Where Does Democracy Thrive:

Climate, Technology, and the Evolution of

Economic and Political Institutions

Stephen Haber

Stanford University and NBER

Draft of August 24, 2012

ABSTRACT:
Why are some societies characterized by enduring democracy, while other societies are either persistently autocratic or experiment with democracy but then quickly fall back into autocracy? I find that there is a systematic, non-linear relationship between rainfall levels and regime types such that such that stable democracies overwhelmingly cluster in a band of moderate rainfall (540 to 1200 mm of precipitation per year), while the world's most persistent autocracies cluster in arid environments and rain-forests. This relationship is robust to controls for the resource curse, as well as to controls for ethno-linguistic fractionalization, the percent of the population that is Muslim, disease environment, and colonial heritage. I advance a theory to explain this relationship, focusing on differences in the biological and technological characteristics of the crops that can be grown in different precipitation environments. Variance in the biological and technological characteristics of crops generated variance in producers' strategies to solve problems of scarcity, giving rise to variance in the distribution of human capital and institutions associated with the protection of property rights. Democracy was more likely to thrive in environments in with a high level and broad distribution of human capital, and with institutions that protected property rights. I test the theory against a unique cross-country dataset, a comparison of democracies and autocracies in antiquity, and a series of natural experiments.

This paper builds upon an earlier collaboration with Victor Menaldo (University of Washington). Our joint paper, "Rainfall, Human Capital, and Democracy," is available on SSRN. I also gratefully acknowledge discussions with Ran Abramitzky, Isa Chavez, Roy Elis, Stanley Engerman, Rob Fleck, Avner Greif, Tim Guinnane, Mark Kleinman, Dorothy Kronick, Naomi Lamoreaux, Ross Levine, Joseph Manning, Ian Morris, Josh Ober, Robert Packenham, Armando Razo, Paul Sniderman, William Summerhill, and Barry Weingast. Nicholas Baldo, Kevin Cook, Anne Given, Scott Khamphoune, Dorothy Kronick, and Cole Lupoli, provided invaluable research assistance. Special thanks are owed to Roy Elis, GIS Genius.

Why are some societies characterized by enduring democracy while other societies are either persistently autocratic or repeatedly fail to consolidate democracy? This question motivated the research of the founding fathers of modern political science, including Lipset (1959, 1963), Huntington (1968), and Dahl (1971), and subsequently became one of the central preoccupations of the field of political economy (e.g., Acemoglu and Robinson 2006). We are, however, still a very long way from a consensus answer, and one of the principle reasons for that lack of consensus is a tendency for the literature to focus on explanatory factors that are not exogenous. Most of the factors that are held to cause democracy are either potentially outcomes of democracy, or are jointly determined, along with democracy, by some unspecified factor (Acemoglu et. al., 2008).

This paper offers a contribution by focusing on an exogenous factor—the level of rainfall—on the long run stability of democracies. My principle findings are three. First, there is a systematic, non-linear relationship between precipitation levels and regime types: stable democracies overwhelmingly cluster in a band of moderate precipitation (541 to 1200 mm, on average, per year), while the world's persistent autocracies cluster in arid zones (0 to 540 mm per year) and rainforest zones (above 1200 mm per year). This finding is robust to controls for possible confounders, such as ethnic fractionalization ethno-linguistic fractionalization, the prevalence of malaria, colonial heritage, natural resource income; and the percentage of the population that is Muslim. This finding is also not sensitive to the window of time over which modern democracies and autocracies can be measured quantitatively. In point of fact, the "Rainfall-Democracy Hypothesis" is not just consistent with the distribution of the world's modern stable democracies; it is also consistent with the distribution of stable democracies in antiquity. Finally, the Rainfall-Democracy Hypothesis is consistent with a natural experiment provided by the dissolution of the Soviet Union.

My second principle finding is that the factor that mediates between precipitation levels and regime types is the ability to grow cereals (e.g., wheat, barley, maize) using rainfed methods of production.[1] Rainfed cereals cannot be grown effectively outside of the 541 to 1200 mm moderate rainfall band; they fail if there is too little or too much rain. The "Rainfed Cereals Hypothesis" is robust to the same possible confounders and time windows as the Rainfall-Democracy Hypothesis. It is also consistent with the distribution of democracies and autocracies in antiquity, and it is consistent with the natural experiment provided by the dissolution of the Soviet Union.

My third principle finding is that the mechanism that mediates between the ability to grow rainfed cereals and stable democracy is their biological and technological characteristics. These characteristics include: low barriers to entry (nobody can own the rain); high levels of storability (cereals keep for years on end); modest scale economies in production (the family farm is the modal production unit); and frequent idiosyncratic production shocks (cereals grown under rainfed production methods often fail because of *local* events, such as a heavy rain late in the growing season). The tubers and tree crops that grow in rainforest zones have low levels of storability (they typically decay within days or weeks of harvesting), and tend not to suffer idiosyncratic production shocks (they are non-seasonal; local weather events cannot ruin a crop in its entirety). Cereals can be grown in arid zones, but they must make use of a water source, such as a river or aquifer, for irrigation,

[1] One might think that annual or seasonal variability in precipitation, as well as average temperature (and its variation) might matter as well. These factors tend to correlate, however, with the average level of precipitation in a non-linear fashion.

which dramatically alters their technological characteristics: access to water can serve as a barrier to entry (whoever controls the rights to water can siphon off all of the farmer's surplus); irrigation increases the minimum efficient scale of production; and production shocks tend to be systemic (all farmers drawing on the same source of irrigation water lose their crops simultaneously), not idiosyncratic.

Variance in the biological and technological characteristics of crops shaped societies' long-run paths of institutional and economic development. Societies located in zones of moderate rainfall were *more likely* than societies in other climate zones to be composed of large numbers of small farmers who: 1) had the potential to accumulate surpluses; 2) could deal with problems of scarcity through trade (because production shocks were idiosyncratic); 3) had incentives to create legal and political institutions designed to protect their surpluses and facilitate transactions; and 4) invest in human capital (specialize economically) in order to take advantage of the possibilities afforded by trade. Over the long-run, those societies were *more likely* than societies in other climate zones to be composed of large numbers of prosperous individuals, with high levels of human capital, engaged in a broad range of high-return economic activities, operating in an institutional environment that limited the reach of the state. Democratic transitions, *when they occurred for whatever reason*, were *more likely* to consolidate in these types of "transactional societies" than in the types of societies that emerged in arid or rainforest zones. This hypothesis is consistent both with econometric tests that introduce proxy measures for a "transactional society," as well as with evidence from comparative economic and political history.[2]

[2] Let me be clear: I am not advancing the hypothesis that democratization happened because of the political preferences of family farmers. In the first place, the hypothesis I advance is about the conditions under which democracies persist, not the conditions that lead to societies

This paper continues as follows. Section One provides a literature review. Section Two demonstrates that there is a systematic, non-linear, and robust relationship between average precipitation levels and regime types. Section Three demonstrates that there is a systematic relationship between average precipitation levels and the ability to grow cereals under rainfed production technologies. It also demonstrates that there is a systematic and robust relationship between the ability to grow rainfed cereals and regime types. Section Four provides a theoretical framework that explains the relationships shown in Sections Two and Three. Section Five tests the theory against various types of evidence, both econometric and historical. Section Six concludes.

Section 1: Literature Review

This paper stands on the shoulders of earlier work by anthropologists, sociologists, economists, political scientists, historians, and biologists.

Anthropologists and sociologists have investigated the relationship between geographic variables and state formation. Carneiro (1970) argues that centralized states first emerged in areas where agricultural production was geographically circumscribed by mountains, seas, or deserts that limited the area that could be cultivated. Wittfogel (1957) famously argued that control of great rivers was the driving force behind centralizing, authoritarian states. A generation of historians has shown that Wittfogel's theory of hydraulic society was a fanciful set of assertions (e.g., Manning 2010). Nevertheless, even if he got the mechanism wrong, Wittfogel was on to *something*: there does seem to be a correlation between agricultural systems based on controlling the waters of a great river and authoritarian

---

to experiment with democracy. In the second place, small farmers have historically espoused all kinds of ideologies and joined all kinds of political coalitions—some of which were decidedly un-democratic (Luebbert 1991).

political institutions—to wit the autocracies that have continually emerged over the past four millennia on the banks of the Nile, Euphrates, Mekong, and Yangtze. Subsequent research by archaeologists, anthropologists, and historians on irrigation-dependent societies (summarized by Fagen 2011) points in a similar direction: irrigated agriculture and political centralization have tended to go together.

A parallel literature in economics has looked for the exogenous drivers of economic development. Hibbs and Olsson (2004) and Putterman (2007) explore the effects of climate, working through the timing of the Neolithic Revolution, on long run growth. Diamond (1997) focuses on the orientation of continents. Acemoglu, Johnson, and Robinson (2001) explain differences in long-run economic growth across former European colonies as a product of differences in institutions that are rooted in differences in disease environments. Engerman and Sokoloff (1997) argue that variance in natural environments (differences in climate, soil quality, mineral endowments, and the size of the native population) across the Americas at the time of European colonization conditioned long-run paths of economic and political institutions, and hence explain present-day income differences across the Americas. Work by Easterly and Levine (2003) shows that geographic factors shape economic outcomes by working through institutions, rather than having a direct effect.

