Historical Underpinnings of Institutions: Evidence from the Neolithic Revolution

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March 2010

Abstract

This paper provides evidence that the Neolithic Revolution, during which humans adopted agriculture for the first time, affected modern institutions by influencing the spread of early institutions. Using novel vegetation data and carbon dates that show the initial agricultural adoption from various Neolithic archaeological sites, as well as data on the level of executive power and local tax levels in Europe and East Asia, the results suggest that the regions which experienced the adoption of agriculture early maintained more extractive institutions that have persisted in the long run.

1 Introduction

How does one explain the rise and development of institutions? Many scholarly works from different fields have examined this important topic, producing invaluable insights with evidence suggesting that modern economic and social outcomes are influenced by past institutions. The importance of the past motivates this study of institutions from a historical perspective; in the endeavor to address the lasting role of early institutions, this paper provides evidence that a certain prehistorical event, namely the Neolithic Revolution, has affected modern institutions through its impact on the spread of early institutions. The Neolithic Revolution was a momentous event of the introduction of agriculture to humans around the year 10,000 BC, and first marked humans' departure from their hunter-gatherer lifestyle. Anthropological studies show that this shift in lifestyle must have had profound effects on population increase and the migration of groups of people, distinguishing regions of early agriculture from those of later periods. The empirical findings presented in this paper show that the regions adopting agriculture early also developed autocratic, extractive institutions in modern periods, while those adopting agriculture late witnessed democratic, egalitarian institutions. The paper provides a novel explanation for this result, arguing that a potential channel through which the Revolution influenced modern institutions was through the diffusion of farmers. It suggests that as farmers spread out to new lands during the Neolithic Revolution, they established institutions that were modifications of their predecessors' institutions, and outcomes of new environment and population. The institutions in the origin of agriculture therefore differed substantially from the ones in the later settlements. While in the origin, large communities formed centralized political systems with hierarchical orders, later migrants established egalitarian political systems that were more suitable for smaller population and new environment. Once these institutions were established, they were modified with traces of the past in the long run. This link back to the prehistoric foundation implies that ancient institutions may remain influential in modern institutional development.

In accordance with the argument that institutions are endogenous in nature, numerous studies have shown that institutions impact growth and development (Tavares & Wacziarg 2001, Rodrik & Wacziarg 2005, Acemoglu, Johnson & Robinson 2001, Acemoglu, Johnson & Robinson 2005, Olken & Jones 2006). Several works suggest that the consequences of enduring institutional characteristics remain significant in the long run, such that past institutions continue to influence today's economic and social outcomes. For example, Bockstette, Chanda & Putterman (2002) shows that countries that maintained state-level governments longer in history have more political stability, institutional development and income per capita. In their work, the authors find that the presence of state-level political institutions from the year 1 to 1950 has positive and statistically significant correlations with both income levels in 1995 and income growth from 1960 to 1995. Putnam, Leonardi & Nanetti (1993) traces the differences of institutional performances in South and Northern Italy back to the year 1100, arguing that Northern Italy's merchant ruling class with horizontal social networks and a lack of hierarchy led to better institutional performance than the South, a region marked by a history of autocratic rulers. In addition, Gennaioli & Rainer (2007) finds evidence of institutional inertia in Africa, in which the author finds that those regions with stronger precolonial political institutions allowed colonial and postcolonial African governments to modernize, and facilitate the provision of public goods.[1]

[1] The importance of the precolonial institutions upon arrival of colonizers and their enduring influence are the focus of seminal anthropological works of Bates (1983) and Boone (2003), which provide excellent historical accounts of institutional inertia.

One way to explain the persistence of institutions is to introduce the concept of investment in institutional capacity, which reduces the cost of maintaining the same institution in the next period. Besley & Persson (2007) for example provides a theoretical exposition of how rulers may invest in institutional capacity in order to sustain their institutions in subsequent time periods. The authors explain that current policy choices are endogenous to past institutions; they discuss institutional adoption of the past, where the state's legal and fiscal capacity result from ex ante investments under uncertainty to maintain institutional capacity. The argument for the current institutional capacity as a function of the past investment makes intuitive sense: once a fortress is built to detract invaders, for example, it is less costly to maintain it than to build it from scratch. Similarly, having an election is a much smoother process when previous elections witness no coup d'etat.

In addition to the past institutions influencing the present, several studies include geography as an important factor of determining current institutions. Both Acemoglu et al. (2001) and Engerman & Sokoloff (1997) for example emphasize the role of geography and historical events, such as the European colonization of the New World, as having had dramatic impact on institutions in the long run. In particular, Acemoglu et al. (2001) attributes the type of colonial institutions that were established to the degree of European settlement, which in turn was influenced by the geography of the settlements. That is, colonies in places conducive to establishing a large number of colonists and low mortality rates formed less extractive institutions similar to their home countries, since they wanted to keep the wealth within the colonies. The authors also argue that there was institutional inertia over time, such that postcolonial institutions remained similar to colonial ones, and the current income differences in these former colonies are traceable back to colonial times. Similarly, Engerman & Sokoloff (1997) suggests that current income differences between North America and Latin America stem from historic farming practice differences due to geographic differences in the two continents. Geographic differences led to large plantations in Latin America but smaller farms in North America, which then led to more extractive institutions in the former and less extractive ones in the latter.

Taking history further back, this paper addresses the potential influence that the Neolithic Revolution may have had on modern institutions. It looks at both prehistoric geography as well as the timing of initial agricultural adoption to investigate their impact on early institutions and tests whether they matter in the long term institutional development. In the literature, there are several works studying the impact of the Revolution on economic outcomes. Olsson and Hibbs (2004,2005) for example find that a region-level indicator of timing of the Neolithic revolution explains differences among countries in incomes and the quality of institutions in 1997; their studies show that the early adopters of agriculture have higher incomes and better institutions for economic development. Chanda & Putterman (2006) and Putterman & Weil (2008) find similar results in their global study of state-level agricultural adoption dates, even after controlling for factors such as the migration of people and the European colonization of the New World.

Adding to these seminal works with long term implications of the Revolution, this paper takes a new approach of considering the intrastate variation and allowing for the comparison of geographically proximate regions that would have been divided by the imposition of modern national boundaries. In contrast to the previous studies that focus on the Neolithic influence on modern income differences, however, the paper specifically identifies the types of early institutions that likely developed as a result of farming expansion. It introduces potential mechanisms behind the initial divergence of early institutions, and therefore proposes to enrich the study of the origin and the development of modern states.

The paper provides two simple models in order to explain the potential influence of Neolithic geography and the timing of initial agricultural adoption on institutions. These models address the empirical findings presented in the paper, which suggest that regions of good soil quality and early adoption of agriculture also developed more extractive, autocratic institutions. The first model therefore describes the rise of early institutions as a function of Neolithic soil quality, in accordance with other works that emphasize the importance of biogeography on the development of institutions (Acemoglu et al. 2001, Acemoglu, Johnson & Robinson 2002, Engerman & Sokoloff 1997). According to this model, the introduction of agriculture led to large settlements and population, and fertile lands suitable for cultivation provided more opportunities for the ruler to extract resources from his people, while less fertile lands witnessed less extractive institutions. The "extraction model" builds on Olson and Hibbs (2004, 2005) and Diamond (2005)'s hypothesis that places that adopted agriculture early did so because they had favorable climates. In terms of the predictions about the resulting institutions, however, this model obtains a different result from what these previous works suggest. In contrast to the claim that countries that were rich because of natural endowments had the resources to build institutions of high quality, the model shows that a "resource curse" was more likely to be present in such place. That is, during the Neolithic Revolution the regions of fertile lands also adopted agriculture early, and they also developed more extractive institutions; the regions that had less suitable lands for agriculture on the other hand adopted agriculture later and developed less extractive institutions. Once these institutions were established, the subsequent institutions inherited the institutional capacity from their predecessors and maintained the characteristics of early institutions in the long run.

The second model embodies the long term influence of early institutions and the Neolithic migration movement argument, and proposes that the rise of different institutions started with the introduction of agriculture and the spread of farmers. According to the model, the Revolution had important impact on the population increase and the diffusion of farmers. Once these farmers migrated to new settlements, they learned, imitated and incorporated lessons from the variable groups of early adopters, and established institutions different from their homelands'. According to this "diffusion" model, later settlements were more likely to develop egalitarian institutions, since they were occupied with migrants who came with the experience of varying institutions, dealt with smaller population and assimilation of hunter-gatherers. The Neolithic geography only indirectly influenced early institutions by affecting the land choice of migrants, who occupied fertile lands first before eventually settling in less suitable lands for agriculture. Therefore the model interprets modern institutions as outcomes of the timing of migration movement, rather than prehistoric geography.[2] These predictions differ from the extraction model, in which Neolithic geography, not the spread of farmers, explains the rise of different institutions.

When one considers the timing of agricultural adoption in a region, the difference in the models' predictions becomes more clear. First, the extraction model suggests that the timing of adoption in a region is irrelevant. The model implies that regardless of the initial adoption date, as long as the soil quality of the region is the same as the one in the origin, the region's institution eventually becomes similar to the one in the origin. On the other hand, according to the diffusion model, the timing of the initial settlement is indicative of the type of people and their institutions established in a region. A region far away from the origin, and therefore experiencing a later adoption date, develops a different institution from the origin even with the same soil quality. In the span of millennia during which agriculture spread throughout the

[2] Putterman and Weil(2008) also put forth the idea that the people, rather than the environment, determine the institution under a different context; the authors look at the ancestry of people back to the year 1500 for different countries, and find that the origin of a country's people matter for today's economic outcomes.

entire continent, the diffusion model suggests that, independent of soil quality, the initial timing of adoption has remained an important indicator for the spread of farmers and the subsequent establishment of different institutions.[3]

In the empirical section, the paper tests the two models by introducing a novel set of data measuring Neolithic vegetation variation for each region. The Neolithic vegetation states are rough indicators of soil quality; given that there is no soil quality data available for the prehistoric period, the paper introduces the vegetation data to estimate which regions had lands more conducive to agriculture. The paper also uses a dataset of discrete executive constraint scores for Europe during the years 1100 to 1850, ranging in values from 1 (dictatorship) to 7 (democracy), and local tax rates for Japan and China for the years 1869 to 1871, and 1908 respectively. These variables are outcome variables that characterize a region's executive power and the level of extraction. The empirical findings generally support the hypothesis from the diffusion model and suggest that through remarkably long term influence of early institutions, early adopters of agriculture maintained more extractive institutions. The model and the empirical evidence together provide a novel perspective on the role of Neolithic endowments and the timing of initial agricultural adoption on institutions.

The paper proceeds as follows: Section 2 provides the details of the two models that offer explanations for the inverse relationship between the agricultural adoption date and the modern institutional measures. Section 3 describes the data used for empirical results, and Section 4 discusses empirical findings for Europe and East Asia that support the models' predictions. Finally, Section 5 concludes by summarizing the findings and offering avenues for future research.

2 Two Development Models of Early Institutions

2.1 The Extraction Model

The introduction of agriculture leads to large settlements and competition for scarce resources. The social hierarchy evident in early civilizations, such as Sumer and Egypt, in and around the points of origin of agriculture suggests that these resources were not distributed equally (Olsson & Hibbs 2005). In explaining the rise of early extractive regimes, Bates, Greif & Singh (2004) for example argues that population increase and accumulation of wealth through agricultural production often lead to violence and private provision of coercion; furthermore, when the private means to protect wealth fail to secure peace with prosperity, the achievement of order requires the establishment of a state.[4] However as the state provides, it also extracts.[5] The introduction of agriculture is therefore likely to be positively correlated with the rise of an extractive institution. Extractive regimes can also arise in populated regions for other reasons; for example, Acemoglu et al. (2002) argues that highly populated regions were likely to form

[3] The model does not diminish the importance of land quality. Far from it, the timing of agricultural adoption was most likely dependent on the soil quality. Given two plots of land equidistant from the origin, farmers were more likely to occupy the one with better soil quality. In fact, the adoption date was dependent on both the distance from the origin and soil quality, among other factors. The empirical results show however that even after controlling for these factors, the adoption dates remain statistically significant and explain variations in modern institutions.

[4] Stevenson (1968) also finds that in studying the evolution of the indigenous states of tropical Africa, the density of the population is positively related with the creation of states.

[5] The apparent rise of an extractive government when in need of a state to protect property rights is what Bates et al. (2004) refer to as the "Weingast Paradox" in Weingast (1995): "a government strong enough to protect property rights... is also strong enough to confistcate the wealth of its citizens."

extractive colonies since larger population means more people can be exploited through forced labor or onerous taxation. In the "extraction" model, one may interpret the initial rise of the extraction-based economy as an outcome of the type of land, which determines the level of population and social stratification. Large family settlements and population increase due to agriculture lead to a primitive extractive economy where the ruling class benefit from taking away a portion of the outputs of the commoners. The extent to which the ruler can extract the output from the people depend primarily on the level of output that each person produces, which in turn is dependent upon the vegetation type/soil quality of the land. In other words, prehistoric institutions are driven by their natural surroundings and how agriculturally suitable the land is. Taking prehistoric geography as the main determinant of modern institutions follows the idea that the natural endowments even in the long run have a significant impact on economic and social outcomes. The extraction model (which is formalized more in detail in Appendix 1a) suggests that the level of extraction is entirely determined by the land's agricultural suitability, and that the geographic conditions causing a headstart of civilization and technology also likely lead to an extractive economy.

