OF POLITICAL AUTHORITY

Both the process of economic differentiation across territories and individuals and the growing possibility of long-term food storage and asset accumulation that resulted from the

[17] In a regression that includes both environmental variables and the number of domesticable species, the latter cease to be significant.

invention of agriculture led to the formation of stable political institutions holding the monopoly of coercive means and projecting them over a specific human community.

As explored in the following section, the cohesiveness, military capacity and territorial scope of those institutions varied with and the nature of the technologies of war in place. While men only had very simple weapons (such as rocks and sticks), political authority was rather horizontal and prone to collapse. Modern post-Westphalian states only appeared after the invention of gunpowder generate sufficiently high economies of scale in the production of violence. Yet all the available anthropological evidence shows that the creation stable power structures came hand in hand with the emergence of highly productive patches and, particularly, with agriculture. Already in relatively primitive horticultural societies, such as the Yanomamo in the Amazon basin (Earle and Johnson 2000) or the Tsembaga and the Enga in New Papua Guinea (Rappoport 1967; Meggitt 1977), power was exercised by "big men" that appealed to their fierceness and military prowess to lead their human communities and to galvanize them into military action against other groups. However, their political integration around them tended to be short-lived: when there was no immediate danger of war, which was the result of strong land competition due to increasing population densities, social units would quickly fragment into a decentralized network of households and dispersed hamlets. In the agricultural societies of the Pacific, the formation of chiefdoms (characterized by hereditary elites) was similarly related to defensive needs. In the well-researched case of the Trobriand Islands, several villages united in a local "cluster" under a permanent leader in response to an endemic state of warfare prior to British occupation (Earle and Johnson 2000). The royal chiefdoms of Hawaii did not emerge to manage any irrigation systems, as initially claimed by Wittfogel (1957) and Service (1962), since they were rather small and limited to a single local community each (Earle 1977, 1978). The formation of a complex monarchy, with a paramount chief owning all the lands and governing an aristocracy of district and community chiefs, was instead the result of protracted warfare to control the most fertile lands (Earle and Johnson 2000).

A similar story arises from the existing archaeological research. Political institutions emerged after (and never before) the transition to agriculture (cf. Thurston and Fischer, ed. 2007, and the chapters therein). In the most investigated region where agriculture appeared independently, the Middle East, there were several villages with an estimated population in each one of them of three to four thousand inhabitants in the southern Levant already in the seventh millennium before Christ (Kuijt 2000). The existing non-domestic structures, such as the defensive walls and the temple shrine of Jericho, from about 6,500 BC (Yadin 1963, Finer 1997), point to the existence of some collective authority. Similarly, recent work on the Euro-Asian steppes indicates that some forms of political authority only emerged after the domestication of animals and plants and the formation of relatively large urban concentrations (Anthony 2000).

The historical evidence of the link between technological innovation and state building becomes much stronger after writing was invented around the end of the fourth millennium before Christ. All states invariably formed in areas that had first transited to agriculture. At the end of the fourth millennium BC there were a few city states, with several thousands of inhabitants, a centralized political authority and fortified walls, in southern Mesopotamia. Egypt became unified under a single monarch at around 3,000 BC. By the end of the third millennium several palaces were built in Crete, spawning the Minoan civilization. A few hundred years later continental Greece witnessed the emergence of several monarchies within what has been called the Mycenaean civilization. The Harrapan culture, with large urban agglomerations and fortified structures, flourished in the Indus valley in the middle of the third millennium BC. The first firm evidence of a state structure in East Asia has been put at around 1,850 BC with the Shang dynasty governing northeastern China. In America, urban settlements and state structures developed in the two main cradles of agriculture: in Mesoamerica about two thousand years ago and in the Andean area around AD 500-700 or perhaps earlier.