Scholarship on natural environments and institutional development is informed by several literatures, spanning economics, biology, and history. Economists have explored how the biological and technological characteristics of crops explain variance in the relations of people to the factors of production, particularly the ownership and use rights to those factors (e.g., Binswanger and Rosenzweig 1986; Allen and Lueck 1998; Dye 1998). That body of work, in turn, is informed by research by biologists on the storability characteristics of different crops, as well as the potential productivity of those crops under different technologies of production (e.g., Collins 1949; Mikkelsen and KeDatta, 1980; Gupta and O'Toole 1986; Abu-Goukh 1986; Ravi, Aked, and Balagopalan 1996; Diop and Calverley 1998; Street and Bollich 2003). Research on natural environments and institutions is also informed by research by historians, who have noticed, going back at least as far as Herodotus (fifth century BCE), that humanly-devised institutions do not emerge independently of the incentives generated by nature. Prominent examples include Gallo (1977), Broadhead (1979), Schwartz (1985), Thornton (2001), and Raaflaub (2007).

Political scientists have focused on the connection between economic organization and regime types. This literature goes back at least as far as Lipset (1959, 1963), Huntington (1968), and Dahl (1971), who noticed that stable democracies, high per capita incomes, and large, educated middle classes tend to co-occur. They therefore concluded that certain "structural" preconditions increased the odds of democratic transition and survival. A parallel body of scholarship, going back at least as far as Moore (1966) looks at regime types as outcomes of long-run historical processes that condition patterns of social organization (e.g., Luebbert 1991; Rueschemeyer, Stephens and Stephens 1992; Collier 1999; Capoccia and Ziblatt 2010).

Scholars using quantitative methods have examined the "structural preconditions" hypothesis. Some of that work found support for the idea that the level of economic development and the distribution of income explain variance in democratic survival (e.g., Przeworski 2000; Boix 2003). Other researchers found that that causality runs the other way: representative political institutions give rise to high per capita incomes and broad distributions of income (e.g., North and Weingast 1989; Acemoglu and Robinson 2006). The emerging consensus seems to be that liberal values, high levels of economic development, and consolidated democracy are part of a general equilibrium whose fundamental drivers are not yet fully understood (e.g., Acemoglu et. al., 2008; Persson and Tabellini, 2009; North, Weingast, and Wallis 2009).

Section II: Precipitation Zones and Regime Types

I begin by documenting the non-linear relationship between precipitation zones and the equilibrium level of democracy around the world. I base the measure of democracy on the Polity 2 score, which is the standard measure of the degree of autocracy/democracy in the comparative politics literature. Polity 2 captures the competitiveness of political participation, the openness and competitiveness of executive recruitment, and the constraints on the chief executive. It is scored annually for every country in the world with a population above 1 million, beginning at political independence, or in 1800 for countries that are not former colonies (Marshall and Jaggers 2008). In order to create a measure that captures both a country's level of democracy and its long-run stability—its equilibrium level—I average each country's' Polity 2 score (hereafter referred to as Average Polity) over long periods of time.

As a first pass at the data, I take Average Polity from 1925 to 2010, and do so because this window of time provides a balance between capturing differences in the equilibrium level of democracy across countries and capturing enough countries to make comparisons meaningful. The longer the time period over which the average is taken, the bigger the gap in Average Polity between the world's oldest and most stable democracies (e.g., Switzerland) and the world's recent, and more fragile, democracies (e.g., Brazil). But, the longer the time period over which the average is taken, the fewer countries there are in the sample, because Polity only provides scores for sovereign nations. Thus, the Y-axis of Figure 1 is Average

Polity for all countries that have continually existed since 1925 (with Average Polity normalized to run from 0 to 100).

The X-axis of Figure 1 is the average level of precipitation within 100 miles of the largest city of every country during the period 1960-69, with the data taken from the Global Historical Climatology Network Database version 2.0, available from the National Oceanic and Atmospheric Administration, National Climatic Data Center. I take the average for this particular decade because it affords very broad cross-sectional coverage, amassing readings from more than 10,000 weather stations around the globe, while allaying possible concerns some readers might have about climate change in recent decades affecting results. I note, however, that the results are not sensitive to the decade chosen: I obtain similar results when I take the average of the decades 1900-09 and 1980-89. I also obtain similar results when I draw the precipitation data from a different source (GAEZ 3.0, which averages across the entire period 1961-90). Indeed, the variance in precipitation across countries is so great that it completely swamps any time series trend that one might detect over the past several centuries in the NOAA data, which extend back to 1697.[3] In fact, the rank ordering of average

[3] Accessible at: http://www.ncdc.noaa.gov/ghcnm/. The NOAA data include monthly readings from up to 14,907 weather stations across the planet going as far back as 1697. The data allow us to estimate rainfall and temperature by triangulation (weighting by distance) for any location in the world, even if that location does not have a weather station. Because there are more weather stations as one moves from 1697 to the present, our measurements become more exact the closer we get to the decade 1980-89, which has the most weather station observations. We note that when we generate time-series graphs of the data for the weather stations that have existed since the early 18th century we do not observe a significant trend. We also note that when we estimate a time series regression on the data for all weather stations we detect a trend rate of growth that is infinitesimally small (0.2 mm per year, which is to say that it would take 500 years for average rainfall to increase by just 100 mm). There is, however, a good deal of year-to-year variability. We therefore employ decade averages in our analyses.

precipitation levels across countries has not changed significantly over at least the past three millennia.

I pick a 100-mile radius around the largest city because the fundamental institutions of modern nation states tended to originate in a core area, and were then transplanted to other areas by assimilation, conquest, and colonization. Examples of such core areas include the Ile de France (the area around Paris, from which the modern French state emerged beginning in the 10th century), the Valley of Mexico (the central plateau around Mexico City, that was the center of the Teotihuacán, Toltec, and Aztec Empires, the Spanish colony of New Spain, and the nation state of Mexico after independence), and the Tokyo region (from which emerged the modern nation of Japan beginning with the Tokugawa Shogunate in 1603). With very few exceptions, the largest city in any country today sits inside this original core area. The results are, however, robust to conducting the analysis on the level of rainfall 200 miles from the largest city, 500 miles from the largest city, and the average for the entire country.

So as to make the graphed data easier to visualize and describe I identify the country observations that meet Jagger and Gurr's (1995) criterion for "coherent democracy" (a polity score of at least 85 and above on our 0 to 100 scale), and denote those cases as Stable Democracies. The countries that meet this threshold are places that have been democratic for decades, if not centuries (e.g., Switzerland). It happens to be the case that a score of 85 is one standard deviation above the sample mean (53). Thus, in order to make it easier to visualize and describe the countries that are at the opposite end of the scale, I identify those observations that are at least one standard deviation below the sample mean. The countries that meet this threshold have been autocratic for centuries, if not millennia (e.g., Iraq, which, until the U.S. invasion of 2003, had never once experimented with democracy since its emergence as an identifiable political entity under Sargon of Akkad in 2350 BCE). I therefore denote those countries as "Persistent Autocracies." The countries that fall within one standard deviation of the mean tend to be places that have either had failed democratic experiments (e.g., Nigeria) or were long-standing autocracies that recently transitioned to democracy (e.g., Mexico). I denote these as non-democracies/democratic transitions.

Figure 1 presents a scattergram of the data. The two vertical lines demarcate 540 mm (the upper bound of a semi-arid climate, following the Holdridge Life Zones classification system) and 1200 mm (the lower bound of a rainforest, following the same system).[4] Thus, the band between those bars is the smallest possible area that can be described as having moderate precipitation.

The graphed data strongly suggest that there are discontinuities in regime types across the three precipitation zones. One way to see this is simply to look at the sample means: from 0 to 540 mm in precipitation per year Average Polity is 22; between 541 and 1200 it jumps to 73; and above 1200 it falls back to 48. A second way to see it is to look at the location of the stable democracies and persistent autocracies: the stable democracies cluster in the 541 to 1200 mm moderate precipitation zone, while the persistent autocracies all fall on either side of that zone. The moderate precipitation zone contains 44 percent of all the countries in the sample, but 82 percent of all the stable democracies and zero percent of the persistent autocracies.

---

[4] There is no single precipitation threshold for a region to be considered as having a semi-arid climate: the threshold depends on total precipitation, the percentage of precipitation that falls during the warmest months, and average annual temperature. In a warm environment (average temperatures of 20 C) and where more than one third (but less than 70 percent) of the rain falls in the hottest months, the upper bound for semi-arid would be 540 mm in precipitation per year. The same is true for a region to be classified as a rainforest: the threshold depends on total rainfall, average temperature, and the distribution of rainfall across the year.