2.2 The Diffusion Model

The diffusion model is based on the "demic diffusion theory" (Bellwood 2005, Cavalli-Sforza, Menozzi & Piazza 1994), which claims that the diffusion of agriculture was through the physical spread of farmers from the origin of agriculture to other parts of the world.[6] Agriculture introduced population pressure and led to the migration of people from the origin of agriculture; as the migrants were equipped with agricultural technologies and settled in new lands, they expanded in numbers and dominated the aboriginal hunter-gatherers. Eventually population pressure within settlements led to similar migration movements to different locations, and the subsequent expansion and domination of an area's existing inhabitants. This chain of events continued until agriculture was adopted in all arable lands. Bellwood(2005:14-15) cites both recent and archaeological examples to show how internally fueled population growth among agriculturalists could be phenomenal, with such high growth rates ending as landscapes filled or as socioeconomic expectations changed.[7]

According to Putterman & Weil (2008), the impact of early development on current economic outcomes are better explained when one takes into account the ancestry of migrants in a country. This result can be interpreted as descendents of different migrants having inherited certain cultural traits conducive to economic development and withstanding changes in environment.[8] Similarly, there may exist a persistent institutional legacy, such that descen-

[6] The "demic" diffusion, first introduced by Ammerman & Cavalli-Sforza (1984, p.26-27, 61-62, 64, 100) refers to a diffusionary process by population growth and new settlements by farmers. On the other hand, the major competing theory, the "cultural" diffusion, involves a process without the movement of migrants. While the issue remains unresolved after decades of debates, the demic diffusion theory is better supported by the data presented in this paper. Similar support come from Bellwood(2005)'s work on the spread of ethnolinguistic groups, Cavalli-Sforza(1994)'s work on genetic spread and Bently, Alexander, Price, Luning, Gronenborn, Wahl & Fullager (2002)'s work on looking at strontium isotope analysis of early Neolithic skeletons. In genetics the demic diffusion will be marked by clines of genetic spread moving northwest from the Near East, while the cultural diffusion will show no such pattern. For evidence supporting the demic diffusion argument refer to Ammerman & Cavalli-Sforza (1984), Cavalli-Sforza et al. (1994), Sokal, Oden & Wilson (1991) and Pinhasi, Fort & Ammerman (2005). Chikhi, Nichols, Barbujani & Beaumont (2002) find an average contribution of between 50% and 65% by Near Eastern farmers to the European gene pool.

[7] For example, Hassan (1981)(P.125) suggests an increase consequent upon early agriculture to be rapid, with a possible increase in world population from 10 million to 50 million.

[8] In a different, more contemporary context, Fisman & Miguel (2006) provides an interesting study on diplomats' parking violations and their home countries' levels of corruption. The findings support the idea of strong

dents establish institutions similar to their ancestors, and build capacity to maintain similar institutional structures in the subsequent generations (Besley & Persson 2007). Under this argument, once an institutions is established in one place, a similar type of institution becomes replicated in the subsequent periods by the descendants. The institution may evolve over time, but maintains central traits of the past. The descendents who migrate to other lands however may have opportunities to establish new institutions, those that are more suitable for different environment and population. From a historical perspective, the Neolithic Revolution made a lasting impression on the development trajectories of early institutions, as the Neolithic farmers modified their institutions over the course of their migration from the origin of agriculture to unexplored lands. The migrant farmers who expanded from their homelands and settled down in new lands possessed their predecessors' behaviors and artifacts, which were transmitted over generations (Spolaore & Wacziarg 2006, Diamond 2005, Richerson & Boyd 2005). Given that these farmers confronted new environment and population, they relied on the knowledge of their ancestors' institutions when establishing institutions of their own. The culling process of choosing desirable institutions for late adopters was affected by environmental factors as well as past institutions and new population. This process explains how human societies in this period of migration accumulated different adaptations to a wide range of environment, before settling down and establishing long lasting institutions of their own. Such adaptations led to a dramatic increase in the amount of behavioral variations among groups, perhaps never witnessed before in human history (Richerson & Boyd 2005, p.107). The diffusion model argues that these learning processes and variations in behaviors had long term influence on institutions, such that modern institutions have their roots going back to the Neolithic Revolution when the initial divergence of institutions occurred as a result of the farmers' migration.

In order to understand how the spread of agriculture influenced the rise of different institutions, consider first areas that had domesticable crop species and initially attracted foragers to settlements and sedentary living. The subsequent adoption of agriculture and the development of complex political organizations in the origin of agriculture appear to have reinforced each other; the former contributed to population increases and large settlements, while the latter facilitated the coordination of large-scale waterworks for irrigation and flood control (Mitchell 1973). Large communities enabled the accumulation of non-portable possessions contributing to technology development (clay pots, for example), societies with specialized workforce including non-food-producers such as craftsman and nobilities. As described above in the extraction model, the rise of non-working class including the clergy and noblemen, the need to feed these non-farmers with surplus produce, as well as the need to protect surplus resources from invaders, all likely led to the rise of extractive political systems with hierarchical orders (Diamond 2005, Wittfogel 1956, Steward 1955, p.261).[9] Appendix 1b graphically describes the development process of institutions when agriculture gets introduced.

According to the demic diffusion theory, population pressure induced by agriculture would have induced a migration of farmers from a settlement to new lands. The late adopters of agriculture, who were colonists dispatched from the origin of agriculture, learned, imitated and incorporated lessons from the variable groups of early adopters. They adopted agriculture and modified their predecessors' institutions to establish their own according to their new environment and population, thereby forming societies of a different nature (see Appendix 1c). In

persistence in cultural norms.

[9] Wilson (1988) and Tilley (1996) even go on to argue that once people became sedentary, they were domesticated and fundamentally changed both social organization, and their psychological perceptions of the worlds. The Neolithic Revolution can then be seen as "an ideological phenomenon, a new way of thinking in which the primary material manifestations were funerary and ritual monuments" (Simmons 2007, p.20).

particular, while the early adopters in large settlements established extractive institutions that coordinated large-scale works, colonies in the frontiers became increasingly aware that the same type of institution was not suitable in the new lands. With the small population of farmers, the settlement was less likely to develop class divisions and centralized control over scarce resources. Furthermore, the coexistence of migrants with aboriginal hunter-gatherers meant that the farmers likely embodied some of the egalitarian traits of existing hunter-gatherer groups.[10] The development of institutions during the Neolithic Revolution was therefore characterized by early settlements becoming substantially different from late settlements, and the latter eventually becoming, over long periods of cumulative adaptation and modification processes, more predisposed towards establishing egalitarian, democratic institutions.

3 Data

The use of a detailed set of carbon-dates spread across Europe and East Asia allows for a measure of the initial agricultural adoption dates for each specific region in consideration. The paper uses a sample of calibrated carbon-dates from the Neolithic sites in Anatolia, the Near East and Europe available from Pinhasi et al. (2005). The data contains a full list of excavation sites (735 in total) that spans from the Fertile Crescent, where there are nine known points of agriculture, to Northwest Europe; the list includes the location coordinates as well as calibrated carbon-dates estimated for each site. For East Asia, the initial agricultural adoption dates are obtained from Stark (2006), Bellwood (2005), and Bale (2001).[11] The six archaeological sites with the earliest evidence of agriculture in East Asia are located in the Yellow River to the north and the Yangtze River to the south in China, with agriculture spreading to Korea and Japan over the time span of 6000 years. The paper uses ArcGIS Geostatistical Analyst's inverse distance weighting method and zonal statistics to obtain calibrated agricultural adoption dates for each region.[12] [13]

The data on the Neolithic vegetation variables for Europe and Asia are based on the maps from Adams & Faure (1997) and Oak Ridge National Laboratory's Environmental Sciences Division.[14] The vegetation maps are the result of a compilation of information of many experts of the Quaternary Environments Network (QEN). Adams and Faure address explicitly the endogeneity issue arising from a map of palaeovegetation backed up by previous assumptions about human subsistence, and assert that the maps are based overwhelmingly on non-archaeological sources. These include foremost the use of plant fossil data (non-domesticated at the advent of

[10] Lee & Devore (1968) argues that constraints on the possession of property as inevitable in mobile hunter-gatherer societies must have led to a generally egalitarian system, and reciprocal access to food resources among the local groups led to trust-building among the groups, while frequent visiting between resource areas prevented any one group from becoming too strongly attached to any single area. Given the mobile lifestyle and the need for large hunting grounds even for small population, Paik (2009) suggests that hunter-gatherers maintained cultural traits perhaps conducive to establishing institutions similar to today's highly industrialized economies: they live in relatively nuclear families, encourage independence rather than compliance in childraising (at least for males), think more in terms of "I", and imposes less emphasis on conformity and more on self-supporting lifestyles.

[11] For the full list of agricultural sites in Asia collected from various references, see Appendix 2.

[12] See Johnston, Ver Hoef, Krivoruchko & Lucas (2003) for more details on the methodology. Other deterministic interpolation methods (ex. radial interpolation) give highly correlated values (0.99). Given that the agricultural adoption dates were non-stationary even after removing the first order trend, the non-geostatistical method was used instead of kriging methods.

[13] Pinhasi et al. provides both calibrated and uncalibrated radiocarbon dates of these various sites- the two measures are highly correlated at 0.99 and I use the calibrated dates here. For a brief description of radiocarbon dating method see Diamond (2005, p.95-97).

[14] www.esd.ornl.gov/projects/qen

the Neolithic Revolution), the most direct source of information on past vegetation. Given that there are still large enough gaps in the pollen and macrofossil record across regions, however, other sources are used as well to supplement the picture from plant fossils. Proxy indicators of past vegetation cover and structure include animal fossils, which give a rough indicator of the ecology of an area in the past. Adams and Faure also argue that sedimentological processes depend on vegetation cover, either in the area where the sediment is being deposited or the area from which it is being eroded; certain types of sediments therefore may be used to support plan fossil data in more accurately describing the type of vegetation. Furthermore, the authors use the standard palaeoenvironmental assumption of the past existence of a monsoon belt, embedded in the drawing of the map. To a lesser extent, the trends predicted by general circulation models (GCMs), which examine the effects of the presence of lower sea levels, cold seas and massive ice sheets in the past are used to describe spatial patterns and vegetation boundaries as well.[15] Finally, the authors use biogeographical clues based on the present day distributions of flora and fauna, as a reference to what may have existed back during the Neolithic period. However, this approach is only used as a way to back up or dispute patterns suggested on the basis of palaeoenvironmental evidence, not as a primary source of ideas and opinions. For the purpose of this paper, the vegetation types listed on the maps are rough measures for the soil quality during the Neolithic period, and are ranked from the best to worst in terms of agricultural suitability as well as vulnerability to exploitation in Appendix 3.[16] In Europe there are nine different vegetation types: Desert, Dry Steppe, Ice, Lake, Polar Desert, Semi-Desert, Steppe-Tundra, Temperate Forest, and Wooded Steppe. In East Asia vegetation types include Semi-Desert, Tropical Rainforest, Dry Steppe, Montane Desert, Forest Steppe, and Cool and Warm Temperate Forest.[17] Each observation records the fraction of each vegetation type occupying the unit of land, summing up to one. Finally, the dataset includes the mean and standard deviation of elevation in each land unit.

For Europe, the outcome variables include Tabellini (2006)'s intrastate, region-specific executive constraint score between 1600 and 1850, as well as Acemoglu et al. (2005)'s state-level executive constraint scores between 1100 and in 1850 with the same coding as in POLITY project (index ranging from 1 indicating dictatorship to 7 indicating democracy). While the executive constraint score embodies more facets of institutional features than just the level of extraction, it is the most commonly used institutional quality measure in the literature. Tabellini(2006)'s Western Europe data is limited in the number of countries, but it allows for a more detailed intrastate analysis with 79 regions in a smaller geographical setting. Acemoglu et al. (2005)'s dataset consists of 26 countries (27 in total, including Southern and Northern Italy) and differentiates the executive constraint scores between Northern and Southern Italy, two regions that historically had very different institutions (Banfield 1958, Putnam et al. 1993).

The construction of the institutional variables for East Asia requires more detailed expla-

[15] For further discussions on the use of general circulation models, see Adams & Faure (1997).

[16] The rankings are based on the correspondence with J. Adams.

[17] The vegetation types are defined as follows. 1. Desert: very sparsely vegetated. 2. Dry Steppe: similar to Steppe-Tundra, with a more temperate climate, open woody vegetation types and low shrubs. 3. Ice. 4. Lake. 5. Polar Desert: very sparsely vegetated with only low herbaceous plants. 6. Semi-Desert: open scrub/grassland. 7. Steppe-Tundra: sparse ground cover, herbaceous with a few low shrubs. 8. (Warm) Temperate Forest: fairly tall, many broad-leaved evergreen/semi-deciduous angiosperm trees but moisture-requiring conifers also tend to be abundant. 9. Wooded Steppe (Cool Temperate Forest): closed forest, including mixed conifer-broad-leaved forest. 10 Forest Steppe: mainly herbaceous steppe, but with scattered clumps of trees or bushes in favourable pockets. 11. Montane Desert (Polar and Alpine Desert/ Dry Sparse Tundra): very sparsely vegetated with only low herbaceous plants/ mainly herbaceous or with low shrubs.

nation. Data are obtained for the time period between the 19th and the beginning of the 20th century; more precisely, the data are from the end of the Edo Period in Japan in 1869-1871, and the late Qing Period in China in 1908. This marks an era after which the Western influence dramatically changed the nations' institutional development; what remained as a continent deeply rooted in neo-Confucianism and autocratic institutions became exposed to the foreign concepts of democracy and communism, constitutions and modern nation-states. In China, the collapse of the central authorities in Qing meant that the local authorities exercised more power than ever before, while in Japan the years between 1869 and 1871 saw the last remains of its feudal system consisting of independent, sovereign domains before the Meiji Restoration.

In order to obtain a suitable institutional measure for the region, it is important to look at the local governments and the behavior of people being governed. Since there is much variation within each country in terms of how local institutions performed and when agriculture was first adopted, the amount of tax burden on commoners by the local authorities at the county (China) and domain (Japan) levels are collected, and taken as a measure for how much the local executives can extract rent out of their people. It is important to note that the collection of tax for the provision of public goods rarely characterized the feudal states in Japan, and local governments in China. On the contrary, under the centralized autocracy in China and feudal system in Japan during this period, historians cite incidents of tax imposed on commoners primarily as means to accumulate wealth for the elite. In Japan *daimyo*'s(vassal lords) who controlled their own domains exerted power through samurais; retainer stipends and personal expenses of the *daimyo* consumed most of the local government revenues (Ravina 1999, P.69) A greater number of samurais and heavier tax rate would have been positively associated with *daimyo*'s extent of power, controlling for the productivity and population for each domain. In China, the Taiping Rebellion during the Qing dynasty was at least partially a consequence of the hardship of an increased tax burden by the local and central authorities (Wang 1973, P.115). Collective actions brought on by commoners to oppose taxation came through various forms and kept the level of revenue extraction in check; these included signing petitions and outright rebellions, as well as consulting with local officials periodically to ensure that the demands of commoners were heard. The regions that were successful in keeping the local tax rates low likely had the active involvement of people taking interest in their local institutions.