## State Formation Across the World

I start exploring the forces behind the process of state formation by looking at the time at which political institutions appeared in all geographical quadrants of the world (as defined earlier). More specifically, I define a state as the existence of a specialized organization with the quasi-monopoly of coercion over a well defined territory. I code an area as having a state if there are contemporary writing materials that report the existence of those structures or if, absent writing records, there are sufficiently large fortified structures that point to the existence of armies and states. I employ the information provided in Kinder and Hilgeman (1974), Mann (1986) and Finer (1997) and several regional histories to date the approximate century at which political institutions formed. In coding the emergence of states I take a conservative approach: for example I date the emergence of states at around 3,000 BC in Mesopotamia and the Near East (when writing records appear for the first time) even though Jericho seemed to have had some fortified structures a few thousand years earlier. Pacific islands are not coded because it is unclear whether (and especially when) complex tribal chiefdoms were born before Europeans explored that area.

[Figure 2 here]

Figure 2, which displays the association between the appearance of state institutions (vertical axis) and the spread of agriculture (horizontal axis) in all the geographical quadrants of the world, reveals three main empirical patterns. First, the transition to agriculture always preceded rather than followed the formation of states. Second, states came into being with a temporal lag with respect to agriculture. Finally, that temporal gap shrank over time, probably due to two facts. On the one hand, the dissemination of intensive agriculture, which started around 4,100-4,000 BC (Barker 2006), raised output and the possibility of accumulation, and stepped up the incentives to establish political institutions. On the other hand, several innovations in military technology resulted in a much higher concentration of coercive resources in the hands of a few individuals. Until the end of the fourth millennium, men employed stone, a material that was too cheap and easily available to give any strong advantage to any of its users, to build weapons. The introduction of copper helmets and swords revolutionized the dynamics of war: they coincided with the appearance of the first Mesopotamian city-states. A few hundred years later, the invention of bronze, an alloy of common copper and tin, exacerbated those trends toward more military specialization (and the creation of states) for two reasons: the hardiness of bronze gave a considerable military advantage to its users; the scarcity of tin and its very localized sources "made it a substance on which it was easy to levy high market prices and heavy transport tolls and taxes at the point of delivery" (Keegan 2004: 238), further fostering that process of concentration of military might among certain strata.

[Table 2 here]

Table 2, which estimates the relationship between the transition to agriculture and the formation of states, confirms the previous discussion. Models 1 and 2 estimate the impact of biogeographical conditions on the birth of states, with and without Antarctica respectively. All the variables are strongly significant and operate as expected. Models 3 and 4 examine the relationship between year of transition to agriculture and year of birth of political institutions (again with and without Antarctica). The relationship is extremely strong with and $r^2$ around 0.6. Model 5 then instruments agriculture through biogeographical conditions to confirm that the process of state formation follows rather than precedes the domestication of animals and plants. Finally, since one can claim that diffusion effects may play an important role in the process of state formation, Model 6 looks at those cases where political institutions formed 'originally' in each area – and not as a result of conquest or colonization by outsiders. The explained variance is about the same.

### VIOLENCE AND POPULATION MIGRATIONS

Besides linking the formation of states to the agricultural revolution (and military technologies), the model in Section 1 sheds light on the origins and direction of violence, with the poor, non-agricultural populations looting the technologically advanced, sedentary societies that emerged after the domestication of plants and animals. That prediction turns out to be a very strong regularity in human history. Populations in peripheral, less rich lands have tended to breed much more war-prone populations than fertile lands. As Adam Smith (1776) already noted, "wealth (…) which always follows the improvements of agriculture and manufacture (…) provokes the invasion of all their neighbors. An industrious, and upon that account a wealthy nation, is of all nations the most likely to be attacked." (Book V, Chapter 1, Part 1).

Ancient Mesopotamia and Egypt, the first centers of agriculture in the Middle East, withstood successive waves of invaders originating in the Caucasus and the Asian steppes such as the Hurrians in the third millennium and the Hyksos in the late second millennium. The Roman Empire fell under the pressure of Germanic tribes. Medieval Europe endured the attacks of periphery populations such as the Vikings, Slavs, Turks and Mongols. Similarly, China was raided and at times governed by several steppe tribes. In Mexico and Central America, once-periphery groups such as the Aztecs came to dominate the core lands of the region.