A skeptical reader might be tempted to argue that the patterns in Figure 1 are an artifact of the period over which polity is averaged: it leaves out the countries that were formed in Africa, Asia, and the Caribbean once colonialism ended in the 1960s. I therefore redraw the graph, substituting Average Polity from 1975 to 2010, and present the results in Figure 2. Picking this short window of time biases the results against the hypothesis: more recently created (and presumably less consolidated) democracies located in the Tropics, such as Trinidad and Tobago, receive the same Average Polity score as long-standing democracies, such as England. Nevertheless, Figure 2 produces the same material results as in Figure 1. The sample mean for countries in the arid/semi-arid zone is only 35, it then nearly doubles to 67 in the moderate precipitation zone, and then falls back down to 53 in the rainforest zone. The distribution of stable democracies and persistent autocracies also mirrors the pattern in Figure 1: the moderate precipitation zone contains 38 percent of the countries in the world, but 60 percent of the stable democracies and only seven percent of the persistent autocracies.[5]

An even more skeptical reader might be tempted to think that these patterns are actually caused by some other omitted factor. In order to test that hypothesis, I estimate a series of Tobit Regressions in Table 1, taking the same parameters for Average Polity and average precipitation as in Figure 2. In order to capture the pattern displayed in Figure 2, I construct two restricted cubic splines of the natural log of precipitation with three knots, in which rainfall is defined to be a continuous smooth function that is linear before the first knot, a piecewise cubic polynomial between adjacent knots, and is linear after the last knot. The location of these three knots was chosen according to Table 2.3 of Harrell (2001), with the first knot placed

[5] I reestimate the standard deviation across this sample. One standard deviation above the mean continues to be 85—the same as Jagger and Gurr's cutoff for a coherent democracy. The cutoff for persistent autocracies rises slightly, from 21 to 24.

at the 10th percentile, the second knot placed at the 50th percentile, and the third knot placed at the 90th percentile.

Specification 1 of Table 1 reports the base results. Each of the precipitation splines is highly significant (p<.001) and has the expected sign (positive in the first spline and negative in the second spline). Specifications 2 through 6 of Table 1 add controls in a stepwise fashion in order to see whether the results obtained in specification 1 are robust. Specification 2 controls for the "resource curse" hypothesis (see Ross 2001), by adding average real crude oil production per capita over the period 1970-2006 (from Haber and Menaldo 2011). Not only are the precipitation splines unaffected in significance or magnitude, crude oil enters the regression as not statistically significant, suggesting that the "resource curse" may be an artifact of omitted variable bias (see Haber and Menaldo 2011). Specification 3 controls for the impact of Malaria, in order to see whether the results are robust to controlling for disease environments (see Acemoglu, Johnson, and Robinson 2001). The percentage of the population in high malaria zones (from Sachs 2003) enters with the predicted sign and significance, but our results are robust to disease environments: the precipitation splines attenuate only slightly, and remain significant at the .001 level. As an additional robustness check, I also controlled for Malaria Ecology (lands well suited to the Mosquito species that are the vector for Malaria, also from Sachs 2003), and obtained materially similar results (not shown). Specification 4 controls for ethnic fractionalization (from Fearon and Laitin 2006), on the theory that countries that are more ethnically heterogeneous are less likely to sustain democracy. Ethnic fractionalization enters with the expected sign and significance, but our regressions results are robust to its inclusion: the precipitation splines attenuate only slightly, and remain significant at the .001 level. As an additional robustness check, I also controlled for ethno-linguistic fractionalization (with the data also from Fearon and Laitin 2006), and obtained materially similar results (not shown). Some scholars (e.g., Huntington 1996, Chaney 2012) have alleged that Islam is antithetical to democracy. I therefore control, in column 5 for the percentage of the population that is Muslim (from Fearon and Laitin 2006). The precipitation splines do attenuate somewhat (not surprising, inasmuch as Islam is the dominant religion in the Middle East, North Africa, Indonesia, Pakistan, Bangladesh and Sub-Saharan Africa, which fall at the very low and very high ends of the rainfall spectrum). Nevertheless, even controlling for Islam, the rainfall splines remain significant at .001.[6] Finally, one might imagine that colonial heritage explains regime types. I therefore introduce dummy variables for being a former British, French, Belgian, Dutch, Spanish, or Portuguese colony in specification 6 (the omitted variable is being a country that was never colonized). The addition of these dummies actually increases the magnitude of the precipitation splines, while having no effect on their level of statistical significance.

Section III: Rainfed Cereals as the Intermediating Factor

Clearly, democracy does not fall directly from the sky with a continual light drizzle. Something stands between the level of precipitation and the level of democracy.

An obvious candidate for the mediating factor is rooted in a brute fact of nature: what farmers can grow (and could grow historically) is driven in large part by a crop's water requirements. Cereals (e.g., Wheat, Barley) do not grow if there is too little or too much moisture. If there is too little, the seeds will not germinate or the plants will wilt in the field. If there is too much, their roots will rot. In addition, heavy rains, particularly late in the

[6] We will later focus on the long-run political institutions of the Middle East and North Africa, and show that those regions were highly autocratic by the standards of their Mediterranean competitors--even before the invention of Islam

growing season, knock grain stalks down in the field, destroying the plants.[7] Heavy rains also give rise to thin soils with high levels of iron and aluminum oxides that are notoriously unsuitable for cereal production. The one exception to this pattern is Rice, which not only grows well in wetlands, but actually becomes much more productive if fields can be flooded via a source of irrigation—the economic and political implications of which we will come back to in detail.[8] Importantly, there are a large number of roots and tubers (e.g., Taro, Cassava, Yams), as well as many tree crops (e.g., Bananas), and some grasses (e.g., Sugar Cane) that thrive under conditions of very high rainfall.

I depict this brute fact of nature in Figures 3 and 4, which draw on the Global Agro-Ecological Zones Version 3.0 model and dataset compiled by the U.N. Food and Agricultural Organization and the International Institute for Applied Systems Analysis (hereafter GAEZ 3.0). GAEZ 3.0 measures soil characteristics (e.g., moisture, temperature, slope, depth, texture, nutrient content, mineral content) at the level of the "tile" (typically ten kilometers square) across the globe averaged over the period 1961-90, and then uses that information to estimate the suitability of the soils in that tile to grow a variety of crops under different irrigation techniques and levels of technology. The resulting soil suitability index (hereafter SI) is the percentage of the maximum attainable yield for any particular crop that can be grown in that tile with those inputs, with values running from 0 (cannot be grown at all) to 100 (can be produced at 100 percent of the maximum attainable yield). In order to look

---

[7] It was for this reason that the Irish so quickly and widely adopted the potato. The rainy climate not only made it near impossible to grow wheat, it often destroyed the oat crop (Fagan 2000).

[8] Periodic flooding of rice fields via an irrigation system confers several advantages: it controls weeds, stabilizes soil ammonium nitrogen, and permits ratooning. The available estimates suggest a roughly 50 percent per acre productivity difference between irrigated and rain-fed rice. As a result, most of the world's rice is grown using irrigated methods of production (Street and Bollich 2003: 276, 290; Mikkelsen and KeDatta, 1980: 165).

backwards in historical time, I draw the soil suitability indices specifying "low levels of inputs" (no chemical fertilizers, pesticides, or herbicides, using traditional cultivars) and rainfed irrigation.[9] In Figure 3, the Y axis is the combined GAEZ 3.0 SI for the cereals that can be effectively grown without man-made irrigation systems (Barley, Buckwheat, Foxtail Millet, Maize, Oats, Pearl Millet, Rye, Sorghum, and Wheat) within 100 miles of the largest city of every country. In Figure 4 the Y axis is the SI for Sugarcane within 100 miles of the largest city in every country. Similar results are obtained using the SI for Bananas or other tropical crops. In addition, the results are robust to conducting the analysis on the level of rainfall 200 miles from the largest city, 500 miles from the largest city, and the average for the entire country. The X axis in both figures is average annual precipitation within 100 miles of the largest city, as described in Figure 1. The upper bound of the semi-arid zone and the lower bound of the rainforest zone are demarcated as in Figure 1.

You do not have to squint to see the patterns in Figures 3 and 4. Figure 3 shows that Rainfed cereals thrive in the same band of moderate rainfall where the world's stable democracies are clustered, while they do very poorly in the arid and rainforest bands, where the world's persistent autocracies are clustered. Indeed, the overlap between Figures 1 and 2 (Precipitation and Average Polity) and Figure 3 (Precipitation and land suitability for rain-fed cereals) is striking. The relationship between the ability to grow rainfed cereals and moderate levels of rainfall is expressed in Table 2, which presents OLS regression results, the parameter estimates of which closely mirror those for precipitation levels and Average Polity from specification 1 of Table 1. Figure 4 shows that the relationships depicted in Figure 3 do not generalize to all crops: Sugarcane does not thrive in the moderate rainfall zone.

---

[9] Soils improve over time spans that are geologic, not historical. While systematic mismanagement can cause soils to degrade over historical time spans, as a practical matter, the GAEZ SI's with low levels of inputs and no irrigation captures what farmers could successfully plant in centuries past.