Among the various taxes imposed, the most important were the land tax and the accompanying agricultural levies. Given that the two countries formed predominantly agricultural societies and rice cultivation constituted the main livelihood for the majority of the nations, cultivated lands and their attached tax rates became the main source of revenue for the rulers. For Japan, the data on local tax burdens imposed on commoners by the end of the Tokugawa regime, 1869-1871, is obtained from Ravina (1999). The output and tax burden per commoner and the size of land are assessed at the domain level. The data for China is obtained from Wang (1973)'s estimates of land tax revenue for provinces of China in 1908. For each county, the total tax collected is the sum of the *ti-ting* quota (the land tax and the labor services combined), the grain quota and their respective surcharges, as well as miscellaneous surcharges imposed (these include collection expenses as well as various province-specific levies specified by Wang (1973)). The provincial level population and cultivated land size, as well as the registered vs. the actual land size of the provinces are included. In addition, Wang(1973) constructs an indicator for whether a province was considered to be developed or not during the period. The Qing provinces are divided into three groups: developed, developing and undeveloped; population pressure in the developed provinces forced people to settle in hitherto unexplored lands, with the migration movement occurring from east to west.[18]

4 Empirical Findings

This section first presents results showing the inverse correlation between the initial agricultural adoption dates and institutional outcome variables, and then the test results of the hypotheses from the extraction and diffusion models. The two models discussed in the previous section differ in terms of their predictions on the significance of vegetation variation, and the adoption dates as proxies for the spread of early institutions. Specifically, the first model implies that the extraction rate in a settlement increases with the level of agricultural suitability, while the second model suggests that a later agricultural adoption date implies a lower extraction rate. While the two hypotheses are related (a following empirical analysis shows that regions suitable for agriculture in fact do tend to adopt agriculture earlier than those that are not suitable), the implications from the two models differ in one important aspect. That is, the extraction model implies that the Neolithic Revolution caused the initial rise of different institutions through population increase and variation in land quality, and that controlling for differences in agricultural suitability, the timing of initial agricultural adoption should not matter. The diffusion model on the other hand suggests that different institutions are the outcomes of the migration movement, and that the timing of agricultural adoption reflects the rate of the spread of the farmers. The model therefore suggests that both the adoption dates and differences in land quality explain modern institutional differences.

In accordance with the argument that the Neolithic vegetation and early institutions had long-term persistence in their characteristics, it is important to check whether the agricultural adoption dates, which proxy for different settlements during the Neolithic revolution, still remains robust after controlling for the modern agriculture. The Neolithic environment likely had an impact on both early and modern institutions in the form of the type of lands available for agriculture, as different Neolithic vegetations meant different qualities of soil suitable for farming. In order to test whether the Neolithic vegetation and the initial agricultural adoption dates indeed have long term consequences, the empirical analysis also includes the fraction of each land unit cultivated into croplands or pastures in modern times, and examines whether institutions are still determined by the Neolithic vegetation and the initial adoption dates. The dataset therefore includes a measure of the extent to which agriculture occupied lands by the year 1600 in Europe, obtained from Pongratz, Reick, Raddatz & Claussen (2008), as well as more detailed accounts of assessed harvest output in Japan and China in the years 1869 and 1908, respectively.[19]

The empirical findings in this paper generally support the implications of the diffusion model. While vegetation variation influences institutions in Europe, this influence mainly disappears when looking at local institutions in East Asia. The adoption date on the other hand remains robust and its coefficient statistically significant in both Europe and East Asia. This suggests that while arable regions lead to more extractive institutions, the causal mechanism

[18] The initial agricultural spread during the Neolithic expansion was from north to south; the empirical section discusses the recent agricultural migration during the Qing period in the opposite direction having a significant impact on the county extraction level.

[19] Using geographically explicit historical land use data available from the Center for Sustainability and the Global Environment (SAGE) at the University of Wisconsin and taking population figures from McEvedy & Jones (1978) as proxy for human land use activity, Pongratz et al. trace back the amount of land used for crops and pastures for all the years from AD 800 to 1992. For each region of Europe, the measure of modern agriculture is the fraction of land used up by crops and pastures.

may be through the geographic influence on the rate of agricultural spread, rather than a direct impact on the level of extraction as argued in the extraction model. The paper further investigates the influence of vegetation variation on the timing of agricultural adoption in a separate set of regressions; the findings from both Europe and East Asia confirm that regions of good soil quality (Temperate Forest, Forest Steppe) adopt agriculture faster than those with low soil quality (Ice, Montane Desert.). That is, vegetation variation, a rough measure for the variation of soil quality during the Neolithic period, affects institutions only indirectly through the timing of agricultural adoption. In conclusion, the empirical findings suggest that prehistorical institutions and events such as the Neolithic Revolution can together determine the development of institutions in the long run. The following analysis describes each regional findings more in detail.

4.1 Europe

Figure 1 shows a vegetation map of Europe at the advent of the Neolithic Revolution, while Figure 2 provides a visualization of agricultural adoption spread in Europe using the inverse distance weighting method. The agricultural origins in the Fertile Crescent are mostly located in the Semi-Desert and Dry-Steppe regions. In Figure 1, there are 11 vegetation types occupying Europe; the northern part of Italy, for example, is occupied with Dry-Steppe and Polar Desert regions, while the southern part is occupied almost exclusively with Wooded Steppe region. The Neolithic vegetation may have had a direct impact through its geographical influence on modern institutions, as evident in the sharp contrast between the two institutions in Italy (Putnam et al. 1993) and their vegetation states. Figure 2 shows all the Neolithic sites in the data, as well as the nine points of the origin of agriculture in the Near East (with the earliest known records of agriculture). The unit of scale for carbon-dates is "Before Present" (BP), where "Present" refers to 1950. The light-colored region of the map represents places of the latest agricultural adoption, which corresponds to low BP years, and the dark-colored region represents the earliest adoption, which corresponds to higher BP years. It is evident that the spread of agricultural adoption is fairly linear in the northwest direction, as discussed by Pinhasi et al. (2005).

Figure 3a delineates a map of the intrastate regions of 8 countries in Western Europe and their average executive constraint scores from over the years 1600, 1700, 1750, 1800 and 1850. Figure 3b is a map of the same regions with corresponding average agricultural adoption dates. For comparison, Figure 3a and 3b map 26 countries in Europe, with the average executive constraint scores and adoption dates respectively for the same years as in Figure 4a and 4b. In both figures, there is a northwest trend towards higher executive constraint score, and the time of initial agriculture is inversely correlated with the institutional variable. The spread patterns on the map suggest that the regions marked by migrants adopting agriculture late seem to have developed institutions with more executive constraint, and that the divergence has been persistent.

Table 1a presents the summary statistics: on average regions in Western Europe during the Neolithic period consisted of 42% Steppe-Tundra, 29% Wooded Steppe, 21% Dry Steppe, 6% Polar Desert, and 2% Ice. The standard deviations for these variables are quite high, however, and some regions are characterized by single vegetation type; all the regions in Belgium, for instance, only have Steppe-Tundra vegetation, while all the regions in Portugal only have Wooded Steppe vegetation. A scalar variable termed "soil quality score" is constructed by assigning an ordinal score for each vegetation type according to Appendix 3. For each geographic unit of analysis, the soil quality score gives the average level of agricultural productivity. The maximum score in the intrastate level analysis is 4 (for a region entirely covered by Wooded Steppe), and the minimum score is 1 (for a region covered by Ice or Polar Desert). The average year of initial agricultural adoption is 6929 years BP, with the earliest known agricultural adoption date in Western Europe being 7585 years BP and the latest 5710 years BP. There is a gradual increase in the average executive constraint score between the year 1600 and 1850. In particular, the average score between 1750 and 1850, during which the Industrial Revolution takes place, increases to 3.66 from 2.39, indicating a clear trend towards democratization in Western Europe.[20]

In comparison to the intrastate summary statistics in Western Europe, state-level indicators in Table 1b show that on average most countries in Europe occupy the regions of Steppe-Tundra(40%), Dry-Steppe(22%) and Wooded Steppe(20.4%), while small fractions or none of the countries occupy Temperate Forest, Desert or Mediterranean Scrubs. The main difference between Western Europe and the rest of the continent is that more countries outside Western Europe adopt agriculture early and are located mainly in the region of Dry-Steppe. At the state level, there is more variation in vegetation types and the range of soil quality score varies between 4 (Wooded Steppe) and 0 (Ice/Tundra Steppe). The earliest agricultural adoption date for a country in Europe is 9310 years BP, about 3700 years earlier than the country with the latest adoption date. The average adoption date for a country is earlier than the average for the regions in Western Europe, and the executive constraint score at the state level is lower than the average for Western Europe in the intrastate level analysis as expected. There is nevertheless a gradual increase in the average score from the year 1100 to 1850, during which the average increases from 1.22 to 2.52.

The regressions presented in Tables 2a and 2b test the significance of the Neolithic vegetation and the initial agricultural adoption dates on modern levels of executive constraint. Table 2a first examines the impact of the two Neolithic variables at the intrastate level, and Table 2b presents the regression results at the state level for comparison. In Column 1 of Tables 2a and 2b, the set of Neolithic vegetation variables are jointly significant, even after controlling for the modern agricultural variable (the fraction of land cultivated by the year 1600). Column 1's in both tables present the test results of the extraction model prediction, and find that regions with better vegetation for agriculture (than Ice) do lead to lower executive constraint scores.[21] In Table 2a, the coefficient for the fraction of a region occupied with Wooded Steppe, which represents the most fertile type of vegetation state for agriculture, is -5.783. This is the lowest value among all the coefficients, and implies that a 10% increase in the fraction occupied with Wooded Steppe, rather than Ice, decreases the constraint score by 0.58. The negative values of the Neolithic vegetation variables also hold in Column 1 of Table 2b.

The coefficient value for the adoption date under Column 2 of each table supports the diffusion model hypothesis; that is, a region that adopts agriculture early is also more likely to have less executive constraint. The value of -2.013 in Table 2a for example implies that a region marked by agricultural adoption 1000 years earlier is likely to experience a 2.013 drop in the executive constraint score. The coefficient value of the adoption date remains statistically negative and significant under all specifications in both tables. Finally, Column 3 includes both the vegetation and adoption date variables. Table 2a shows that the set of Neolithic vegetation variables is jointly significant and the adoption date variable is also statistically significant, with signs supporting both models' predictions. When the adoption date variable is included, however, the coefficients of the vegetation variables decrease significantly in magnitude under

[20] The Industrial Revolution, was arguably one of the most significant events in the human history, marking a departure from the Malthusian Era and the beginning of high income growth; see (Clark 2007)

[21] Since the vegetation variables add up to one, the fraction of a region ocupied with Ice is omitted.

Column 3. This decrease implies that much of the influence of vegetation variation on the outcome variable may be through the timing of agricultural adoption. Furthermore, the result under Column 3 of Table 2b does not reject the hypothesis that the vegetation variables are jointly insignificant. Furthermore, controlling for the adoption date, the coefficient values for the Neolithic vegetation variables under the column change signs to yield the opposite findings from the extraction model. The adoption date variable on the other hand remains statistically significant and supports the diffusion model hypothesis. Column 4 in each table replaces the set of vegetation variables for the scalar soil quality variable, and shows that the statistical significance of the adoption date does not change with the different vegetation measure.

Given the regression results in Tables 2a and 2b, one may ask what the role and magnitude of vegetation variation is in influencing the timing of agricultural adoption. Given a choice of lands that are equidistant from the homeland, it is reasonable to imagine that the first migrants are likely to settle in lands that are the most fertile for agriculture. That is, controlling for the distance away from the homelands, regions with fertile lands may witness earlier agricultural adoption. The implicit assumption here is that the cost of travelling is directly proportional to the distance covered, such that the lands farther away are more costly to move to. This also means that controlling for land types, agricultural adoption occurs later in regions farther away from the origin. To test these predictions, regions in Europe are dissected into 1-degree by 1-degree square cells,[22] and for each cell the fractions that different vegetation types occupy and the minimum distance away from the points of origin of agriculture are obtained. Furthermore, for each cell the mean and the standard deviation of elevation are obtained as rough measures for cost of travelling in addition to the distance measure. Table 3a provides the summary statistics for Europe; there are 1579 cells covering the continent. The average minimum distance to one of the nine archaeological sites, in which the earliest dates of agricultural adoption dates are recorded, is 17.95 degrees and the mean elevation is 0.39 degrees. On average, about 40% of each cell is covered by Steppe-Tundra, the dominant vegetation type that covered most lands in Europe at the advent of the Neolithic Revolution.

Table 3b presents the results where the dependent variable is the mean agricultural adoption date for each cell and the findings correspond to the extraction and diffusion models' predictions. The omitted vegetation variable here is the fraction of the cell occupied by Ice; with the exception of the fraction occupied with Lake, each vegetation variable has a statistically significant and positive coefficient value under all specifications to suggest that even controlling for the distance away from the origin of agriculture, the lands suitable for agriculture witness agriculture earlier than those that are not as suitable. The coefficient value for the fraction that Temperate Forest occupies under Column 2 for example suggests that an increase of the fraction of Temperate Forest occupying the unit of land by 10% expedites the adoption of agriculture by 213.46 years. Dry-Steppe, Wooded-Steppe and Semi-Desert, the regions more similar in climate to Temperate Forest, have positive coefficient values greater in magnitude than Steppe-Tundra and Polar Desert, the regions that lead to delayed agricultural adoption due to their less favorable conditions for agriculture. The coefficient value for the distance measure is negative and statistically significant, to suggest that as predicted by the hypotheses, the regions farther away from the origin of agriculture adopted agriculture later, controlling for Neolithic vegetation variation. In Column 4, the coefficient value of -60.57 for the distance measure implies that increasing the distance between a region and the origin of agriculture by one degree leads to 60.57 years of delay in the adoption of agriculture. Finally, both the mean and standard deviation of elevation, included as additional geography control variables, have

[22] 1 degree is about 111km.

statistically significant coefficients. The standard deviation of elevation can be interpreted as a rough measure for the cost of travelling; the results from Column 3 and Column 4 suggest that regions of high standard deviation in elevation adopt agriculture later.