### MILITARY TECHNOLOGY AND TYPE OF POLITICAL INSTITUTIONS

As pointed out at the beginning of the paper, the type of state, ranging from a 'self-governing' or republican constitution to a monarchical or dictatorial regime, depends crucially on the military ratio between looters and producers. As military technologies benefit the former, that is, as bandits' comparative advantage at waging war increases, monarchies become more spread and horizontal polities or republican compacts less frequent.[18] War technologies (ranging from the type of weapon to the organization of an army) also affect the political structure or internal hierarchy of monarchical systems, which, following a commonly accepted approached in modern political thought (Anderson 1974: 397-400), ranged from despotic systems to feudal kingdoms. In despotic or sultanistic regimes, such as the one prevailing in the Ottoman Empire and in most Asian kingdoms, servants are vertically integrated in a state structure and depend completely on the monarch. In a feudal monarchy the allies of the ruler, even when they were subservient or vassals to the latter, conserve some autonomy of power (in the form of weapons or assets) and often participate in some institutional structure (such as an assembly of warriors or a parliament of notables) that 'constrains' the monarch (or, at least, monitors the execution of the pact kings and vassals have struck with each other).

Probing the impact of war technologies on the nature of political institutions faces substantial empirical challenges. War technologies can be roughly clustered in two groups: the types of weapons employed in the battlefield and, the organization of the army (including the kinds of tactical strategies made in war). Although they ultimately linked to each other (relying on horses and horse chariots leads to the development of a strong cavalry and the use of highly mobile units to harass the enemy), I treat them as two separate domains and focus on the impact of weapons over organization on political institutions three reasons. First, the organization of the army is generally linked to (and often follows from) strict technological innovation in weaponry: for

[18] In addition to the type of war technology, the costs of self-defense for producers may be affected by the levels of competition among looters. A bandit-lord who has to fend off the assault of other agents of his same type will have fewer resources left to enslave other communities of producers. As emphasized by Hansen (2000), many (if not most) of the thirty city-state systems that he has identified emerged in the margins of empires or kingdoms with insufficient means to exercise complete control over their nominal territories. For example, after the collapse of the Carolingian empire, the exercise of political authority was substantially weak in the decentralized areas of the Lotharingia: that may explain why European cities emerged mostly in the axis Flanders-North Italy already in the early Middle Ages (Dhondt 1976).

example, the hegemony of cavalry was a direct consequence of the introduction of the stirrup. Second, changes in military organization and tactics are harder to trace and more volatile in nature (many military strategies are related to the creativity of a particular general) than armament. Finally, the structure of the army is prone to be endogenous to political choices: the organization of an army (for example, in terms of the strength and autonomy of its rank-and-file vis-à-vis its leadership) may be fashioned by its leadership to maintain type of power structures in place (again, from feudal to sultanistic).

The rate of military innovation in weapons is partly a function of the general rate of technological change (which, as stressed in chapter 1, derives through a process of learning-by-doing) and partly a function of societal and political institutions. However, once a new and more effective weapon is invented, societies hurry to adopt it independently of their institutional set-up. Otherwise, they disappear. Accordingly, the emergence of new arms (from knifes to cannons) may be arguably thought of as exogenous to the choice of political institutions and can be exploited to gauge the impact of war technologies on the distribution of power across individuals. More specifically, I look at the political consequences of what have been considered five key technological innovations in military weaponry: the use of metals and particular bronze to manufacture weapons; the development of the horse chariot; the introduction of iron; the invention of the stirrup; and the expansion of gunpowder.[19] Whenever it is possible, I examine their effect conditional on a second (strongly exogenous) parameter: the geography to which they were applied.

In the discussion of the impact of those different military innovations, the goal is to show that when the new technology of war shifts the balance of power in favor of looters and away from

[19] Although these technological innovations do not exhaust the list of invented weapons (since there are other tools such as the bow, fortifications, etc.), they are arguably the most important in military history (Andreski 1968, Keegan 2004).

producers, republican or horizontal compacts give way to monarchical regimes. Notice that the structure of the test is asymmetrical in the following sense: the existence of monarchies (or a dictatorship) does not disprove the theory even when the military advantage of looters over producers is low because a dictator or monarch may govern alone if he can destroy the capacity of the opposition to coordinate against his rule (Tullock 1987; Kuran 1991). In other words, monarchies can exist even when weapons do not give their rulers much comparative advantage. But republican polities cannot survive when challenged by powerful looters.