It should therefore not come as a surprise that there is a systematic relationship between the GAEZ SI for rainfed cereals and Average Polity. Figure 5 presents a scattergram with Average Polity from 1975 to 2010 on the Y axis and the SI for rainfed cereals within 100 miles of the largest city in each country on the X axis. As in Figures 1 and 2, I identify those countries that meet the criteria for Stable Democracy and Persistent Autocracy. There are two ways to look at the data in Figure 5. The first is to simply focus on the slope of the trend line, which indicates that as the ability to grow rainfed cereals increases, so does Average Polity. The second is to focus on how the Stable Democracies and Persistent Autocracies cluster. If we focus on the Stable Democracies, we find that none of them are located at very low levels of soil suitability (an SI of ten or less), and that the vast majority of them cluster at SI's of 25 or above. If we focus on the Persistent Autocracies, we find that none of them are located at very high levels of soil suitability (an SI of 60 or above), and that the vast majority of them cluster at SI'ss of 25 or below. That is, 57 percent of the countries in the world have cereal SI's of 25 or above, but that group of countries contains 77 percent of the Stable Democracies and only 30 percent of the Persistent Autocracies.

Specification 1 of Table 3 models the relationship between the Cereal SI and Average Polity. It indicates that as the SI for rainfed cereals increases by one percentage point, Average Polity increases by .59 of a percentage point ($p<.001$). That is, a one standard deviation increase in the Cereals SI (s.d.=18.5) produces an 11 percentage point increase in Average Polity (one-third of a standard deviation). Given that the range of the Cereals' SI data runs from 0 to 78, the implication is that as one moves across the four standard deviations in the sample range, Average Polity increases by 44 percentage points.

In Table 3, I attempt to make these results disappear by controlling for factors that researchers have posited as alternative explanations for the distribution of democracies and autocracies around the world. I add, in a stepwise fashion, the same covariates as in Table 1. The covariates enter with the expected sign and significance, but none has a strong material effect on the results. The largest effect is exerted by controlling for the percent of the population that is Muslim, but even in the presence of this control variable, a one percentage point increase in the Cereals SI still implies an increase in Average Polity of .35 of a percentage point ($p<.01$). Most of the covariates have very small effects. In fact, in the presence of the Cereals SI variable, one of the covariates that has received considerable attention in the literature (crude oil production) has a trivial effect: for every dollar increase in per capita crude oil production, Average Polity only decreases by .003 of a percentage point. The implication is that, controlling for its soils, had Nigeria produced no crude oil from 1970 to 2006, its Average Polity score would have increased by only 1 point (on a 0 to 100 scale).

Section IV: Theory

What accounts for the patterns we see in Figures 3 and 4? What is it about the ability to grow rainfed cereals that pushes countries in the direction of Stable Democracy?

Let us build up a theory that starts with brute facts of nature. First, the crops that grow under different rainfall conditions have vastly different storability characteristics. Cereals can be stored for years on end because they have low moisture contents and go dormant after harvest. Such is not the case for the roots, tubers, grasses, and tree crops that grow under high rainfall conditions. They have high moisture contents, high respiratory rates, are subject to fungi and microbial attack, and typically do not go dormant after harvest. Some tropical crops decay within hours of harvest (e.g., Sugarcane), some last but a few days (e.g., Bananas), some a few weeks (e.g., Taro), and some a few months (e.g. Yams).[10]

Second, cereal crops are seasonal, tropical crops are not. If it is too wet or too dry at a particular time in the growing season, an entire cereal crop can be lost. Tropical crops do not have seasons, they ripen year round.

Third, human beings do not control where and when it will rain—and variance in rainfall can be local. Thus, rainfed cereal crops are subject to idiosyncratic production shocks: a crop can fail in one locality but come to harvest a few localities away.

Fourth, the level of a river or an aquifer tends to be uniform across its entire area. A low level of precipitation at a river's source means drought for all farmers downriver. A high level of precipitation at a river's source means flooding for all farmers downriver. The implication is that when farmers rely exclusively on rivers or aquifers for irrigation, production shocks are systemic, not idiosyncratic: if one locality's crop fails because of a drought or flood, every localities' crop fails.

Let us now add some well-established facts about from decades of social science research spanning archaeology, history, and economics. These are not brute facts of nature, but they are not in debate.

First, crops that can be easily stored can be easily traded, and can serve as a source of accumulation. Crops that cannot be easily stored cannot be easily traded, and therefore do not

[10] Sugarcane is the quintessential example: If cut cane is left unprocessed for more than 12 hours, the sugar is lost to fermentation (Binswanger and Rosenzweig 1986; Dye 1998). Bananas and Cassava can be stored for only five to seven days; Taro for two to six weeks; Sweet Potatoes two to four months; Yams 12 to 18 weeks (Ravi, et. al., 1996; Diop and Calverley1998; Abu-Goukh 1986).

serve as a source of accumulation (except as body fat). The implication is that crops that can be easily stored and traded can be easily stolen or taxed.

Second, differences in the storability characteristics of crops have huge implications for the optimal scale of production. Cereals grown under rainfed conditions exhibit quite modest economies of scale: beyond the scale of a family farm, efficiency falls dramatically because of the high costs of monitoring non-family labor (Binswanger and Rosenzweig 1986; Engerman and Sokoloff 1997; Allen and Lueck 1998).[11] Tropical crops grown for local use are also characterized by modest economies of scale. A farmer growing a non-seasonal crop such as yams or taro has only the most minor concerns about monitoring costs; there is not even a harvest season that requires him to coordinate the labor of family members.

When tropical crops are grown on a commercial basis, however, the minimum efficient scale grows by several orders of magnitude. There are tremendous economies of scale in the processing of tropical crops to make them less perishable so that they may enter trade: sugarcane, for example, must be milled by massive machines and the juice boiled in giant vats (or spun in centrifuges). Until they are processed, however, the high perishability of tropical crops means that there are hold-up problems between farmers and refiners or distributors: the refiners or distributors have incentives to renegotiate the contracted price with farmers while the product rots; farmers respond in kind, holding back on deliveries while the produce already purchased by a distributor rots. The combination of high perishability and sizable scale economies in processing and distribution means that there has to be very

[11] The U.S. experience in the late nineteenth century with "Bonanza Farms" (massive grain farms in the Midwest that were owned by corporations and run like manufacturing companies) demonstrates the phenomenon: much to the shock of their shareholders, the bonanza farms quickly failed, their lands gradually bought up by homesteaders (Allen and Lueck 1998).

careful coordination between sugar growers and processors. Mills, boilers, packing plants, and refrigerated ships lose money for their owners every minute that they remain idle. The economically efficient solution is vertical integration: the creation of a single firm that owns every stage of production and distribution. The classic cases are bananas (May and Plaza 1958), sugar (Binswanger and Rosenzweig 1986; Dye 1998), and pineapples (Coulter 1934; Collins 1949; Wilson 1948), but the phenomenon holds for just about any tropical crop that enters long-distance trade; they are grown on massive plantations.

Third, humanly devised methods of irrigation increase farm sizes. Building and maintaining an irrigation system represents a sizable fixed cost, which pushes a farm's average cost curve upwards, thereby shifting to the right the point at which the average cost and marginal cost curves intersect. The minimum efficient scale of production is now no longer predominantly determined by the farmer's monitoring costs, but is also determined by the need to operate on a scale large enough to efficiently exploit a system of canals, trenches, and gates (Allen and Lueck 1998).

Fourth, nobody owns the rain as it falls, but once it is channeled into a river or aquifer, it becomes appropriable. People have not figured out how to claim property rights over rain, but they have been claiming property rights over rivers, streams, and aquifers for millennia. The implication is that when a crop must be produced using irrigation from a river, stream, or aquifer, whoever has property rights to the water can, literally, siphon off the farmer's surplus. Farmers who rely on the rain do not face this problem of appropriation.

Implications for Social Structures, Incentives, and Institutions

Let us now think through the implications of these facts for the organization of agriculture, social structures, the incentives facing farmers, and the institutions that are likely to emerge across different precipitation/crop zones. Let me be clear, however, that the theory I am advancing is probabilistic. It is about the way that biology and technology nudges—indeed pushes—societies down particular paths of institutional development. It does not mean that all societies in a particular precipitation/crop zone *must* go down that path. It means that, all other things being equal, they have a higher probability of going down that path than a society in a different precipitation/crop zone.

Moderate Rainfall Zones

Let us begin with the world's moderate rainfall zones. The crops that grow there (and that have grown there for centuries, if not millennia) tended to be seasonal, highly storable, characterized by modest economies of scale in production, and subject to idiosyncratic production shocks. Barriers to entry created by access to water were non-existent: nobody owned the rain. During the period when most people in moderate rainfall societies worked in agriculture—which is to say up until the late nineteenth century—those production characteristics meant that family farms tended to be the modal production unit and that problems of scarcity could be dealt with through local or regional trade.

Storable surpluses were a mixed blessing: they created a basis for accumulation and trade, thereby incentivizing specialization and investments in human capital; but they also created a basis for theft and taxation. Agriculturalists in such a society therefore had incentives to support a state that was powerful enough to protect their surpluses from other economic agents via the enforcement of property rights and contracts, but that was not so powerful that it could commandeer their surpluses for its own ends. The quintessential examples are the parliaments that stretched from England to Poland and Hungary beginning in the 11^{th} century, which served as courts and tax collectors for kings, but which also increasingly came to serve as bulwarks against the arbitrary exercise of royal power (Strayer 1973).