4.2 East Asia

Figure 5 shows the initial agricultural spread in East Asia, and Figure 6 provides a visualization of the agricultural adoption spread in East Asia. In Figure 5, there are 2 vegetation types (Cool and Warm Temperate Forest) occupying Korea and Japan, and 7 vegetation types (Semi-Desert, Tropical Rainforest, Dry-Steppe, Montane Desert, Forest Steppe and Warm and cool Temperate Forest) occupying China. Figure 6 shows all the Neolithic sites in the data, as well as the six possible points of origin of agriculture in East Asia. The unit of scale for carbon-dates is Years BC. The dark-colored region of the map represents places of the latest agricultural adoption, which corresponds to high BC years, and the light-colored region represents the earliest adoption, which corresponds to lower BC years.

Figures 7a and 7b present the agricultural spread in the domains of Japan and the variation in domain tax burden levels, respectively.[23] A similar pattern between the two maps is visible: the northeast and southwest domains in Japan had more tax burdens, while the middle part experienced less taxation by the local authorities. Tables 4a, 4b and 4c show the summary statistics as well as the regression results for Japan testing the hypotheses from the two models. Table 4a lists socioeconomic factors including each domain's tax rate, number of retainers, assessed output, as well as the size of land. In Tables 4b and 4c, the dependent variables are the amount of tax burden per commoner and the number of retainers, respectively. Column 1 result in Table 4b shows that as predicted, the output size in each domain influences the outcome variable; a higher domain tax is associated with higher productivity. There appears to be little vegetation variation in the lands;[24] the regression outputs under Columns 2, 4 and 5 in Table 4b for example show that the fraction of land occupied with Cool Temperate Forest has a small and statistically insignificant coefficient value. The adoption date variable on the other hand has a positive and statistically significant coefficient value, with or without the inclusion of the vegetation variable. This variable remains statistically significant and positive in sign for both tables; a later adoption of agriculture is linked to higher local tax burden as well as a greater number of retainers under each *daimyo*. The positive value clearly suggests that an earlier agricultural adoption date leads to a higher local tax rate. For example, according to the result in Column 3 of Table 4b, a domain marked by earlier agriculture by 1000 years would have experienced an increase in tax burden of 0.164 (in *koku*). This implies about a 33% increase in the tax rate from the mean. In Table 4c, a domain marked by earlier agriculture by 1000 years would have experienced an increase in the number of retainers per 100 commoners by 1.308.

Figures 8a and 8b show the spread of agriculture in China as well as the county-level tax

[23] For each domain the domain tax burden variation is calculated as (actual tax burden-estimated tax burden)/(estimated tax burden), with the estimate obtained from regressing the tax burden as a function of the number of retainers, assessed output per commoners, and acres. The variation attempts to capture the extent of the domain lord (*daimyo*)'s power over local taxation, *controlling* for the number of retainers, output and land size.

[24] Japan is divided into two types of land: Warm and Cool Temperate Forest. The distinction between the two, as described in Footnote 12, may not be sufficient to capture differences in the agricultural suitability. Both the Kyushu site in the Southwestern Japan and the Kazahari site of Northeastern Japan developed agriculture around 900 BC, and the two are located in different type of land (Kyushu in Warm Temperate Forest, and Kazahari in Cool Termperate Forest).

burden levels, respectively.[25] Tables 5a and 5b give the summary statistics and regression results. China summary statistics in Table 5a show a list of socioeconomic factors that likely influenced local tax burden at the county level other than the Neolithic factors. These include the official *ti-ting* (the land tax and the labor services combined) and grain quota mandated by the central authorities, as well as the population, and various measures of how much land is cultivated out of the total. The list also includes a dummy variable for whether a county is in a developed province or not. In a developed province, agriculture is already the main source of livelihood for most commoners, whereas a developing province is considered as a "frontier" land for those who do not own farmlands in the developed provinces. During the Qing period there was a rapid increase in population and consequently a migration of people willing to settle in new lands: from the east, where all the developed provinces were located, to the west. The indicator variable is thus included in the regressions to control for the more recent flow of migration in the opposite direction from the initial agricultural spread.

In the case of China, on average the lands during the Neolithic period consisted of 73% Temperate Forest, and 26 % Tropical Rainforest. These vegetation types would have been suitable for agriculture, and it is no surprise that they provided grounds for another Neolithic Revolution independent of the Fertile Crescent in the Middle East. The fact that almost all the lands in the analysis are agriculturally suitable also implies that the impact of soil quality on local institutional variation would likely have been small in China. The soil quality score is again constructed by assigning an ordinal score for each vegetation type. According to Appendix 3, a rough ranking of vegetation in terms of agricultural suitability is constructed. The maximum score in the intrastate level analysis is 4 (for a region entirely covered by Temperate Forest), and the minimum score is 0 (for a region covered by Montane Desert or Boreal Forest). The average year of initial agricultural adoption is 4285 years BP, about 2700 years later than the average year in Europe.

Table 5b shows that the mandated quota levels by the central authority, provincial population, registered area variables as well as the provincial development indicator all affect the local tax rate. According to the output under Column 1, a population increase of a million people is likely to increase the county tax rate by 1229 *taels* (the currency unit during the Qing period), while a county located in a developed province is likely to experience a 10529 *taels* higher tax rate. Furthermore, regions that have higher quotas mandated by the central authority also tend to have higher local tax rate, as evident in the positive coefficient values of *ti-ting* and grain quota variables. Columns 2 and 4 of Table 5b show the regression results that include the county-level Neolithic vegetation variables. Column 5 shows a different specification with the soil quality score replacing the set of vegetation types as a measure for land quality. When the set of vegetation variables are controlled for under Column 4, the coefficient value for the agricultural adoption date becomes statistically significant and increases in magnitude, compared to the value under Columns 3. Under columns 2 and 4, the F-test statistics do not reject the joint null hypothesis of the variables having zero coefficient values; the test results suggest that the Neolithic vegetation variables do not have significant roles in determining the local tax rate in China during this period. The positive signs of the adoption date coefficients in Table 5b imply that China may have indeed experienced a similar impact of farmer diffusion

[25] For each county included, the local tax burden variation is calculated as (actual total tax burden-estimated total tax burden)/(estimated total tax burden), with the estimate obtained from regressing the total tax collected as a function of ti-ting quota, grain quota, provincial population, cultivated land size, area of registered land, actual area and indicator for whether a county is in a developed province or not. The local tax burden variation attempts to capture the extent of the local magistrate's power over commoners in extracting rent, *controlling* for other variables that affect the total tax collection amount.

on the subsequent institutional development, as was more clearly evident in Japan and Europe. The impact however seems much weaker, given the multiple points of origin of agriculture as well as a more recent reverse migration movement.

In Tables 6a and 6b, geographic regions in East Asia including China, Korea and Japan are dissected into square cells and analyzed in the same manner as presented in Tables 3a and 3b for Europe. According to Table 6a, which shows the summary statistics of 796 cells occupying the regions of East Asia, Cool and Warm Temperate forests occupied most lands at the advent of the Neolithic Revolution. Table 6b results confirm that vegetation variation influence the adoption date, although the influence of vegetation types on the adoption date is not robust or uniform across specifications.[26] Exceptions include the fractions occupied with Semi Desert and Forest Steppe; for both vegetation types, the positive coefficient values suggest that an increase of the fraction of Semi Desert or Forest Steppe occupying the unit of land expedites the adoption of agriculture. As in the case of Europe, controlling for Neolithic vegetation variation, regions closer to the origin of agriculture are also early adopters of agriculture; Column 2 of Table 6b for example shows the coefficient value of -199.44 for the distance measure, implying that an increase in the distance between the origin and the region by 1 degree is likely to delay agricultural adoption by 199 years. The results hold when the elevation measures are included, and match the results obtained in Europe.

5 Concluding Remarks

The study of institutions entails an emphasis on the significance of time, as institutional capacity and capital investment for growth inexplicably depend on the past institutions. Investigating the endogenous nature of institutions from a historical perspective thus yields valuable insights not obtained from the cross-sectional analysis of different states in a contemporary setting. The focus of this paper is to provide an explanation for the rise and the development of early institutions that have influenced the institutions of today. The paper traces the history of institutions back to the Neolithic Revolution, and investigates the empirical finding that the regions of early adopters of agriculture witnessed more autocratic, extractive modern institutions than the regions of late adopters.

The paper introduces two models to explain the relationship between the adoption date and modern institutions. In the extraction model, the level of extraction, or the rent obtained by the ruler in a settlement, is purely an outcome of the type of vegetation the settlement is located in, and the timing of adoption of agriculture plays no independent role in determining the extraction amount that the ruler can take from the people. A land occupied by the type of vegetation readily available for agriculture witnesses a higher rate of extraction, while the opposite holds for a land that requires more effort in cultivation. As a model that emphasizes the importance of prehistoric biogeography, this model closely follows the current stream of economic literature studying the impact of the Neolithic Revolution and the prehistoric environment on economic and institutional development (Chanda & Putterman 2006, Putterman & Weil 2008, Olsson & Hibbs 2004, Olsson & Hibbs 2005), in which the timing of agricultural adoption is taken as a channel through which the prehistoric environment affects current income levels in the long run. While the extraction model takes Neolithic vegetation variation as the main driver behind different rates of extraction, the diffusion model explains the rise of different regimes principally as an outcome of the spread of farmers during the Revolution. It shows that extractive regimes

[26] As in the case of Table 2b, the omitted variable in the regression is the fraction of land occupied with Montane Desert.

were no longer viable in later settlements, with sparse population and new environment where the migrants had opportunities to establish new institutions. This diffusion model emphasizes the migration movement and institutional culling process, rather than the type of land that the migrants settled, to have long lasting effects on subsequent institutions. Using the carbon dates of the initial agricultural adoption from Neolithic archaeological sites in Europe and East Asia, vegetation data at the advent of the Neolithic Revolution and institutional measures for various years, this paper tests these two models and mainly finds empirical support for the diffusion model.

In conclusion, the empirical findings suggest that the Neolithic Revolution played a crucial role in the spread of early institutions. The divergence in these institutions appear to have persisted over long periods of time, as evident by the strong inverse relationship between the adoption date and modern levels of constraint on the executive as well as local tax rates. This paper focuses on the study of new institutionalism from a historical perspective, which provides an understanding of the possible channels through which societies arise. Related research topics to this work include finding the links between the Neolithic Revolution and the current linguistic and cultural differences as reflected in responses from various surveys, such as the World Value Survey. Following Putnam et al. (1993), Platteau (2000) and Tabellini (2006)'s work, Paik (2009) for example tests the hypothesis that the initial divergence from the Neolithic Revolution may have led to differences in institutions that in turn developed enduring and different cultural traits for each group of people. The paper compares responses among the respondents from the World Value Survey across different regions in Europe and matches these differences geographically to the regions' initial agricultural adoption dates.

The significance of the diversity of Indo-European languages and its implication on modern institutions are also promising research areas in the study of institutions. Several works in anthropology as well as economics have looked into linguistic divergence as a proxy for cultural differences; there is evidence that genetic and linguistic distances are positively correlated, and both have been used to determine institutional differences as well as human capital and growth differences.(Fearon 2003, Spolaore & Wacziarg 2006, Alesina, Devleeschauwer, Easterly, Kurlat & Wacziarg 2003) Bellwood (2001) in particular makes an argument for the potential that the early dispersals of agriculture and the early spreads of certain major language families are linked to the same underlying set of causes- the Neolithic Revolution. From this perspective, a relative homogeneity of the Indo-European language spread can be indicative of a rapid demic expansion (continuous population growth along an expansion front) across Europe as argued by Ammerman & Cavalli-Sforza (1984), while more diverse linguistic and archaeological populations can indicate a delayed expansion across Europe where the hunter-gatherer neighbors of the agriculturalists could have been assimilated into the agricultural economy more gradually with traces of persistent hunter-gatherer traits. The split-off in the Indo-European linguistic tree in Europe, whether punctuated(rake-like shape) or gradual (tree-like shape), can be a result of some complex environmental barriers and native hunter-gatherer resistance. If Bellwood (2001)'s argument stands correct, the linguistic divergence then may proxy for the long term level of heterogeneity of a region occupied by both migrant farmers and aboriginal hunter-gatherers. It can be used to determine whether the subsequent institutions in these heterogenous regions differed from those in homogenous regions, controlling for the timing of agricultural adoption.[27]

[27] Depending on the type of institutions that the native hunter-gatherers established prior to the Revolution, the hunter-gatherers may have survived the invasion, or perished. The crucial assumption in the demic diffusion theory is that farmers were able to replace hunter-gatherers, perhaps with the advances in technology that came with the introduction of agriculture. One can imagine that only the hunter-gatherer institutions of centralized, heavily militarized regimes were able to resist the migrant invasions, in which case the heterogeneous group of

Investigating the relationship between linguistic diversity and the Neolithic Revolution may therefore add new insights to the existing studies of ethnic fractionalization, its origins as well as its impact on social and economic outcomes.