## The Metal Revolution and Bronze Weapons

As mentioned before, the existing archaeological evidence shows that the first Neolithic agrarian communities in the Middle East tended to organize in relatively compact urban nuclei endowed with shared infrastructures (such as walls and temples) that pointed to some form of political life. Although they presented some traces of labor specialization, most studies agree that households were the basic units of production. They also conclude that they were "homogeneous with regard to wealth and status" (Voigt 1990: 7). Individual high-status burials at that time were very scarce (Simmons 2000), there were little differences in residential architecture (Kuijt 2000) and the existing communal structures did not seem to embody any status differentiation (Monahan 2007).

The formation of states characterized by a clear hierarchical political structure and some kind of division between a military, religious and bureaucratic elite and a mass of subordinate laborers only took place around the late fourth millenium, that is, a few thousand years after the domestication of plants and animals. Their emergence coincided with the metal revolution and the use of copper to build short-range weapons, such as maces, axes, swords, helmets and shields. Copper maces and axes have been dated from as early as 3,500 BC and 3,100 BC respectively. An Egyptian palette of the end of the fourth millennium depicts spears, shields and bows. (Yadin

1963). Several steles from the period, such as the one of the king of Lagash, Eanatum II, showed also soldiers wearing metal helmets and marching arrayed in columns. It is from that period of time that we have clear evidence of fortified cities in the Palestine area already by the end of the fourth millennium (Yadin 1963) and in Mesopotamia in the first half of the third millennium (Keegan 2004).

Copper weapons were not very effective since they were heavy and cracked easily. Bronze, an alloy of copper and tin, had a much bigger impact on war and on the structure of political institutions. Its relative malleability as well as its sturdiness gave a clear competitive edge to those that employed it. Moreover, the scarcity and geographical concentration of tin resulted in a correlated concentration of power in the hands of a few armies and their rulers. Bronze helmets and swords were in use in Mesopotamia by around 2,300 BC. It was at that precise moment of time that the old Mesopotamian city-states collapsed and were replaced by the first big monarchical states in the Middle East – Sargon of Akkad, for example, created an empire of roughly the size of modern Iraq (Keegan 2004: 132-133; Anthony 2010).

Likewise, the formation of strong state institutions is correlated with the development of strong bronze technologies in China. In the late Neolithic, there were several social systems in the middle Yellow River valley, such as the Longshan culture, underpinned by political institutions: some sites were walled and had some palatial structures and there were high-prestige burials. However, the size and disposition of urban nuclei across the region seems to point to many small competing polities coexisting in the area and governed by chiefdom-level structures (Liu and Chen 2003). The first centralized political system only appeared in the first half of the second millennium around the Erlitou site in the Yiluo basin: the population settlement pattern in the region took a strongly hierarchical shape with a large town (reaching perhaps 30,000 inhabitants) and multiple secondary nuclei; the Erlitou site was characterized by high levels of stratification with strong burial differences across individuals and a large temple-palace complex. Although the production of Bronze was known to the Longshan people, their metallurgical techniques were limited to making small objects. Multi-piece mold casting techniques were only developed after 1700 BC. Erlitou's bronze foundry was located in close proximity to the palatial area and metal production was put at the service of the ruling elite to produce weapons and prestige goods employed in rituals. Archaeologists have not identified any clay mold to make agricultural implements (Liu and Chen 2005). The large-scale production of bronze (from the so-called Erlitou Phase III onward) coincides with the territorial expansion of Erlitou's material culture. Although it is not possible to interpret the spatial distribution of Erlitou's artifacts and production techniques (such as ceramics) as a sign of political control, its geographical reach (to the south until the Yangtze River) points to the formation of a powerful polity. Erlitou "emerged from a sea of chiefdoms" and its "rapid expansion … suggests that other regional polities, most likely chiefdoms, were relatively weak and could not compete with the first state" (Liu and Chen 2005: 169).