Over the course of centuries, the pressures and tensions inherent in these "Transactional Societies" were more likely than others to give rise to a society made up of large numbers of prosperous citizens with high levels of human capital, *engaging in a diverse set of economic activities well beyond agriculture*, residing in a state designed to support transactions, rather than prey upon property rights. Trade was initially a mechanism to deal with problems of scarcity, but once there were social surpluses and mechanisms to protect transactions, trade created incentives to specialize (invest in human capital), so that significant percentages of the population moved into non-agricultural endeavors. Sokoloff's "non-mechanized factories" and common-man inventors of the 1820s and 1830s in the United States are quintessential cases in point, but so are the manufacturing centers of Ancient Greece and the Roman Republic, as well as the various "putting out" enterprises that covered England and Continental Europe beginning in the 18th century. High levels of human capital, in turn, made it easier to craft institutions designed to facilitate transactions and limit predation.

Democratic transitions, when they occurred for whatever reason, were more likely to consolidate in these societies than in others. In the first place, these states already had institutions designed to check the power of sovereigns (Strayer 1973). In the second place, elites in these states, while they may not have thought of democracy as a first-best outcome, did not live in fear of a tyranny of an impoverished majority seeking redistribution (and retribution): their incentives to either resist democracy ex ante, or undermine it ex post, were weaker than in other societies (Acemoglu and Robinson 2006). Finally, the high level and broad distribution of human capital in those societies meant that once democratization occurred citizens were better able to monitor and discipline politicians, holding them accountable and incentivizing them to provide public goods that strengthened democracy (Keefer and Vlacui 2008).

ARID ZONES

Modest scale economies of production, and low barriers to entry did not characterize the crops that could be grown in arid zones. The need for irrigation created barriers to entry: whoever had property rights to water had de facto property rights to the land, thereby allowing them to siphon off whatever agricultural surpluses were produced. Most of the population was therefore composed of impoverished peasants, or pastoral nomads living at the desertic fringes of the irrigated zones, not family farmers who could accumulate tradable surpluses. Quintessential examples include Egypt from the beginning of the 4^{th} millennium BCE to the present, Ancient Mesopotamia and modern Iraq, Persia and modern Iran, and the Hohokam civilization of the U.S. Southwest.

Arid-zone farmers had incentives to support a state—it was not just imposed on them—but their incentives were different from farmers in moderate rainfall zones. In the first place, they had weak incentives to clamber for institutions designed to protect their tradable surpluses, because those surpluses had already been siphoned off by the elites and elite-organizations (Temples, Pharaohs, Kings, and local potentates) that controlled access to water. In the second place, farmers operating in an irrigation-dependent system could not easily solve the problem of scarcity through trade (the way farmers in rain-fed systems could): variations in output caused by floods or droughts was more likely to be system-wide than local. Farmers therefore needed an institution that could capture scale economies in the storage of grain so as to insure against society-wide harvest failures, and that institution had to be strong enough to prevent any one group of economic agents from commandeering that surplus for its own ends. In short, they had incentives to support a powerful state designed to insure against systemic risk, rather than a limited state designed to protect transactions—Pharaonic Egypt perhaps being the archetype. The states that emerged, in short,

In some semi-arid environments there were pockets where rain fed agriculture was possible, such as the narrow strips of Algeria, Tunisia, and Libya that sit next to the Mediterranean, the plains of Syria, and Southwest Iran. The term "pockets of agriculture" is not a metaphor: the environment circumscribed good farming territory much more strictly than it did in areas of moderate rainfall, such as Europe, India, or North America east of the Mississippi. These societies tended to be composed of nomadic and semi-nomadic pastoralists who dedicated themselves to providing long distance transport for the specialized goods produced by the societies with moderate rainfall that bordered them. Classic examples include the Bedouin tribes that ran the caravan trade across the Arabian Peninsula; the Berbers who controlled the trans-Saharan trade between the Magreb and the Sahel; and the various tribal peoples of the Eurasian Steppe that provided the transport for the famed Silk Road between China and Western Europe.

To the degree that this type of economy generated incentives to specialize, it was toward developing skills associated with mobility and violence. When such a society was lucky enough to find an extraordinary leader, such as Attila or Genghis Khan, it could be militarily potent. These societies therefore, for short periods of time, occasionally attained considerable riches by raiding and conquering the cereal-based agricultural societies next to them, but they did not to produce incentives for the population to make investments in the specialized skills that are the basis of trade itself.

In short, the natural environment created weak incentives for economic agents to invest in human capital or development institutions designed to limit the power of rulers. Indeed, the power of rulers was what made their commitment to providing insurance when crops failed credible. When such societies experimented with democracy for whatever reason, they therefore had a lower probability of success than societies in moderate rainfall zones.

RAINFOREST ZONES

In the tropics it was, of course, possible to grow food without the need for irrigation—but what could be cultivated tended to be neither seasonal nor storable. These crop features had two ramifications. First, crops that are not easily stored are not easily traded, and thus there were weak incentives for agents to specialize or make inter-generational investments in human capital. Second, the fact that it was difficult to accumulate agricultural surpluses meant that there were weak incentives to support the development of a state. What role, exactly, would a state have served in a society based on the production of crops that ripened continually throughout the year, but that could not be traded because they decomposed within days or weeks of being harvested? This is not to say that states did not exist, but it is to say that when they did so they tended to be predatory: when the only way to store an agricultural surplus is in human body fat, the most obvious source of public finance is the coerced muscle power of human beings. Even this mode of public finance, however, quickly hits natural limits: coerced muscle-power is not particularly valuable if it is being used to produce something that cannot, itself, be accumulated or traded. It is telling that the only large-scale rainforest zone state confronted by the Europeans in the sixteenth century, the Kingdom of the

Kongo, was characterized by a low population density, miniscule cities, and a predatory, yet impoverished, nobility—that is, until a technological break-though in the form of the Portuguese Caravel allowed that nobility to take advantage of a lucrative external market for coerced muscle power (Broadhead 1979; Thornton 2001).

The invention of steam power, the Bessemer method of producing steel, and refrigeration in the nineteenth century permitted the commercialization of many low-storability, non-seasonal tropical crops, but it did not shift incentives in the direction of a society that was likely to be conducive to democratic survival. The fundamental characteristics of tropical crops (high perishability, large economies of scale in processing and distribution) had powerful ramifications. There were strong incentives for producers to backwards integrate into every step of the process of production and distribution, and thus the scale of enterprises tended to be dictated by the step that had the largest minimum efficient scale—which was typically in processing or distribution. The modal production unit was not a family farm, but a massive plantation. The quintessential example was Pineapple production: until the 1960s, 85 percent of the world's pineapples were grown on a single 200,000 acre plantation owned by the Dole Family on the island of Lanai, Hawaii. Bananas are another case in point: two firms, United Fruit and Standard Fruit (which later merged to become Chiquita Banana), owned the plantations in Central America, the International Railroads of Central America, the steamships that carried the bananas to New Orleans, and the distribution network in the United States. The resulting societies were not made up of large numbers of prosperous farmers with high levels of human capital, but of impoverished laborers whose ability to accumulate surpluses were very low and whose incentives to make intergenerational investments in human capital were very weak.

Plantation owners in such societies had an incentive to create a state, but not one designed either to protect transactions or insure against catastrophic harvest failure: the state was simply one more step in the process of production and distribution into which the plantation owners backward integrated; it existed to enforce *their* property rights and maintain a compliant workforce. Perhaps the best known examples are the "Banana Republics" of Central America, where United Fruit and Standard Fruit, for all intents and purposes were the state, removing presidents at will. The Hawaiian Republic is a perhaps less well known—but even more powerful—example: the sugar barons that ran Hawaii as their own private fief before it became a U.S. territory were the children of New England missionaries. Hawaiian political institutions did not resemble those of Honduras because of the cultural preferences of the elite; they were Central American because the relentless logic of biology and technology pushed them in that direction.

Democratic experiments in these settings were therefore less likely to result in democratic stability than in moderate rainfall zones. In the first place, any attempt at democratization had to be built upon a pre-existing state lacking in institutions designed to limits its authority and discretion. In the second place, any attempt at democratization had to be built upon a social structure characterized by high levels of inequality. As a consequence of these two factors, elites had strong incentives to resist democracy ex ante or undermine it ex post. Finally, any attempt at democratization had to be built upon big mismatches in human capital: citizens were not in a strong position to monitor and discipline politicians.

A Chinese Coda

Some readers may be wondering where China and the long-standing authoritarian states of Southeast Asia fit into this framework. Their agricultural systems are based, after all, on the production of a high storable crop that can be efficiently grown on small production units: wetland rice.

The key to understanding why China and the countries of Southeast Asia have never experimented with democracy is the word "wetland." Rice can be grown under rainfed conditions, but it almost never is. Indeed 95 percent of the world's rice is grown using humanly-devised irrigation systems because of the sizable gains in productivity afforded by flooding rice fields: first to keep down weeds, and then later in order to get a second crop from the same plants (a practice known as ratooning). This means that farmers along the Yangtze and Mekong have always been in a position similar to that of arid-zone farmers: the entities that have property rights to water could siphon off all their surplus; and problems of scarcity had to be solved through centralized grain storage, rather than trade, because production shocks were systemic, not idiosyncratic. Powerful state existed, but their role was not to facilitate transactions; it was to serve as an insurance mechanism. The incentives for farmers to specialize (invest in human capital) were therefore weak. These societies, in short, were not fertile grounds for democratic stability—Thailand being perhaps the most obvious case in point.