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Appendix 1a: Extraction Model

To begin, suppose that in a settlement, the introduction of agriculture causes population increase and subsequent social stratification, such that there are two classes: the ruling class and the commoner class. Suppose also that each class can be represented by a single member; that is, within each group all members are identical. In a two-stage setting, the representative ruler first decides how much to extract from the representative commoner. The commoner then decides how much to produce. Both the ruler and the commoner make decisions based on the vegetation type of the land, denoted as $\alpha \in (0, 1)$. A low level of α denotes the type of vegetation that initially has high marginal returns to effort and are readily available for agriculture. It is representative of the origins of agriculture where the cultivation of crops come as both a result of human innovation and part of the natural evolution of wild crops, and includes vegetation types such as Warm Temperate Forest. A high level of α on the other hand denotes the type of vegetation unsuitable for agriculture and requiring more effort to cultivate, such as Polar Desert and Ice.

In the first stage, the ruler chooses τ the extraction rate to maximize rent R:

$$\max_{\tau \in [0,1]} R(\tau) = \max_{\tau \in [0,1]} \tau l^{\alpha}, \text{ s.t. } l \in [0, 1]$$

where $\tau \in [0, 1]$ is the fraction of output taken away from the commoner, and $l \in [0, 1]$ is the expected level of effort exerted by the commoner to produce crops.

In the second stage, the commoner chooses l the level of effort to maximize his utility π:

$$\max_{l \in [0,1]} \pi(l) = \max_{l \in [0,1]} (1 - \tau) l^{\alpha} - l$$

The utility is determined by the portion of the output that the commoner keeps $(1 - \tau)l^{\alpha}$ and the disutility from working the land $(-l)$.

The equilibrium extraction rate, τ is solved using backward induction. The second order condition (SOC) of the commoner's utility function is always negative; setting the first-order condition (FOC) to be zero and solving for l thus gives the optimal effort level l given the extraction rate τ:

$$l = \left(\frac{1}{\alpha\,(1 - \tau)}\right)^{\frac{1}{\alpha - 1}}$$

Substituting l, the ruler maximizes his rent with respect to τ:

$$R = \tau\left(\frac{1}{\alpha\,(1 - \tau)}\right)^{\frac{\alpha}{\alpha - 1}}$$

where setting the FOC to be zero gives the equilibrium extraction rate τ^*[28]:

$$\tau^* = 1 - \alpha$$

[28] SOC of the rent function gives

$$\frac{\partial^2 R}{\partial \tau \partial \tau} = \frac{\alpha}{(\alpha - 1)^2\,(\tau - 1)^2}\left(\frac{n}{\alpha - \alpha\tau}\right)^{\frac{\alpha}{\alpha - 1}}(2\alpha + \tau - 2)$$

which is always negative for $\alpha \in (0, \frac{1}{2})$, such that $\tau^* = 1 - \alpha$. For other values of α, there are three possible values that τ can take to maximize R: 0, $1 - \alpha$, and 1. $\tau = 0$ and $\tau = 1$ yield stricly smaller R than $\tau = 1 - \alpha$, since both of the extreme values yield $R = 0$. This makes intuitive sense: setting $\tau = 0$ means that the ruler receives zero output, and setting $\tau = 1$ means that the ruler takes away everything, motivating the commoner to produce nothing.

Note that the equilibrium extraction rate is decreasing in the initial soil quality/vegetation type α; that is, the more readily available the land is for agriculture, the more the ruler can extract the output from his citizens.

Given $\tau^* = 1 - \alpha$, each citizen exerts the amount of effort:

$$l^* = (\frac{1}{\alpha^2})^{\frac{1}{\alpha-1}}$$

which gives the output function:

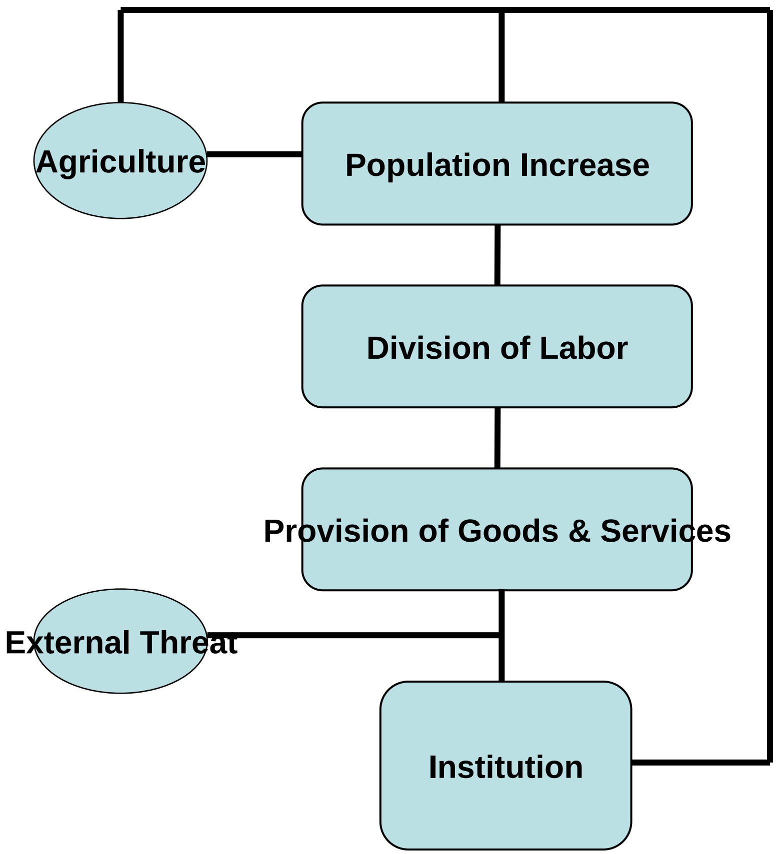
$$\pi(l^*) = \alpha(\frac{1}{\alpha^2})^{\frac{\alpha}{\alpha-1}} - (\frac{1}{\alpha^2})^{\frac{1}{\alpha-1}}$$

The ruler then obtains the extraction amount/rent from a given settlement:

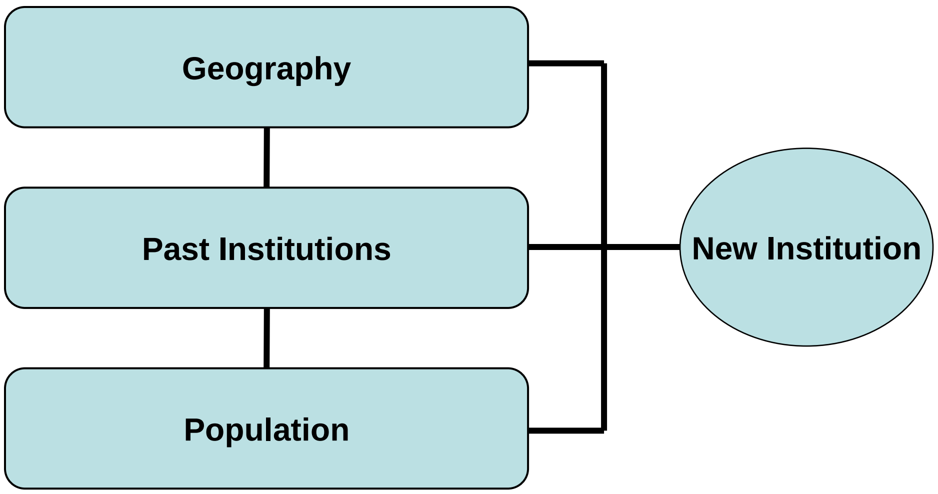
$$R^* = (1-\alpha)(\frac{1}{\alpha^2})^{\frac{\alpha}{\alpha-1}}$$

The main implication from the model is clear: as shown in the relationship between τ^* and α, the more agriculturally suitable a settlement is, the more ruler can take from the people in terms of a higher rate of extraction.

Appendix 1b



Appendix 1c



Appendix 2: Construction of Agricultural Adoption Spread in East Asia

The estimates are obtained mainly from two reference books. The first one is *Archaeology of Asia(2006)*, a compilation of works by archaeologists covering different parts of Asia and providing reference to how agriculture spread across the continent. In particular, the dates and figures from Koji Mizoguchi, Gary W. Crawford, Peter Bellwood, Anne P. Underhill and Junko Habu are used to obtain agricultural site information. The second book is Peter Bellwood's First Farmers (2005), which gives a more comprehensive set of adoption dates as well as the directions of agricultural spread. For Korea data points are from Bale(2001) and Crawford and Lee(2003). The list of archaeological sites as well as their references are listed below (AA: Archaeology of Asia; FF: First Farmers)

Name	*Country*	*Date (in BC)*	*Note:*	*Source*
Yangzi River drainage basin	China	6500		P. 83, AA
Jiahu	China	6000-7000		
Pengtushan	China	7500-6100		
Bashidang	China	7500-6100		
Diaotonghuan	China	900		
Caoxieshan	China	2500	Evidence of Rice Paddies	
Korea	Korea	3500-2000	No evidence of agriculture between 10000BC and 7000BC in North China/Korea	
Hemudu	China	5000-4500		
Nanzhuangtou	China	9000-8000	Evidence of Pottery, but no agriculture	
Diaotonghuan	China	10000	Hints of wild rice exploitation, but not domestication	
Kyushu	Japan	400	balanced agricultural intensification	
Kyushu	Japan	800-900	Earlier evidence of rice cultivation	
Tohoku	Japan	100	Yayoi transfomation moved northeastward until all but Hokkaido.	
Kazahari (Northeastern Japan)	Japan	900	Early evidence of rice cultivation before the Yayoi Expansion. Japan stayed in an "in between" states due to the success of Jomon strategies to intensify food production.	
Origin of agriculture, Cishan	China	6500		Pg. 106, AA
Origin of agriculture, Peiligang	China	6500		

Origin of agriculture, site A	China	6500	center of a cluster	
Origin of agriculture, site B	China	6500	center of a cluster	
Jiahu	China	7000-6000	center of a cluster	
Chengtoushan	China	4500-3000	center of a cluster	
Caoxieshan	China	4500-3000		
Depenkeng	China	3500	near Pengtoushan	
Area 1 (the central Yellow River valley)	China	6200	near Pengtoushan	Pg. 123, AA
Area 2 (the northeast)	China	6300-5600		
Area 3 (the lower Yellow River valley)	China	6600-4800		
Area 4 (the central Yangzi River valley)	China	7000-5200	Xinle and Ahaobaogou culture	
Area 5 (the lower Yangzi River valley)	China	5000-4500		Pg. 129, AA
Area 6 (southernmost China)	China	5000	Hemudu; Dapenkeng culture	
	China			
Xianrendong	China	11000		
Diaotonghuan	China	11000		
Korea, North	Korea	3500	through Manchuria (millet; rice came later from eastern China)	Pg. 116, FF
Yangshao Culture (Yellow River Valley)	China	5000		Pg. 123, FF
Daxi Culture (Yangzi River)	China	5000-4000		
Shixia Culture	China	3000		
Hong Kong and Pearl Delta	China	3000		
Houli/Beixin/Dawenkou Culture	China	5500-4500		
Hemudu/Majiabang/Songze Culture	China	5000-3500		
Dapenkeng Culture	China	3500		
eastern Gansu (Dadiwan)	China	slightly later than 6500		pg. 121, FF
Shandong (Houli and Beixin)	China	slightly later than 6500		
Jiahu	China	7000-5800		
Oghyon	Korea	650		Bale
Pomuigusok	Korea	3500		
Odong	Korea	1250		
Chitam-ni/Soktal-li	Korea	2000		
Kawaji/Chuyob-ni	Korea	3700		
Hunam-ni	Korea	1050		
Songgung-ni	Korea	700		
Tongchon-dong	Korea	650		
Ogbang & O-un	Korea	800		

Figures Referenced: P. 83, 107, 123 (AA), P. 123 (FF), Bale (Figure 1)

Appendix 3: The Soil Quality Ranking of Vegetation Types

Vegetation in Neolithic Europe

Productivity Ranking:
HIGHEST
Wooded Steppe
Mediterranean Scrubs
Temperate forest, Lake
Dry Steppe and Semi desert
Steppe-Tundra
Desert
Polar Desert, Ice
Tropical Extreme Desert
LOWEST

Vegetation in Neolithic Asia

Productivity Ranking:
HIGHEST
Cool and Warm Temperate Forest
Forest Steppe
Tropical Rainforest
Dry Steppe and Semi Desert
Montane Desert, Boreal Forest
LOWEST