Erlitou entered a phase of decline by the middle of the second millennium. That coincided with the rise of the early Shang state (the Erligang culture), centered around Zengzhou, about 50 miles east of Erlitou. The new state inherited and strengthened the political structures and territorial patterns of expansion of Erlitou. Zhengzhou developed into a large, walled city, stratified between an elite occupying the inner city and a population of commoners engaged in craft production in the outer ring. Bronze was still under the control of the rulers and directed to the production of weapons and ritualistic objects (Liu and Chen 2003: 85-99). The Erligang culture expanded beyond the borders of the Erlitou culture from southern Inner Mongolia to northern Hunan. Most of the expansion, which was accompanied by population migration and colonization processes, was military in nature and was directed to the control and exploitation of natural resources, especially copper, tin, lead, and salt. Several lead isotopic analysis of Shang bronzes show a process of substitution of southern copper mines for western copper mines. That change in the geographical sources of copper matches a shift in the location of Erligang-early Shang sites (Liu and Chen 2003: 126-130).

## Horses and Two-Wheeled Chariots

The introduction of horses and, especially, of two-wheeled chariots transformed war-making and the distribution of political power even more decisively. The domestication of the horse took place by around the middle of the fourth millennium BC among nomadic pastoralist groups in the Euroasian steppes. The horse led to an increase of the territory that could be exploited economically: it increased the scale and efficiency of herding and it expanded the distance over which goods could be traded; and it led to the formation of a naturally expanded. From a military point of view, it led to emergence of a mounted raiding. Raiding remained circumscribed, however, to the harassment of other tribes and the theft of cattle until the invention of the short bow in the second half of the second millennium BC. At that point the cavalry was born: as Anthony (2010) puts it "arrows could be fired behind the rider with penetrating power. This maneuver, later know as the 'Partian shot', was immortalized as the iconic image of the steppe worker." (223-4)

The social and political consequences of horse raiding have been well studied in the context of the Americas. Native Americans adopted the horse fairly quickly and independently of their degree of contact with the Europeans. Moreover, American Indians developed most of the equipment and techniques related to horse riding: for example, Ewers (1955) determined that, out of the 119 traits he identified as characteristic of the North American Plains "horse complex", only 9 were direct European borrowings. In short, we can treat the introduction of horses as an one-time, exogenous shock. The expansion of horse raiding had to main effects. On the one hand, it exacerbated conflict and war and the expansion of particular tribes: the Apaches, Comanches and Sioux in North America; the Abipon, Mocovi and Mbaya in South America. In North America, with low initial population densities, horse raiding resulted in the destruction of many horticultural societies and the adoption of mounted raiding across tribes. In South America, with much higher population densities, horsemen enslaved some populations and extorted tributes from others. On the other hand, horse-using intensified social inequalities and redefined the role and status of men within the tribe.[20]

Although horse raiding redefined war and the structure of political relations, it was the two-wheeled light chariot that had a decisive impact in the process of state formation. By the end of the third millennium BC Mesopotamians had already developed four-wheeled and two-wheeled battle chariots. However, because they were too heavy and had to use a front axle, they were rather slow and their use restricted to frontal charges (and javeline throwing). At the end of the second millennium B.C. the invention of the spoked wheel and of light chariot bodies combined with the use of fast horses (in place of the former onagers) radically altered war making. The speed of transportation was multiplied by ten to about 20 miles per hour. Military effectiveness at the battle camp also increased extraordinarily. Since a single chariot crew (one driver and one archer) could kill about six men a minute circling at a distance of 100 to 200 yards, ten chariots (or twenty men) could cause over half a thousand casualties in about ten minutes. This generated "a chariot-warrior group, skilled fighters who monopolized the use of their specialized and extremely expensive vehicles, together with complementary weapons, such as the composite bow, and who dominated an entourage of secondary specialists – grooms, saddlers, wheelwrights, joiners, fletchers – essential to keeping war chariots and horses on the road" (Keegan 2004: 159).