Section V: Empirical Tests

The theory advanced in this paper is that growing storable crops using rain-fed technologies across large numbers of production units gave rise, over time, to a series of social characteristics and institutions that were conducive to democratic consolidation: a high average level of human capital, a broad distribution of income, and a limited state that facilitated transactions. How do we know that those really were the mediating factors between precipitation levels and democracy?

Cross-Country Regressions

Let us begin by returning to the regressions we estimated in Sections Two and Three, in which we modeled Average Polity from 1975 to 2010 as a function of precipitation levels (Table 1) and soils suitable for growing rainfed cereals (Table 3). We have theorized that what stands between precipitation levels and democracy, and soils suitable for rainfed cereals and democracy, is a complex of social structures and institutions. It follows that if we were able to introduce a set of variables that control for that complex of social structures and institutions that both the precipitation splines (Table 1) and Cereal SI variables (Table 3) would attenuate.

Several factors guide my choice in the specification of this intervening variable. The first is parsimony. The more variables one enters into a regression with 136 cases the less one can have confidence in the results. Moreover, one might easily imagine that these social structures and institutions interact with one another; and thus can be thought of as a vector. As a practical matter, this means that we ideally want to introduce a single variable that captures that vector. The second is endogeneity. Any institutional variable runs the risk of being endogenous to regime type. This means that any mediating variable should be taken from the period before 1975, and the farther back in time we measure that variable the greater the confidence we can have that it is not endogenous.

Taking these two factors into account, I employ a single variable that has been employed in the economic history literature as a proxy for the level and distribution of human capital: the Whipple Index for adult populations in 1910 (from Crayen and Baten 2010). The intuition behind the Whipple Index is simple: the ability to correctly identify one's own age is a good test of basic numeracy; and basic numeracy is a robust indicator of one's level of human capital. It follows that the larger the percentage of the population that incorrectly identifies their ages (by heaping their reported ages on census returns around multiples of five, as in stating one's age, incorrectly, as 45, instead of correctly, as 43) the lower the level of average human capital in a society. Whipple Indexes therefore run from 500 (everyone rounds their age to the nearest five years) to 100 (no one rounds their ages).

Crayen and Baten (2010) estimate Whipple Indexes for populations aged 23 to 72 for 165 societies from 1820 to 1949. I draw on their 1910 cross-section, which contains sufficient observations to make analysis meaningful. Given that we are observing adults aged 23 to 72 in 1910, and that investments in human capital tend to be made when people are young, it follows that we are observing human capital investments that took place in the mid to late 19^{th} century. It is highly unlikely that these estimates are endogenous to regime types measured from 1975 to 2010.

Figure 6 shows the relationship between the Whipple Index in 1910 and Average Polity from 1975 to 2010. There are two ways of visualizing the data. One is to focus on the slope of the trend line, which is strongly negative: as the Whipple Index increases (human capital falls) Average Polity falls. A second is to focus on the location of the Stable Democracies, which cluster in the upper-left hand corner (high levels of human capital and high levels of Average Polity go together). In short, Figure 6 indicates that there is a strong relationship, and the century between the measurement of the Whipple Index and Average Polity suggests that the relationship is causal.

Figure 7 shows the relationship between the Whipple Index in 1910 and the Rainfed Cereals Soil Suitability Index. Again, the trend line suggests a relationship: as the SI for Rainfed Cereals increases, the Whipple Index Falls (human capital improves).

Table 4 therefore estimates a series of regressions designed to see if the soils suitable for rainfed cereals works on Average Polity through the vector of social structures and institutions proxied by the Whipple Index. Specification 1 is the base regression of Average Polity on the Cereals SI. Specification 2 re-estimates that regressions across the same observations for which we have Whipple Index values in 1910. Specification 3 then adds the Whipple Index. The coefficient on the Cereals SI is no longer statistically significant, but the coefficient on the Whipple Index is significant ($p<.001$) and of large magnitude: a one point decrease in the Whipple Index results in a 0.17 increase in Average Polity. That is, a one standard deviation decrease in the Whipple Index (75 points) produces an increase in Average Polity of nearly 13 points (roughly 40 percent of a standard deviation).

As a robustness test, in Table 5, I repeat this same set of regressions, but now substitute the Rainfall Splines for the Cereals SI. Specification 1 provides the base results. Specification 2 reestimates the base regression over the same set of observations for which we have Whipple Index values in 1910. Specification 3 introduces the Whipple Index. The results indicate that the Whipple Index mediates between the Rainfall Splines and Average Polity: neither spline is statistically significant; and the Whipple Index is highly significant ($p<.01$) and of large magnitude. A one standard deviation decrease in the Whipple Index (75 points) produces an increase in Average Polity of 11 points (roughly one-third of a standard deviation).

An Out of Sample Test from Antiquity

Does the relationship between rainfall and democracy hold before the advent of modern democracy in the 19th Century? There was, of course, a much earlier experiment with representative institutions, one that took place in antiquity, in both Greece (from the late 6th through the late 4th centuries BCE) and the Roman Republic (from the early 5th through the late 1st centuries BCE). This out of sample test confers an additional advantage: it allows us the opportunity to perform a robustness test on the possibility that some cultural value that happens to correlate with zones of very low and very high rainfall, such as Islam, is driving our results. I doubt this to be the case, because our regressions include controls for these Islam. Nevertheless, drawing a comparison during a period in which neither Christianity nor Islam yet existed might provide comfort to the preternaturally skeptical.

The world's oldest states ring the Eastern Mediterranean. Circa 500 BC, these included the Persian Empire (which at this point controlled the other great state of Antiquity, Egypt), the city-states of Mesopotamia and the Levant, the Roman Republic, and the Greek City States. Four facts about this world provide a measuring rod with which we can assess the theory. The first is that the place where representative institutions first emerged, Greece beginning in the sixth and fifth centuries BC was located in a band of moderate rainfall. The second is that Greece was an intensively agricultural society that produced storable crops under rain fed technologies that had modest economies of scale in production: wheat, legumes of various types, grapes (stored as wine), and olives (stored as oil). The third is that the social structure of fifth century Greece was not only highly egalitarian (Morris 1996, 1997), but the level of human capital was quite high and broadly distributed (Ober 2008). Indeed, the democratic city states of fifth century Greece were remarkable in their level of literacy and the sophistication of their citizens. The fourth is that the backbone of these independent city states were citizen militias: Greek Hoplites were part-time soldiers and full-time farmers who were required to purchase their own (rather expensive) equipment: bronze armor, helmet, greaves, spear, sword, and shield.

Greek city states were very much unlike their major competitor: the Persian Empire, which included present day Iran, Iraq, Syria, the city states of the Levant, and Egypt. With the exception of a few pockets in Syria and Jordan, farming in the Persian Empire was based on tapping the waters of great rivers: the Tigris, the Euphrates, and the Nile. The Persian state, and the local kings and notables who swore fealty to it, extracted the surplus generated by these small farmers through the control of irrigation water. As a result, the Persian Emperor did not field citizen militias against Greek Hoplites: he rented mercenaries with his considerable tax revenues. The Greek Hoplites exercised rights of suffrage and representation. No such institutions existed in Persia.

This comparison between Greece and Persia is not simply a statement about Athens, the most democratic—and most intensively studied—of the Greek states. As Runciman has pointed out, even the Greek oligarchies were democratic when compared to the rest of the Eastern Mediterranean. Sparta, for example, had two kings who balanced each other's power, the ephors (officials who controlled foreign policy), and the Gerousia (an elected council of elders). Citizens voted on actions proposed by the Gerousia. Over time, the kings became figureheads, with real power vested in the ephors and the Gerousia.

There was only one other place in the Ancient world that approximated Greek democracy, the Roman Republic. Like the Greek democracies, Rome was located in a band of moderate rainfall. Like the Greek democracies, farmers in the Roman Republic produced crops that were notable for their high degree of storability—most particularly wheat, which was the staple of the Roman diet. Like the Greek democracies, at the time that the Republic was founded in 508 BC, agriculture was organized around small farms. In fact, like the Greek democracies, the Roman Army was a citizen militia composed of farmers who were required to purchase their own (expensive equipment). It was this citizen army that conquered Italy (often granting the inhabitants of other city states Roman citizenship afterwards), and it was this citizen army that defeated Hannibal in the Punic Wars (Goldsworthy 2003). Even more striking, the Roman Republic was run as a direct democracy—only assemblies of citizens had the right to pass legislation—and the right to vote required military service (Millar 2002). Indeed, the term "legion," which Hollywood has taught us to associate with professional, permanent armies, is from the Latin word for levy: a call up of the citizen militia (Goldsworthy 2003). The great latifundia of Ancient Rome—massive estates owned by absentee grandees and worked by slaves—came into existence only later, once Rome had expanded across the rest of the Mediterranean world and Western Europe and it became unfeasible to fight campaigns with a citizen militia. It was at that point, once the army was staffed by professional soldiers from very humble backgrounds, that the democratic political institutions of the Republic went into decline: they had no incentives to support democracy, and every incentive to follow their ambitious military leaders into politics. It is striking that when the Republic fell, and the Roman Empire was founded (500 years after the creation of the Republic, in 27 BC) Rome was no longer a society of small farmers, but had become a society of landlords who worked their estates with slaves captured in foreign wars.