Figure 1

Vegetation Map of Europe, 10800-10000 14C Yrs Ago

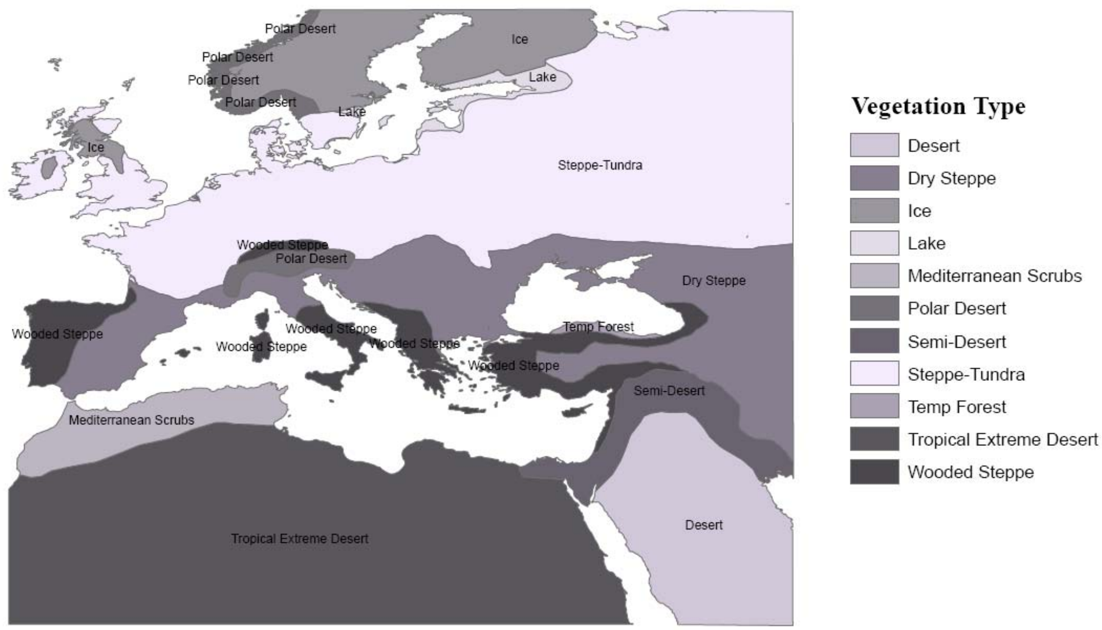


Figure 2

Agricultural Spread in Europe

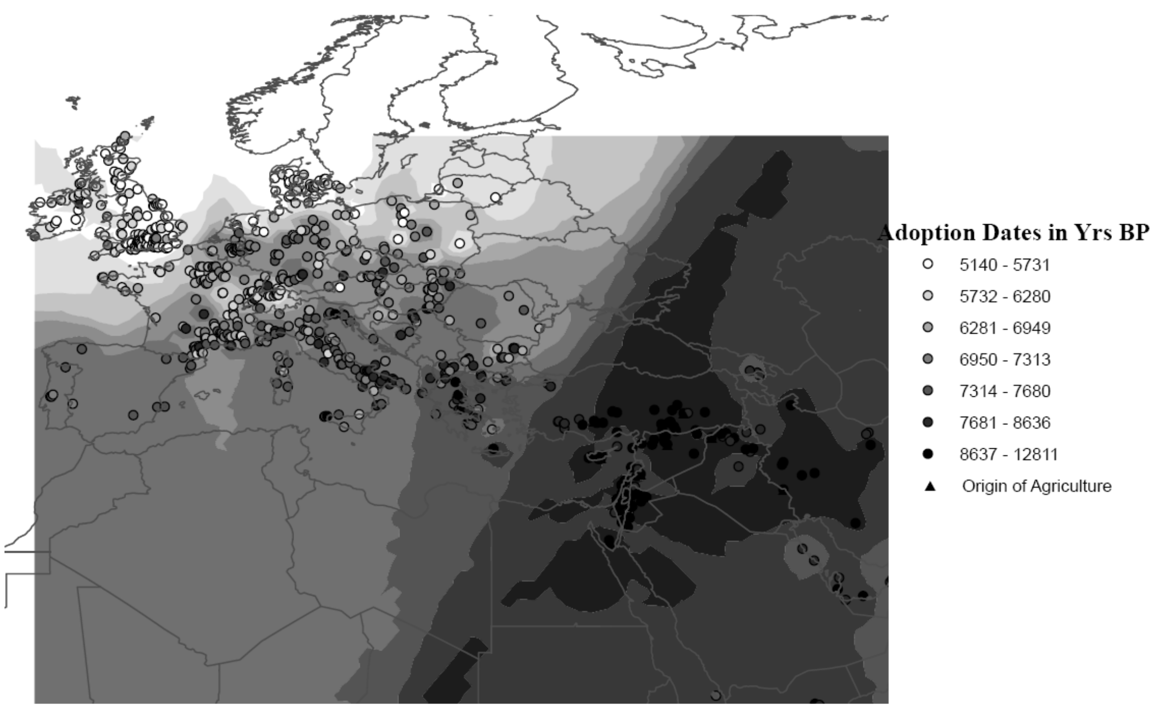
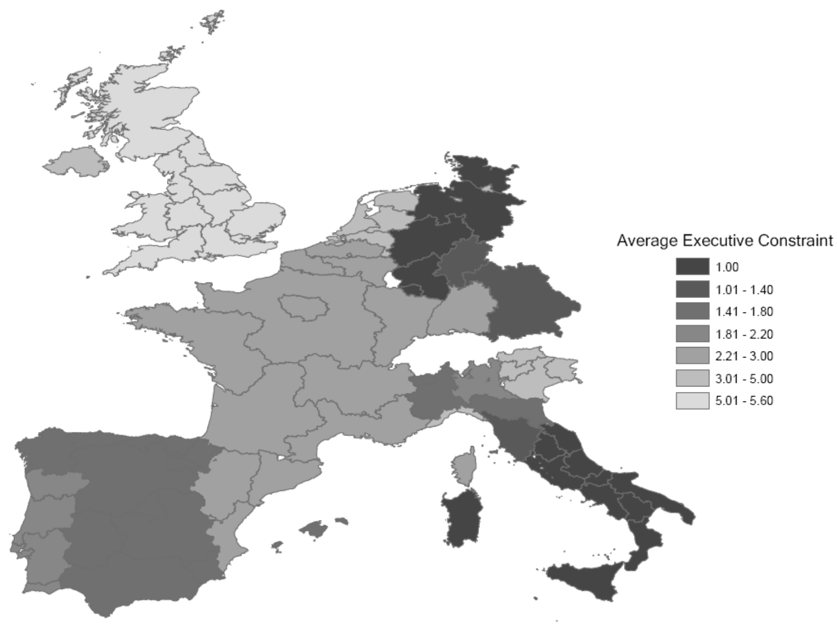


Figure 3a

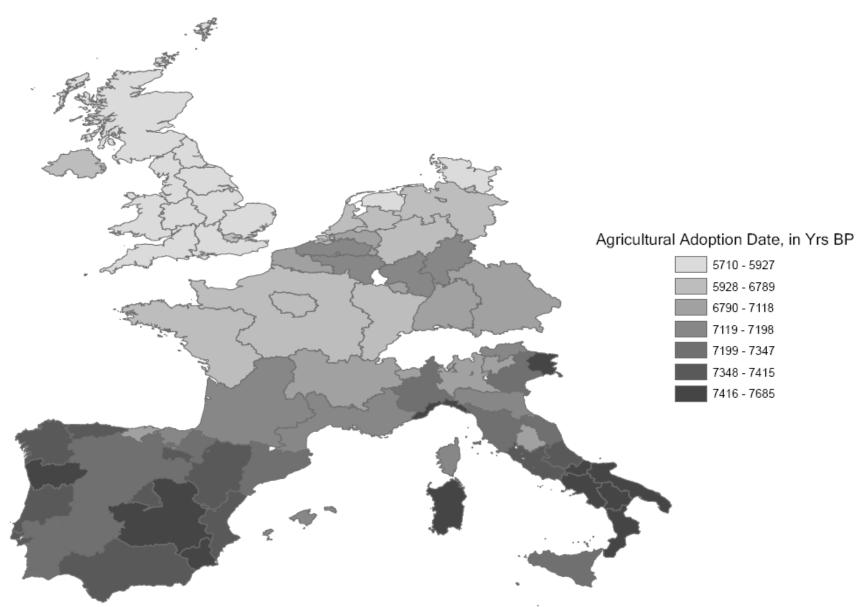
Europe (Regional) 1600-1850



Tabellini (2006)

Figure 3b

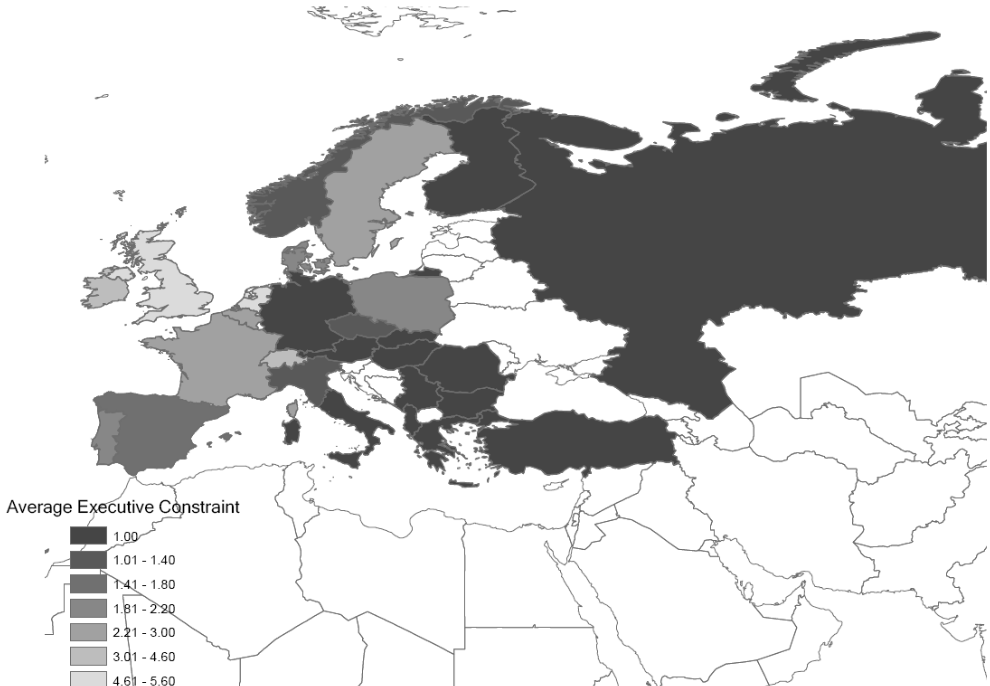
Agricultural Adoption Spread in Europe



Pinhasi et al. (2005)

Figure 4a

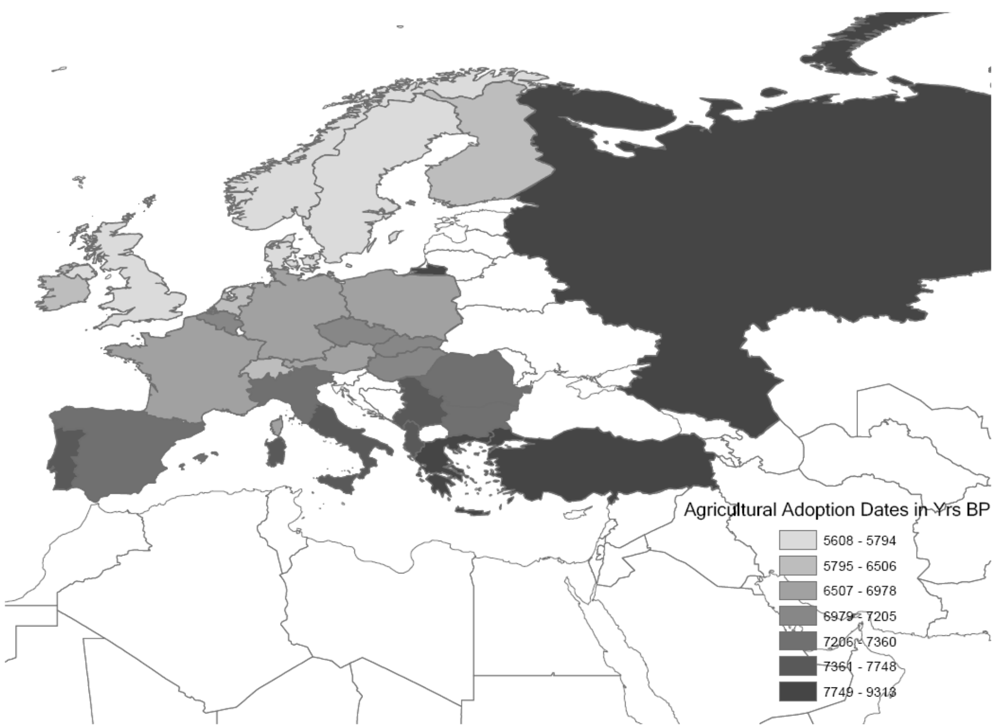
Europe (State-Level) 1600-1850



Acemoglu, D., Johnson, S. & Robinson, J. (2005)

Figure 4b

Agricultural Adoption Spread in Europe



Pinhasi et al. (2005)