The pastoralist peoples in the margins of the Eurasian steppes were the first to employ the horse chariot. They could easily apply all their riding and hunting skills to these new technologies of war. They applied to humans all their pastoralist techniques: "they knw how to break a flock up into manageable sections, how to cut off a line of retreat by circling to a flank, how to compress

[20] This paragraph relies on Anthony (1986:301-303).

scaterred beasts into a compact mass, how to isolate flock-leaders, how to dominate superior numbers by threat and menace, how to kill the chosen few while leaving the mass inert and subject to control" (Keegan 2004: 161). Attracted by the much richer agricultural lands to the South and East, they launched successive waves of attack: the Hyksos penetrated Egypt, the Hurrians and Kassites entered Mesopotamia, the Aryans conquered India and certain tribes originating in the proto-Iranian heartland in the Altai established China's Shang dynasty.

The success of the chariot peoples was generally short-lived: the Assyrian and Egyptian elites copied their war strategies and restored their control over their own lands. But the horse chariot led to the consolidation of a set of 'feudal' states with a narrow aristocracy of warriors exercising full control over their subjects (McNeill 1982). The Old Testament provides us with direct, written information on this transformation in Israel. During the period of the Judges, Israel's army was essentially a militia "made up of warriors from individual tribes who were summoned to battle only in emergency" (Yadin 1963: 255) and the internal organization and equipment of each tribal unit remained in the hands of each clan. In response to the attacks of the peoples of the sea, David and his descendants professionalized its army, introducing a regular army and a body of heavily armed charioteers, and effectively constructing a centralized monarchy in the process (1S: 7:15-10:27, 16:1-14).

**[Iron**

Whereas the use of bronze weapons and the horse chariot reduced $\theta_D$ or the military effectiveness of producers, the discovery of how to make weapons out of iron allowed a "relatively large proportion of the male population [to] acquire metal arms and armor" (McNeill 1982:12), mostly because there is a large supply of iron ores in the world (about 4 percent of the earth mass is iron ores). Although with some lag, this led to relatively more egalitarian political and social structures. After the expulsion of the Etruscan kings, iron cheapened the access to arms, made infantry central in war and secured the political ascendancy of Roman rural strata – to the point that only those who were too poor to equip themselves for military service were practically deprived of the vote" (Andreski 1968: 54).[21] In Greece, where the irregularity of the terrain (and the type of crops) made the use of chariots rather ineffective [check Victor Hanson], the spread of iron weapons broke the hegemony of the bronze-wielding aristocracy and equalized conditions. As pointed by Aristotle in his *Politics*, "where the nature of the country can admit a great number of horse, there a powerful oligarchy may be easily established", "where the troops are chiefly heavy-armed, there an oligarchy, inferior in power to the other [the calvary-dominated one] may be established" and, finally, "the light-armed and the sailors always contribute to support a democracy" (Book 6, Part 7). Thus, whereas Athens was a maritime republic, Thessaly, where the cavalry was always the main army, remained wholly unaffected by democratic movements (Andreski 1968: 45).]

**Stirrup and Armoured Cavalry**

After its invention in the early fourth century AD, the stirrup was widely employed in China by the fifth century, reached Japan during the following century and then Eastern Europe by the seventh century. By the ninth century the stirrup jointly with the saddle and the introduction of heavy armament such as the lance were fully widespread in Europe. Given the high cost of equipping one knight, the rise of the armored horseman tipped the balance again in favor of the specialized warrior. Under the Sassanid dynasty and after the introduction of heavy protective armor, peasants were reduced to harsh servitude. Under the T'ang dynasty the situation of the Chinese peasant also worsened considerably (Andreski 1968: 46-49).[22] At the elite level, however,

[21] Even when the armed men had the right to participate in politics, the vote was weighted according to the costs of the armament, that is, it was biased in favor of the cavalry and the heavy infantry.

[22] For an analysis of feudalism as a function of the introduction of the stirrup, see Lynn White Jr. (1962). But

the consequences differed markedly across subcontinents. Whereas the impact of heavy cavalrymen operated through cohesive armies and stable imperial bureaucracies in China (Dien 2000), in Europe it took place in a rather fragmented and conflict-ridden continent and became associated with feudalism.