A Natural Experiment

The collapse of the former Soviet Union and the dissolution of Yugoslavia provide a natural experiment with which to test our theory. During the 18th and 19th centuries Russia conquered and colonized regions that until then had been organized as mini-kingdoms, such the Ukraine, Belarus, Moldova, and Georgia, or that had been populated by tribal peoples not organized into states, such as the so-called stans in Central Asia. After the Russian Revolution, Stalin set these areas up as Soviet Republics, and for the next seven decades they were subjected to an experiment in social engineering, which included ideological indoctrination, the forced adoption of the Russian language, the collectivization of agriculture, and the steady influx of Russian colonists. This experiment was then broadened at the end of World War II, when the Soviet Union occupied the formerly independent states of Eastern Europe, such as Poland, Latvia, Lithuania, Czechoslovakia, Romania, and Bulgaria.

A similar experiment in social engineering was carried out by Joseph Broz Tito in Yugoslavia after the country was liberated from the axis powers by partisans. Within a year after the end of World War II, Yugoslavia was reconstituted as the Federal People's Republic of Yugoslavia, which was explicitly modeled on the Soviet Union.

When the Soviet Union collapsed in 1991, most of these former Soviet Republics and occupied states asserted their independence and emerged as sovereign countries. Yugoslavia's regime soon followed, and the country broke up into a series of independent republics.

Fortunately, for us, they represent a broad range of rainfall levels: former Yugoslavia and the western entities of the former Soviet Union (including its satellite states) fall into the moderate rainfall band, most of Central Asian States lie outside of it.

The moderate rainfall zones of Eastern Europe had been populated by small cereal-growing farmers since the late middle ages, when they were colonized by farmers from the West (Gerschenkron 1943; Blum 1957, 1961; Brenner 1976). From roughly 1600 to 1850, some of these areas (particularly Eastern Germany, Poland, the parts of Ukraine) were subjected "the second serfdom"—a period of drastically reduced rights enforced by a militarized, trading elite (Moore 1966).[12] Nevertheless, well before the Soviet Union was formed and Eastern Europe was occupied by Stalin's armies, these regions had returned to small-holder agriculture. How else would we explain Stalin's drive to exterminate the kulaks of the Ukraine, a group of grain growing family farmers who were highly independent and resistant to the reduction of their political and economic rights? Vanhanen's (2003) data on the structure of farming around the world in the early twentieth century is illuminating in this regard: it indicates that, prior to collectivization under the Soviets, family farms were as common in the regions affected by the "second serfdom"—most particularly Poland, Czechoslovakia, and Russia—as they were in Western Europe. In short, property rights in Eastern European cereal agriculture can be thought of as an equilibrium of small-holdings punctuated by an aberrant period in which land was aggregated into large estates.

This was not the case in Central Asia, most of which was too dry to support agriculture of any type, except in a few isolated valleys. Central Asia, prior to the arrival of the Soviets and their massive irrigation projects, was populated largely by pastoral peoples who were organized into clans, tribes, or mini-kingdoms. Indeed, the present-day "countries" of Kazakhstan, Kyrgyzstan, Uzbekistan, and Tajikistan, are all Soviet inventions: they did not

[12] Readers familiar with the political science literature on historical-institutionalism may be wondering how this history can be reconciled with Moore's (1966) famous argument (drawing on Gerschenkron 1943, and Blum 1957, 1961) that the enserfment of small, grain growing farmers in Eastern Europe—most particularly Prussia—was the driving force behind the authoritarian governments of that region. Grain exports, in Moore's view, drove the creation of a militarized, status-oriented, landowning elite that quashed small farmers and ultimately contributed to the rise of fascism. It is important to keep in mind, however, that Moore, and the works from which he drew, explicitly acknowledged that the re-enserfment of Eastern Europe's independent farmers was a deviation from an underlying trend. Moore, in fact, went to great pains to point out that Eastern Europe's system of large-scale landholding was economically inefficient compared to the family farms that it replaced; it was precisely for this reason that repression was a necessary ingredient to make the system work (p. 437).

exist as states prior to the 1920s, when Stalin sent teams of anthropologists to the region to figure out who should be in which "Soviet Republic."

Is there an association between the average level of precipitation and Average Polity from 1991 to 2010 in the former USSR, Soviet Bloc, and Yugoslavia? Figure 8 suggests that there is. The trend line (a third order polynomial, in order to capture the non-linear relationship between precipitation and polity) indicates that Average Polity climbs steeply as we move from the low rainfall countries (mostly located in Central Asia) to the moderate rainfall countries. Indeed, 24 percent of the variance in Average Polity among these countries can be accounted for by precipitation alone. The positive correlation between precipitation and Average Polity levels off around 800 mm of precipitation per annum. There is then a very gentle negative trend once one crosses this threshold, though there are very few countries around which the trend is fitted beyond 800 mm. A second way to visualize the data is to look at the distribution of stable democracies (Average Polity of 85 or above) and extreme autocracies (Average Polity of 24 or below). All of the extreme autocracies are located in the arid band (precipitation of 549 or less per year). Twelve of the 13 stable democracies are located in the moderate rainfall band; only one (Mongolia) is located in the arid band.

Is the relationship between precipitation levels and regime types working through the suitability of the soils for the production of rain-fed cereals? Figure 9 provides some (suggestive but weak) evidence that it is. The trend line has a positive slope, though the there is a great deal of dispersion around the mean (R^2 is .06). The extreme autocracies are located in the bottom left quadrant of the graph (their maximum cereal suitability index is 43). The stable democracies tend to cluster Cereal SIs above 30.

Section V: Conclusion

Researchers have been interested in explaining the distribution of democracies and autocracies since the first democratic states came into existence in antiquity. Interest in this topic was revitalized in the aftermath of the Second World War, as researchers tried to explain the success (or more commonly the failure) of the new democracies that were created in Africa, Asia, and Latin America during the 1950s and 1960s. The fall of the Soviet Union only increased scholarly interest: why have some former communist countries, such as Poland, succeeded in creating a stable democratic order, while democracy died in the cradle in others, such as Kazakhstan?

In recent years, scholars have generally come to the view that "fundamental institutions," explain the types of regimes that dot the planet, as well as a host of other outcomes that tend to be correlated with those regime types. They have not yet, however, generated a consensus about the identity of those fundamental institutions, nor have they explained their origins.

This paper therefore advances a theory rooted in brute facts of nature to explain where fundamental institutions come from and how they determine democratic success. It then tests that theory against evidence. There are, doubtless, disadvantages to this approach. It does, however, confer an obvious advantage: a theory rooted in the constraints imposed by nature mitigates the problems of endogeneity that have fueled scholarly dispute—some of it acrimonious—that have tended to bedevil the literature.

References

Abu-Goukh, A.A. 1986. "Effect of Low Oxygen, Reduced Pressure and Use of 'Purafil' on Banana Fruit Ripening." *Sudan Agricultural Journal* 11: 55-67.

Acemoglu, Daron, Simon Johnson, and James Robinson. 2001. "The Colonial Origins of Comparative Development: An Empirical Investigation." *American Economic Review* 91: 1369-1401.

Acemoglu, Daron, Simon Johnson, James A. Robinson, and Pierre Yared. 2008. "Income and Democracy." *American Economic Review* 98: 808–42.

Acemoglu, Daron, and James Robinson. 2006. Economic Origins of Dictatorship and Democracy. (New York: Cambridge University Press).

Allen Douglas W., and Dean Lueck. 1998. "The Nature of the Farm." *Journal of Law and Economics* 41: 343-86

Baldwin, Robert. 1956. "Patterns of Development in Newly Settled Regions." *Manchester School of Economic and Social Studies* 29: 161-79.

Binswanger, Hans, and Mark Rosenzweig. 1986. "Behavioral and Material Determinants of Production Relations in Agriculture." *Journal of Development Studies*: 503-39.

Blum, Jerome. 1957. "The Rise of Serfdom in Eastern Europe." *The American Historical Review* 62: 807-36.

Blum, Jerome. 1961. *Lord and Peasant in Russia from the Ninth to the Nineteenth Century*. Princeton: Princeton University.

Brenner, Robert. 1976. "Agrarian Class Structure and Economic Development in Pre-Industrial Europe." *Past and Present* 70: 30-75.

Broadhead, Susan Herlin. 1979. "Beyond Decline: The Kingdom of the Kongo in the Eighteenth and Nineteenth Centuries." *The International Journal of African Historical Studies* 12: 615-50.

Capoccia, Giovanni, and Daniel Ziblatt (editors). 2010. "Special Issue: The Historical Turn in Democratization Studies." *Comparative Political Studies* 43(8/9).

Carneiro, Robert. 1970. "A Theory of the Origin of the State." *Science* 169: 733-38.

Chaney, Eric. 2012. "Democratic Change in the Arab World: Past and Present." Harvard, mimeo.

Collins, J. L. 1949. "History, Taxonomy and Culture of the Pineapple." *Economic Botany* 3: 335-59.