Figure 5

Vegetation Map of East Asia, 7000-8000 Yrs BC

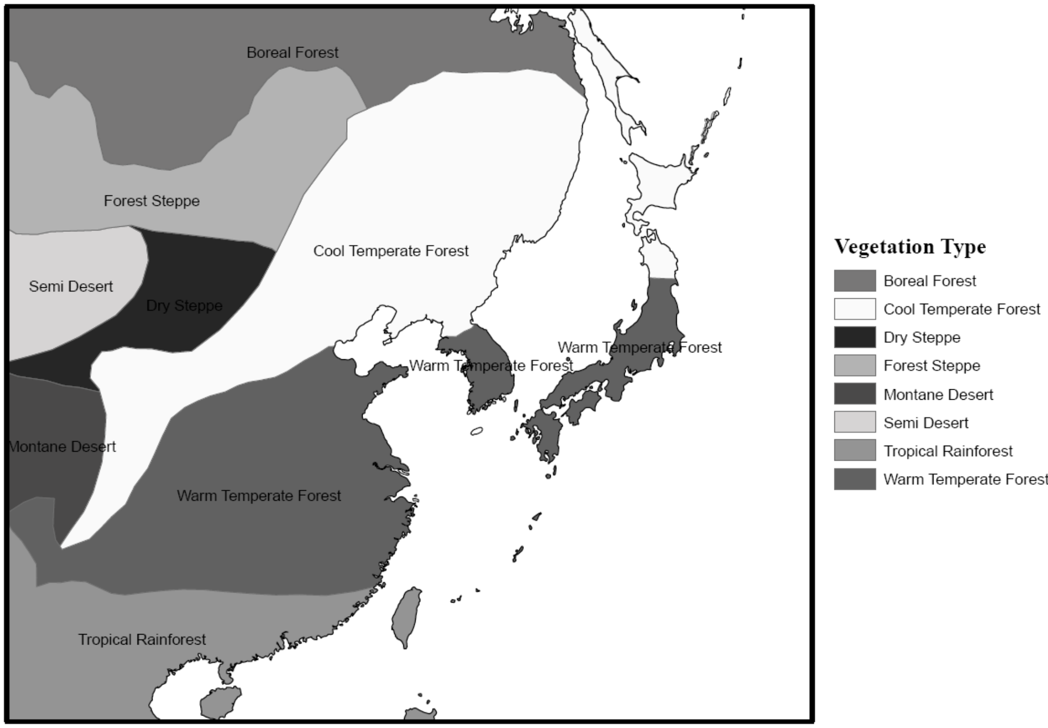


Figure 6

Agricultural Spread in East Asia

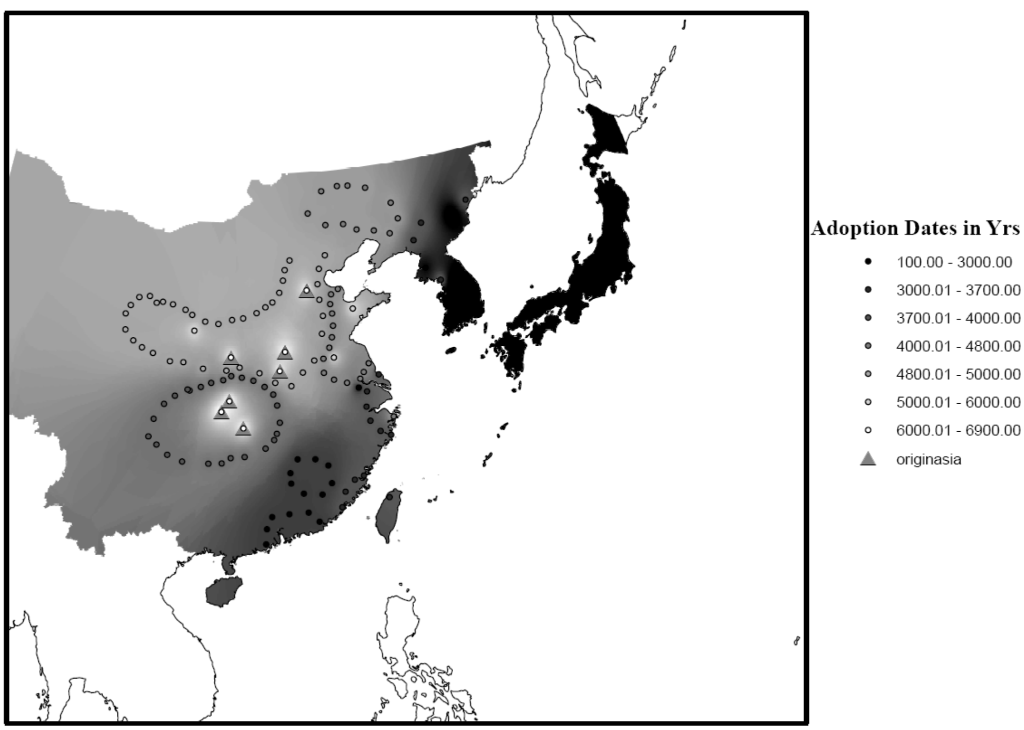


Figure 7a

Agricultural Spread in Japan

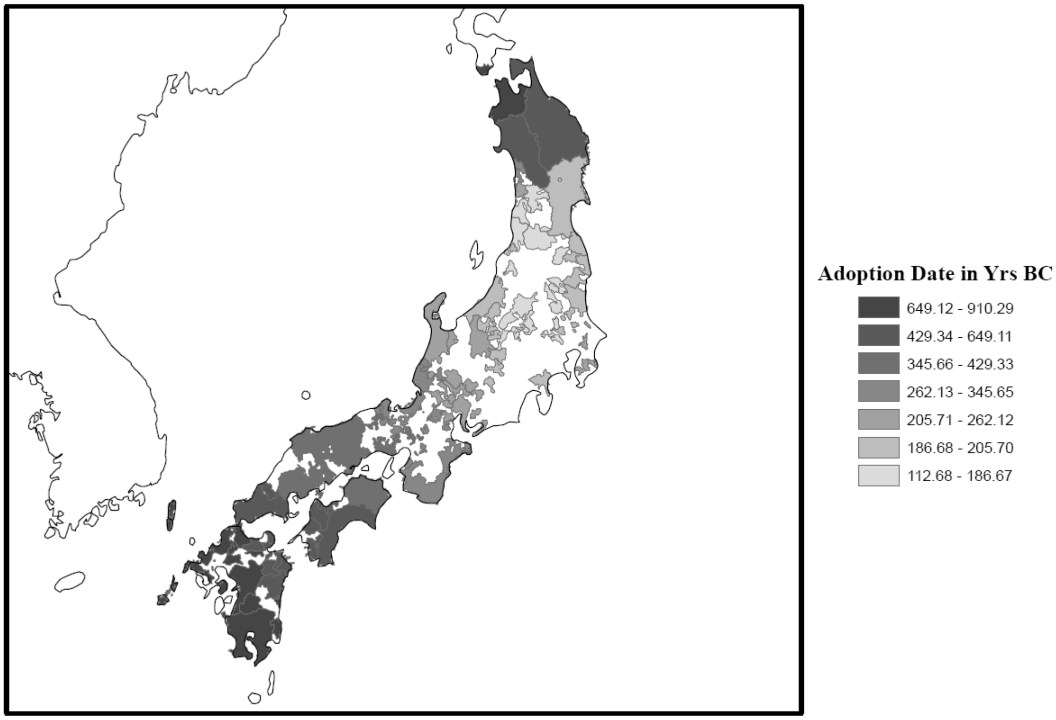


Figure 7b

Local Tax Burden in Japan, 1869-1871

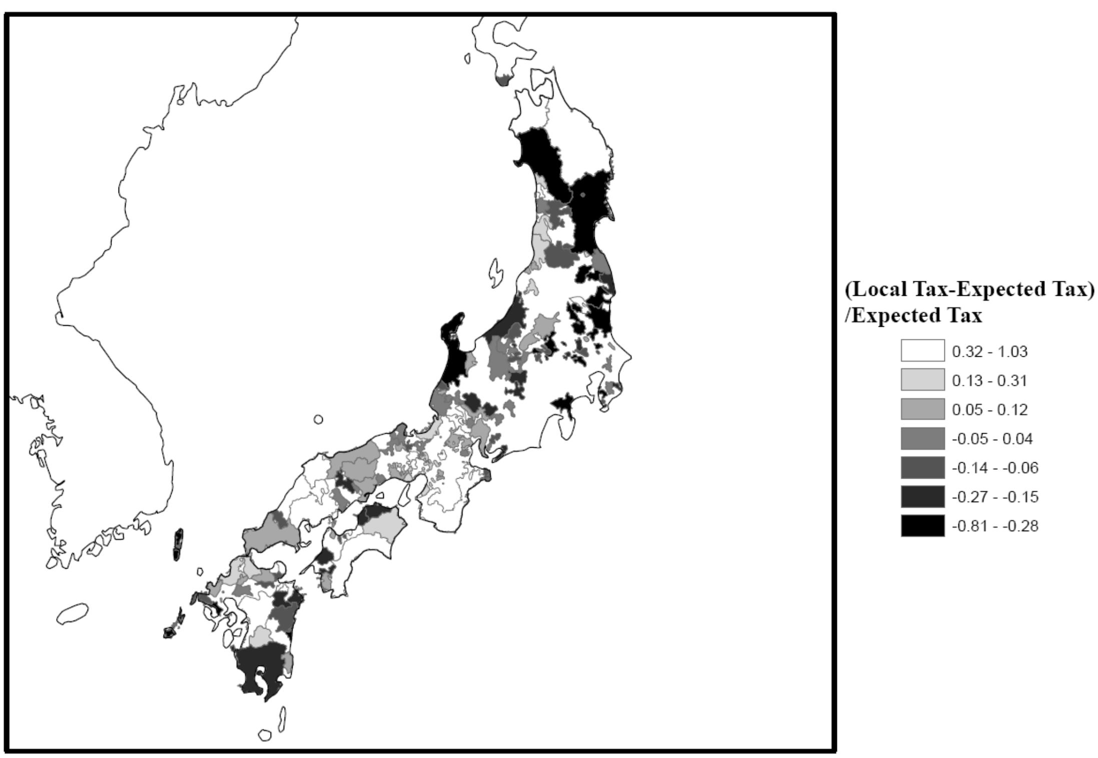


Figure 8a

Agricultural Adoption Spread in China

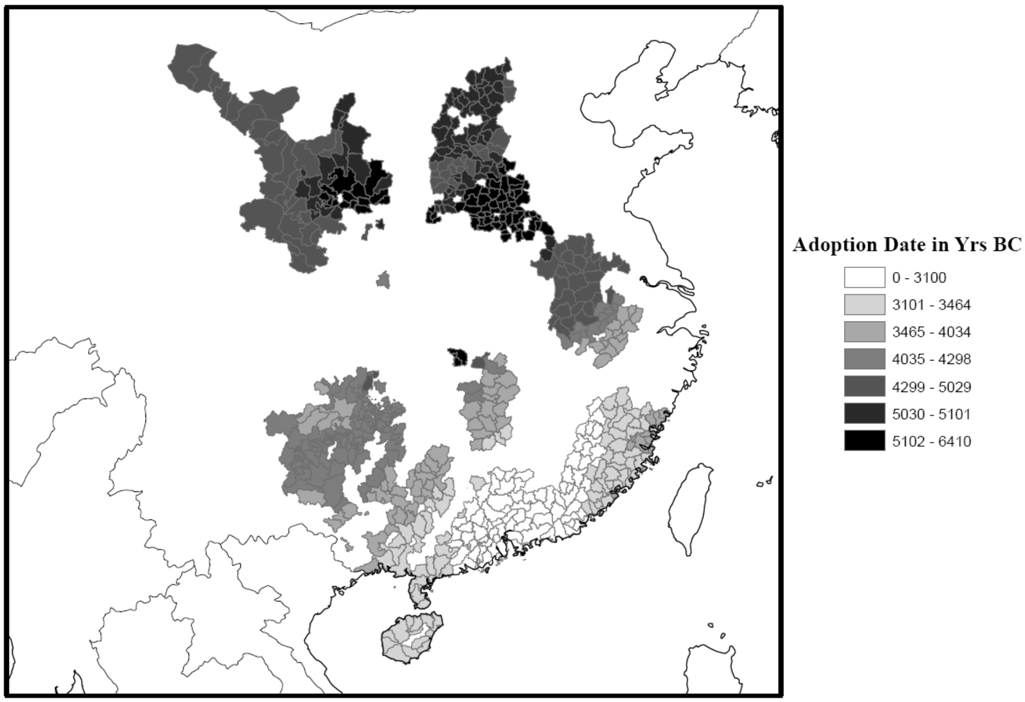


Figure 8b

Local Tax Burden in China, 1908

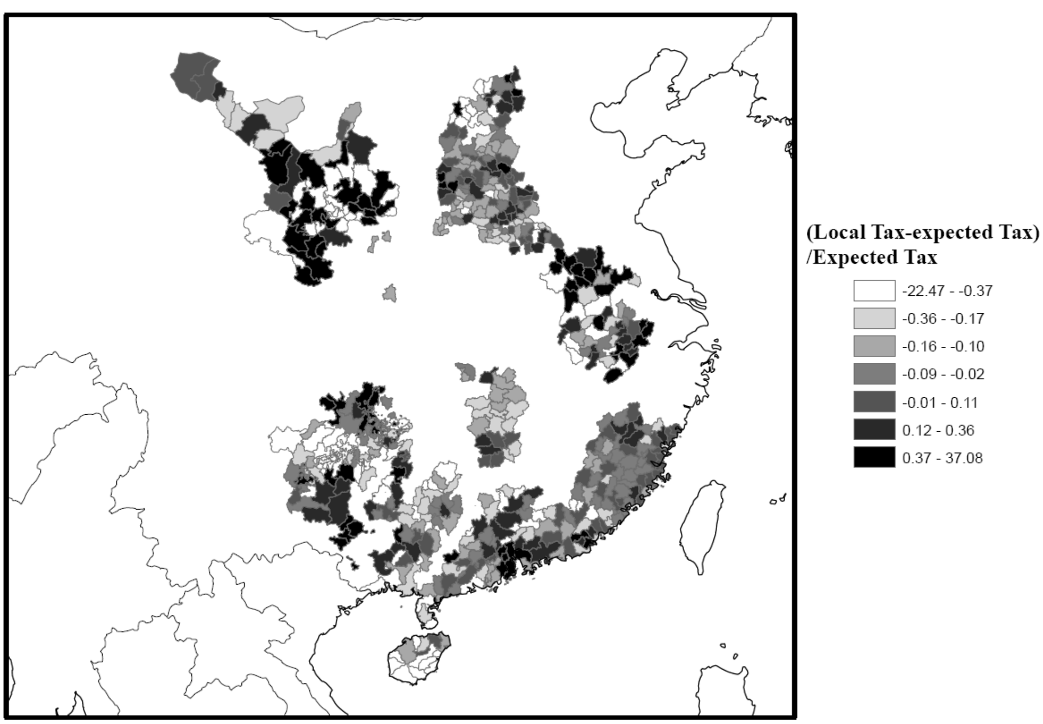


Table 1a

Europe Summmary Statistics-Intrastate Level

Variable	Obs	Mean	Std. Dev.
Socio-political Variable			
Executive Constraint, 1600	79	2.09	1.32
Executive Constraint, 1850	79	3.66	2.11
Neolithic Variables			
Ave. Agric. Adoption Date (1000 Yrs BP)	395	6.93	0.59
S.D. Agricultural Adoption Date (1000 Yrs. BP)	158	0.15	0.11
Neolithic Polar Desert (Frac. Of Region)	395	0.06	0.21
Neolithic Wooded Steppe (Frac. Of Region)	395	0.29	0.43
Neolithic Dry Steppe (Frac. Of Region)	395	0.21	0.36
Neolithic Steppe-Tundra (Frac. Of Region)	395	0.42	0.47
Neolithic Ice (Frac. Of Region)	395	0.02	0.11
Soil Quality Score	395	2.70	0.93
Other Variable			
Fraction of Land Cultivated by 1600	395	0.25	0.09