The geographical diversity of Europe allows us to test directly the hypothesis that war technologies shape political institutions in the following sense. The stirrup and heavy cavalry constituted spread rather quickly across Europe. However, their effectiveness and ultimate adoption depended on the nature of each region's terrain. If military techniques mattered for politics, the institutions of feudal rule should have emerged in those areas favorable to combat by armored horsemen. Indeed, feudalism replaced previous forms of social and political organization in the broad plains of continental Europe, where heavy cavalry became the dominant type of military force: that transition was completed after Charlemagne in France and Germany; in Catalonia by the tenth century; in England with the Norman invasion;[23] in Poland after the gradual clearance of forests and morasses facilitated the movement of horses; in the lowlands of the Balkans with the invasions of the Avars, Bulgars, Magyars and Petchnegs; in Denmark by the beginning of the lower Middle Ages (Andreski 1968: 59-61, 66-67; Rogowski and McRae 2008).

By contrast, feudalism did not succeed in those terrains where heavy cavalry was ineffective. Infantry prevailed in Sweden due to the density of forests and in Norway, Switzerland and the highlands of the Balkans due to their mountainous nature. There was never serfdom in Sweden, the only country in Europe where representatives of the peasantry sat in parliament. The inhabitants of the high Swiss cantons always governed themselves through communal assemblies.

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see Bachrach (1970) and, more recently, Richard Alvarez. 2000. "Saddle, Lance and Stirrup: An Examination of the Mechanics of Shock Combat and the Development of Shock Tactics". Classical Fencing.

[23] English feudalism declined after 1300 – arguably after the English learned the use of the long bow in their wars against the Welsh (Andreski 1968: 64-65).

And in the highlands of Serbia, Bosnia and Montenegro “the semi-nomadic mountaineers [lived] under the tribal democracy tempered by patriarchy” without any ruling nobles (Andreski 1968: 67).[24]

According to Ferejohn and Rosenbluth (2010), medieval Japan presented the same pattern. Sea-faring pirates resisted political incorporation successfully. Likewise, the inhabitants of several islands, such as Kyushu and Shikoku, could maintain their political autonomy until the early seventeenth century. Finally, feudal rule hardly penetrated those areas, such as mountain villages and religious communities, protected by rough terrain.

**[The Use of Gunpowder]**

## CONCLUSIONS

[24] In Japan feudalism crystallized with the expansion of heavy cavalry – but faced too pockets of resistance in mountainous areas (Ferejohn and Rosenbluth 2009).

**TABLE 1. ESTIMATING THE CAUSES OF THE AGRICULTURAL REVOLUTION**

| | Model 1 | Model 2 | Model 3 | Model 4 | Model 5 | Model 6 |
|---|---|---|---|---|---|---|
| Dependent Variable | Years to Agriculture | Years to Agriculture | Years to Agriculture | Animals | Plants | Years to Agriculture |
| Constant | 11,252.23*** (455.15) | 11,140.79*** (461.60) | 10,150.80*** (522.74) | -3.023*** (0.683) | -5.214** (2.506) | 9,907.42*** (205.45) |
| Climate | -830.41*** (120.75) | -959.37*** (125.04) | -662.03*** (169.82) | 0.492*** (0.181) | 1.540** (0.665) | |
| Latitude | 8.06** (3.62) | -27.55*** (7.99) | -32.68*** (10.59) | 0.008 (0.005) | 0.0781*** (0.020) | |
| $(\text{Latitude})^2$ | 73.57*** (7.531) | 131.76*** (13.87) | 91.90*** (25.75) | -0.017 (0.011) | 0.0080 (0.042) | |
| EW Axis / NS Axis | -1,479.41*** (233.01) | -1,169.92*** (243.91) | -1,172*** (256.38) | 3.778*** (0.350) | 8.690*** (1.283) | |
| Island | 2,299.94*** (334.57) | 1,688.18*** (360.26) | 1,992.86*** (522.74) | -3.329*** (0.502) | -9.946*** (1.842) | |
| Plants | | | | | | 84.53*** (27.98) |
| Animals | | | | | | -505.02*** (93.66) |
| Universe | All | Excluding Antarctica | Excluding post 1,500 A.D. | All | All | All |
| Observations | 234 | 203 | 122 | 234 | 234 | 234 |
| R-squared | 0.55 | 0.55 | 0.45 | 0.56 | 0.47 | 0.17 |

Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

**TABLE 2. ESTIMATING THE EMERGENCE OF STATES**

| Dependent Variable | Emergence of State (Original & Derivative) | | | | | Emergence of State (Only Original) |
|---|---|---|---|---|---|---|
| | Model 1 | Model 2 | Model 3 | Model 4 | Model 5 (Instrumented) | Model 6 |
| Constant | 2,540.13*** | 2,474.89*** | 1,263.65*** | 1,255.73*** | 1274.43*** | 1,266.83*** |
| | (211.44) | (218.47) | (43.31) | (51.03) | (52.05) | (173.05) |
| Climate | -260.77*** | -311.08*** | | | | |
| | (54.82) | (57.75) | | | | |
| Latitude | 4.69*** | -9.44** | | | | |
| | (1.68) | (3.76) | | | | |
| $(\text{Latitude})^2$ | 22.85*** | 45.74*** | | | | |
| | (3.44) | (6.46) | | | | |
| EW Axis / NS Axis | -928.00*** | -792.82*** | | | | |
| | (112.16) | (119.89) | | | | |
| Island | 706.34*** | 448.98*** | | | | |
| | (155.59) | (171.48) | | | | |
| Year of Transition To Agriculture | | | 0.327*** | 0.324*** | 0.357*** | 0.446*** |
| | | | (0.016) | (0.019) | (0.025) | (0.046) |
| Observations | 229 | 198 | 229 | 198 | 198 | 46 |
| $R^2$ | 0.449 | 0.454 | 0.638 | 0.607 | 0.601 | 0.684 |

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Figure 1. Transition to Agriculture and Biogeographical Conditions

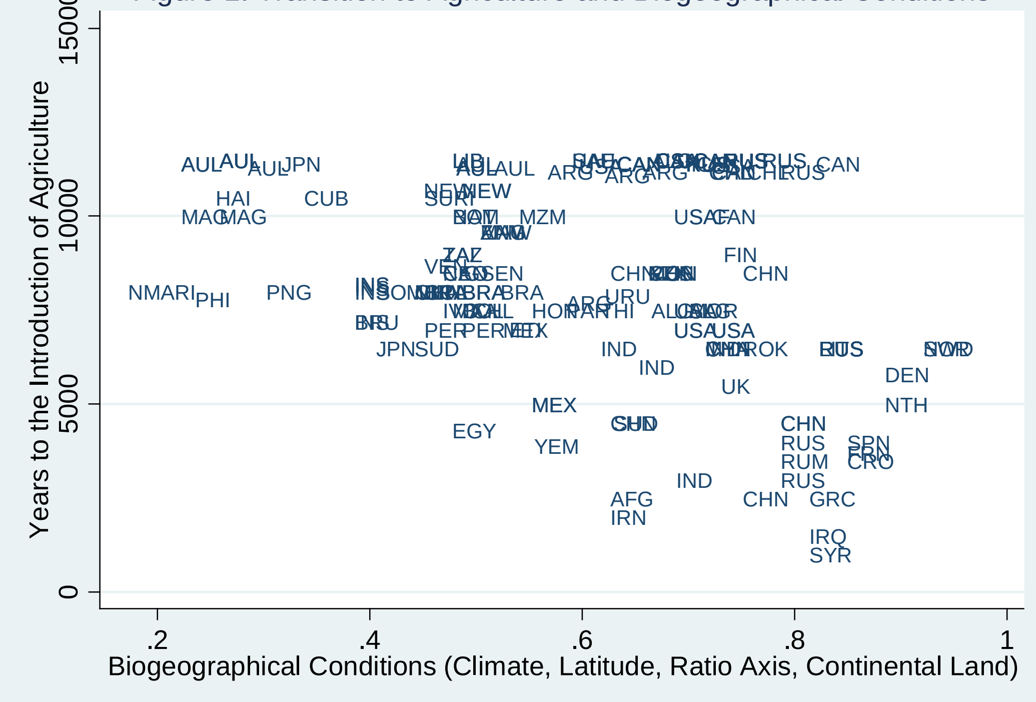


Figure 2. Transition to Agriculture and Birth of State Institutions