Europe Summmary Statistics-State Level

Variable	Obs	Mean	Std. Dev.
Socio-politica Variable			
Executive Constraint, 1100	27	1.22	0.58
Executive Constraint, 1850	27	2.52	2.19
Neolithic Variables			
Ave. Agric. Adoption Date (1000 Yrs BP)	270	6.98	0.84
Neolithic Wooded Steppe (Frac. Of Region)	270	0.20	0.33
Neolithic Polar Desert (Frac. Of Region)	270	0.07	0.15
Neolithic Dry Steppe (Frac. Of Region)	270	0.22	0.32
Neolithic Temperate Forest (Frac. Of Region)	270	0.00	0.01
Neolithic Steppe-Tundra (Frac. Of Region)	270	0.40	0.43
Neolithic Semi-Desert (Frac. Of Region)	270	0.00	0.02
Neolithic Ice (Frac. Of Region)	270	0.10	0.25
Soil Quality Score	270	1.65	1.15
Other Variables			
Fraction of Land Cultivated by 1600	270	0.22	0.10

Table 2a

Effect of Agricultural Adoption on Executive Constraint-Intrastate Level

	(1)	(2)	(3)	(4)
Neolithic Polar Desert (Frac. of Region)	-4.236		-0.564	
	(0.746)**		(1.406)	
Neolithic Wooded Steppe (Frac. of Region)	-5.783		-1.622	
	(0.836)**		(1.65)	
Neolithic Dry Steppe (Frac. of Region)	-5.192		-1.059	
	(0.786)**		(1.518)	
Neolithic Steppe-Tundra (Frac. of Region)	-3.834		-1.342	
	(1.660)*		(1.47)	
Soil Quality Score				-0.28
				(0.289)
Fraction of land cultivated by Year 1600	0.488		0.467	0.863
	(1.754)		(1.285)	(1.29)
Constant	6.573	16.034	16.425	14.658
	(1.202)**	(2.793)**	(2.892)**	(2.942)**
Observations	395	395	395	395
Adjusted R-squared	0.36	0.45	0.47	0.5
Joint F-Test (Ho: Vegetation Variables=0)	>1000		16.30	5.3
p-value	0.00		0.00	0

Robust standard errors in parentheses; clustered at the state level

* significant at 10%; ** significant at 5%; ** significant at 1%

Omitted Variable: Fraction covered by Neolithic Ice & Year=1600

Year dummies included (not shown)

Score=Wooded Steppe*4+Dry Steppe*3+Tundra*2+Polar Desert*1+Ice*1

Table 2b

Effect of Agricultural Adoption on Executive Constraint-State Level

	(1)	(2)	(3)	(4)
Neolithic Wooded Steppe (Frac. of Region)	-2.725		2.818	
	(2.08)		(3.188)	
Neolithic Polar Desert (Frac. of Region)	-2.049		0.93	
	(3.56)		(3.26)	
Neolithic Dry Steppe (Frac. of Region)	-3.636		2.084	
	(2.032)*		(3.108)	
Neolithic Steppe-Tundra (Frac. of Region)	-1.602		2.552	
	(1.95)		(2.72)	
Neolithic Semi-Desert (Frac. of Country)	-3.762		28.485	
	(5.270)		(16.928)	
Neolithic Lake (Frac. of Country)	-36.47		-8.542	
	(27.692)		(31.397)	
Soil Quality Score				0.104
				(0.184)
Fraction of land Cultivated in 1600	2.236		-3.271	0.491
	(2.531)		(3.068)	(2.09)
Ave. Agric Adoption Dates (1000Yrs BP)		-0.892	-1.561	-0.994
		(0.304)**	(0.673)**	(0.383)**
Constant	4.338	8.728	11.945	9.165
	(1.985)**	(2.326)**	(3.286)**	(2.736)**
Observations	135	135	135	135
Adjusted R-squared	0.2	0.23	0.35	0.33
Joint F-Test (Ho: Vegetation Variables=0)	7.81		2.67	3
p-value	0.00		0.04	0.02

Robust standard errors in parentheses; clustered at the state level

* significant at 10%; ** significant at 5%; ** significant at 1%

Omitted Variable: Fraction covered by Neolithic Ice & Year=1600

Year dummies included (not shown)

Score:Wood*4+TempForest*3+Lake*3+DrySteppe*2+SemiDesert*2+TundraSteppe*1+PolarDesert*0+Ice*0

Table 3a-Europe Summary Statistics

Variable	Obs	Mean	Std. Dev.
Mean Agricultural Adoption Date (in Yrs. BP)	1579	7701.20	1339.82
S.D. Agricultural Adoption Date (in Yrs. BP)	1579	97.10	93.99
Minimum distance to an origin of agriculture (in Deg.)	1579	17.95	11.48
Mean Elevation (in Km)	1579	0.39	0.43
S.D. Elevation	1579	0.15	0.17
Fraction occupied by Desert	1579	0.12	0.32
Fraction occupied by Lake	1579	0.02	0.12
Fraction occupied by Steppe-Tundra	1579	0.41	0.48
Fraction occupied by Ice	1579	0.05	0.21
Fraction occupied by Polar-Desert	1579	0.02	0.13
Fraction occupied by Semi-Desert	1579	0.04	0.19
Fraction occupied by Dry-Steppe	1579	0.21	0.39
Fraction occupied by Wooded-Steppe	1579	0.12	0.31
Fraction occupied by Temperate Forest	1579	0.00	0.06
Soil Quality Score	1579	3.51	1.50

Table 3b- Agricultural Spread in Europe

	(1) Initial	(2) Distance	(3) Elevation	(4) Dist+Elev
Minimum distance to an origin		-63.294		-60.566
		(1.992)**		(1.968)**
Fraction occupied by Desert	3189.536	1653.322	2938.180	1566.286
	(48.823)**	(59.572)**	(67.250)**	(61.163)**
Fraction occupied by Lake	304.688	-244.668	472.139	-122.986
	(56.505)**	(59.186)**	(67.560)**	(63.133)*
Fraction occupied by Steppe-Tundra	1292.389	759.720	1367.390	826.094
	(58.648)**	(46.369)**	(67.408)**	(49.166)**
Fraction occupied by Polar-Desert	166.783	136.536	51.921	82.373
	(113.788)	(76.221)*	(99.837)	(74.318)
Fraction occupied by Semi-Desert	3943.502	1994.555	3954.790	2088.874
	(71.021)**	(85.360)**	(82.265)**	(88.349)**
Fraction occupied by Dry-Steppe	2456.261	1310.036	2349.926	1300.398
	(67.788)**	(58.855)**	(76.679)**	(62.143)**
Fraction occupied by Wooded-Steppe	2196.772	1245.753	2186.384	1289.713
	(68.438)**	(62.747)**	(78.612)**	(66.982)**
Fraction occupied by Temperate Forest	4115.599	2134.559	4044.138	2187.047
	(225.089)**	(205.304)**	(204.116)**	(207.686)**
Mean Elevation			786.438	479.381
			(72.571)**	(49.642)**
S.D. Elevation			-878.609	-579.070
			(214.242)**	(140.089)**
Constant	5824.562	7815.155	5669.299	7639.287
	(33.951)**	(66.746)**	(50.393)**	(72.127)**
Observations	1579	1579	1579	1579
Adjusted R-squared	0.49	0.67	0.52	0.68

Robust standard errors in parentheses

** significant at 10%; ** significant at 5%; ** significant at 1%*

Omitted variable: Fraction occupied by Ice

Table 4a: Japan Summary Statistics

Variable	Obs	Mean	Std. Dev.
Socio-political Variable			
Tax burden (*gendaka*) per commoner in *koku* *	164	0.48	0.19
Retainers per 100 commoners	164	1.86	1.20
Assessed Output (*kusadaka*) per commoner in *koku*	164	1.26	0.47
Size in 1000 Acres	164	0.07	0.14
Std Dev. Agricultural Adoption Date in 1000 Yrs BC	164	0.01	0.02
Neolithic Variables			
Mean Agricultural Adoption Date in 1000 Yrs BC	164	0.36	0.19
Fraction of Cool Temperate Forest in Region	164	0.05	0.22
Fraction of Warm Temperate Forest in Region	164	0.95	0.22

**1 koku=150 kg of rice*

Table 4b: Effect of Agricultural Adoption on the Level of Tax Burden in Japan, 1869-1871

*Dependent Variable: Tax burden (gendaka) per commoner in koku**	(1)	(2)	(3)	(4)
Assessed output (kusadaka)/commoner in koku	0.279	0.281	0.280	0.281
	(0.022)**	(0.022)**	(0.022)**	(0.022)**
Land Size (in 1000 Acres)	-0.165	-0.182	-0.199	-0.205
	(0.067)**	(0.075)**	(0.065)**	(0.076)**
Frac. of land occupied by Cool Temperate Forest		0.029		0.012
		(0.062)		(0.067)
Mean agricultural adoption date in 1000 Yrs. BC			0.165	0.164
			(0.062)**	(0.062)**
Constant	0.135	0.132	0.077	0.077
	(0.026)**	(0.026)**	(0.031)**	(0.031)**
Observations	164	164	164	164
Adjusted R-squared	0.51	0.51	0.54	0.54

Robust standard errors in parentheses

* significant at 10%; ** significant at 5%; ** significant at 1%

Table 4c: Effect of Agricultural Adoption on the Level of Tax Burden in Japan, 1869-1871

Dependent Variable: Retainers per 100 commoners	(1) Initial	(2) Neolithic Veg	(3) Adoptn Date	(4) Neolithic Veg + Adoptn Date
Assessed output (kusadaka)/commoner in koku	1.369	1.4	1.377	1.399
	(0.213)**	(0.207)**	(0.210)**	(0.203)**
1000's Acres	1.375	1.106	1.103	0.916
	(1.16)	(1.30)	(1.12)	(1.24)
Frac. of land occupied by Cool Temperate Forest		0.484		0.350
		(0.435)		(0.489)
Mean agricultural adoption date in 1000 Yrs. BC			1.347	1.308
			(0.562)**	(0.584)**
Constant	0.033	-0.011	-0.438	-0.456
	(0.26)	(0.25)	(0.360)	(0.351)
Observations	164	164	164	164
Adjusted R-squared	0.29	0.3	0.34	0.34

Robust standard errors in parentheses
* significant at 10%; ** significant at 5%; ** significant at 1%

Table 5a
China Summary Statistics

Variable	Obs	Mean	Std. Dev.
Socio-political Variable			
Total Tax Collected (in *tael*)	673	47777.63	46517.51
Titing Quota (in *tael*)	664	16732.39	16554.38
Grain Quota (in *shih*)	537	3421.48	4558.42
Provincial Population (in millions)	673	21.89	10.90
Cultivated Land (in million *mou*)	673	58.68	32.22
Area (in Km-squared)	673	2709.94	3520.55
Area of Registered Land (in million *mou*)	673	33.02	21.69
1 if province was developed	673	0.60	0.49
Neolithic Variables			
Mean Agricultural Adoption Date in Yrs BC	672	4284.54	863.24
Fraction of Dry Steppe in region	672	0.01	0.07
Frac. of Semi-Desert in region	672	0.01	0.09
Frac. of Warm Temperate Forest in region	672	0.60	0.48
Frac. of Cool Temperate Forest in region	672	0.13	0.32
Frac. of Tropical Rainforest in region	672	0.26	0.43
Frac. of Montane Desert in region	672	0.00	0.03
Other Variables			
Minimum Distance to the Origin of Agriculture	672	4.57	2.66
Mean Elevation (in Km)	672	0.62	0.60
Std. Elevation (in Km)	672	0.19	0.13
Soil Quality Score	672	3.71	0.47

1 mou=0.165 acre; Tael was a unit of currecy in China equivalent in value to about 1.3 ounces of silver.
Shih is a measure of grain volume, equivalent to about 175-195 Ibs. of milled rice

Table 5b: Effect of Agricultural Adoption on Local Tax Burden in China, 1908

	(1)	(2)	(3)	(4)	(5)
Provincial population, in millions	1,229.170	1,388.288	1,290.317	1,600.782	1,292.55
	(131.143)**	(266.586)**	(188.291)**	(270.872)**	(189.703)**
Area in Km-squared	-0.014	-0.475	-0.014	-0.538	-0.081
	(0.617)	(0.685)	(0.619)	(0.719)	(0.686)
=1 if Province was already developed	10,529.259	10,713.224	11,705.913	15,014.902	12,096.684
	(5,574.009)*	(4,248.541)**	(4,936.477)**	(2,971.562)**	(4,821.133)**
Registered land area, in million mou	-341.789	-432.414	-402.329	-660.796	-425.555
	(103.506)**	(76.883)**	(109.962)**	(166.772)**	(91.095)**
Titing quota, in tael	1.809	1.859	1.810	1.877	1.823
	(0.220)**	(0.243)**	(0.219)**	(0.255)**	(0.232)**
Grain quota, in shih	4.720	4.778	4.719	4.781	4.699
	(1.401)**	(1.545)**	(1.406)**	(1.548)**	(1.400)**
Frac. Dry Steppe		-28,059.700		-28,623.953	
		(23,484.567)		(23,434.888)	
Frac. Warm Temperate Forest		-15,131.023		-16,173.070	
		(9,375.989)		(10,405.118)	
Frac. Cool Temperate Forest		-4,572.524		-4,647.895	
		(6,578.794)		(6,883.228)	
Frac. Tropical Rainforest		-12,674.601		-11,459.669	
		(10,078.470)		(10,962.144)	
Soil Quality					-2,058.403
					(2,912.081)
Mean Agric. Adoption Date in Yrs BC			1.127	4.599	2.006
			(2.928)	(2.360)*	(2.271)
Constant	-16,312.723	-3,867.448	-21,226.202	-23,239.941	-16,891.917
	(5,414.682)**	(9,608.457)	(10,395.008)*	(14,694.945)	(13,689.792)
Observations	527	527	527	527	527
Adjusted R-squared	0.86	0.86	0.86	0.86	0.86
Joint F-Test (Ho: Vegetation Variables=0)		2.06		1.18	
p-value		0.18		0.39	

Robust standard errors in parentheses;clustered at the provincial level
* significant at 10%; ** significant at 5%; ** significant at 1%
*Omitted Neolithic Veg. variable: Fraction of land occupied with Montane Desert
Score=Cool/Warm Temperate Forest*4+ Tropical Rainforest*3+ Dry Steppe*2+ Semi-Desert*2+ Montane Desert*1