Coulter, John Wesley. 1934. "Pineapple Industry in Hawaii." *Economic Geography* 10: 288-96.

Crayen, Dorothee, and Joerg Baten (2010). "Global Trends in Numeracy 1820–1949 and its Implications for Long-Term Growth." *Explorations in Economic History* 47:82-99.

Dahl, Robert. 1971. *Polyarchy: Participation and Opposition* (New Haven, Yale University Press).

Dye, Allen. 1998. *Cuban Sugar in the Age of Mass Production: Technology and the Economics of the Sugar Central, 1899-1929.* (Stanford: Stanford University Press).

Diop, A., and D.J.B. Calverley. 1998. "Storage and Processing of Roots and Tubers in the Tropics." Food and Agriculture Organization of the United Nations, Agro-industries and Post-Harvest Management Service, Agricultural Support Systems Division. Available at: http://www.fao.org/docrep/X5415E/X5415E00.htm

Easterly, William, and Ross Levine. 2003. "Tropics, Germs, and Crops: How Endowments Influence Economic Development." *Journal of Monetary Economics* 50: 3-39.

Engerman, Stanley, and Kenneth Sokoloff. 1997. "Factor Endowments, Institutions, and Differential Paths of Growth Among New World Economies: A View from Economic Historians of the United States," in Stephen Haber ed., *How Latin America Fell Behind: Essays on the Economic Histories of Brazil and Mexico, 1800-1914* (Stanford: Stanford University Press), pp. 260-306.

Fagan, Brian. 2010. *Elixer*. New York: Basic Books.

Gerschenkron, Alexander. 1943. *Bread and Democracy in Germany*. Berkeley and Los Angeles: University of California Press.

Huntington, Samuel P. 1968. *Political Order in Changing Societies* (New Haven, Yale University Press).

Huntington, Samuel P. 1996. *The Clash of Civilizations and the Remaking of World Order* (New York: Simon and Schuster).

Lipset, Seymour Martin. 1959. "Some Social Requisites of Democracy: Economic Development and Political Legitimacy." *American Political Science Review* 53: 69-105.

Lipset, Seymour Martin. 1963. *Political Man: The Social Bases of Politics* (Garden City, N.Y., Doubleday).

Manning, Joseph G. 2010. "Ancient Egypt and the Resource Curse." Mimeo, Yale University.

Marshall, Monty, and Keith Jaggers. 2008. "Polity IV Project: Political Regime Characteristics and Transitions, 1800-2006." University of Maryland.

Morris, Ian. 1996. "The Strong Principle of Equality and the Archaic Origins of Greek Democracy." In Josiah Ober and Charles Hedrick (eds.), *Demokratia*. Princeton: Princeton University Press, pp. 19-48.

Morris, Ian. 1997. "Archaeologies of Equality? The Greek City-States," in Deborah Nichols and Thomas Charlton (eds.), *The Archaeology of City-States: Cross-Cultural Approaches*. Washington, DC: Smithsonian Institution, pp. 91-105.

North, Douglass C. and Barry R. Weingast. 1989. "Constitutions and Commitment: the Evolution of Institutions Governing Public Choice in Seventeenth-century England." *The Journal of Economic History* 49(4): 803-32.

North, Douglass C., John Wallis, and Barry Weingast. 2009. *Violence and Social Orders: A Conceptual Framework for Interpreting Recorded Human History.* New York: Cambridge University Press.

Ober, Josiah. 1998. *Political Dissent in Democratic Athens*. Princeton: Princeton University Press.

Ober, Josiah. 2008. *Democracy and Knowledge: Innovation and Learning in Classical Athens* (Princeton: Princeton University Press).

Persson, Torsten, and Guido Tabellini. 2009. "Democratic Capital: The Nexus of Political and Economic Change." *American Economic Journal: Macroeconomics* 1: 88-126.

Przeworski, Adam, Michael Alvarez, José Antonio Cheibub, and Fernando Limongi (2000). *Democracy and Development: Political Institutions and Well-Being in the World, 1950-1990*. New York: Cambridge University Press.

Raaflaub, Kurt A., Josiah Ober, and Robert Wallace with contributions by Paul Cartledge and Cynthia Farrar. 2007. *Origins of Democracy in Ancient Greece* (Berkeley: University of California Press).

Ravi, V., J. Aked, and C. Balagopalan. 1996. "Review on Tropical Root and Tuber Crops I: Storage Methods and Quality Changes." *Critical Reviews in Food Science and Nutrition* 36:661-709.

Ross, Michael. 2001. "Does Oil Hinder Democracy?" *World Politics* 53: 325-61.

Schwartz, Stuart. 1985. *Sugar Plantations in the Formation of Brazilian Society: Bahia, 1550-1835* (New York: Cambridge University Press).

Strayer, Joseph. 1973. *On the Medieval Origins of the Modern State.* (Princeton: Princeton University Press).

Thornton, John. 2001. "The Origins and Early History of the Kingdom of Kongo, c. 1350-1550." *The International Journal of African Historical Studies* 34: 89-120.

Wilson, James N. 1948. "Pineapple Industry of Hawaii." *Economic Geography* 24: 251-62.

Wittfogel, Karl. 1957. *Oriental Despotism: A Comparative Study of Total Power* (New Haven: Yale University Press).

Figure 1
Precipitation and Average Polity, 1925 to 2010

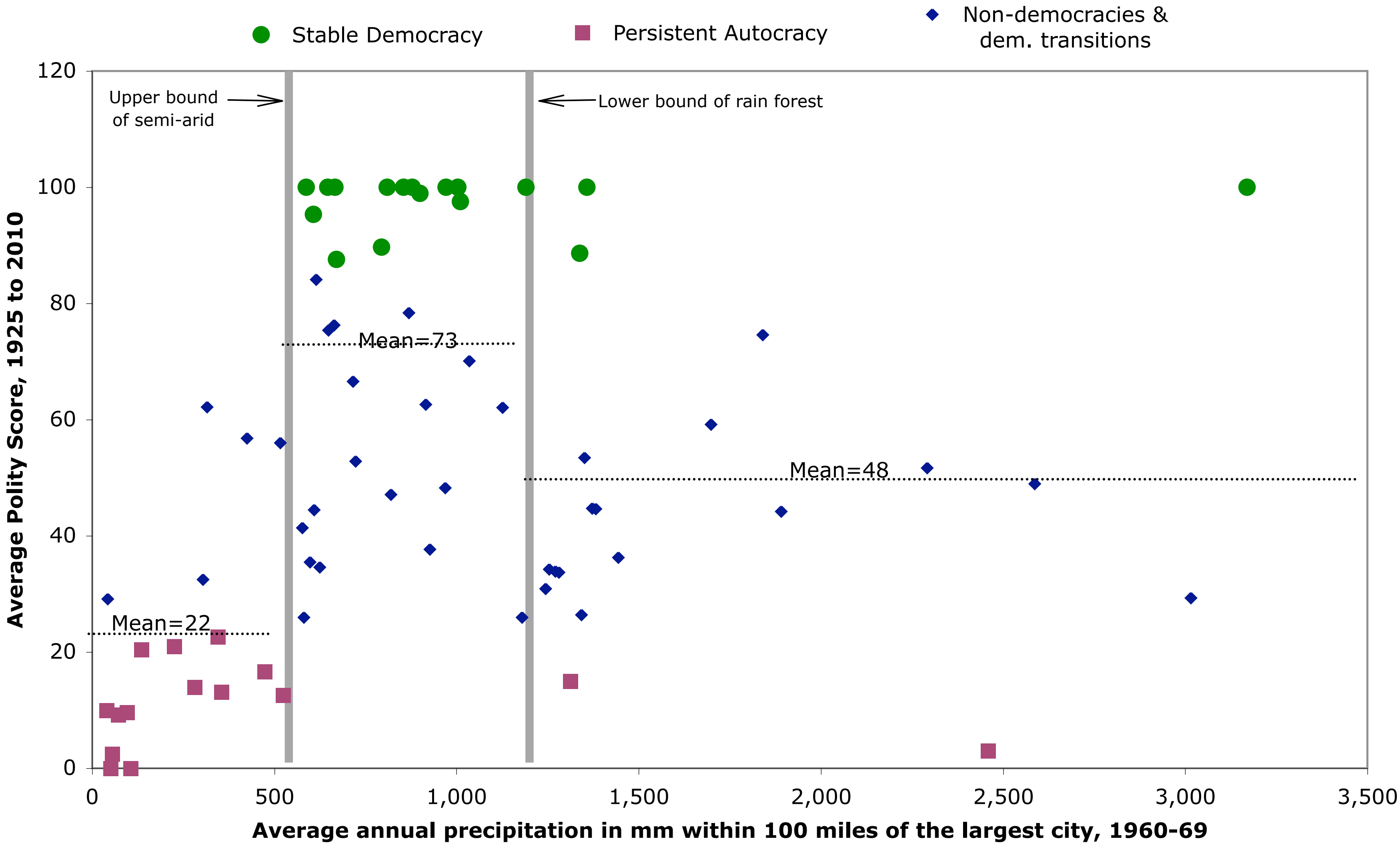

Figure 2
Precipitation and Average Polity, 1975-2010

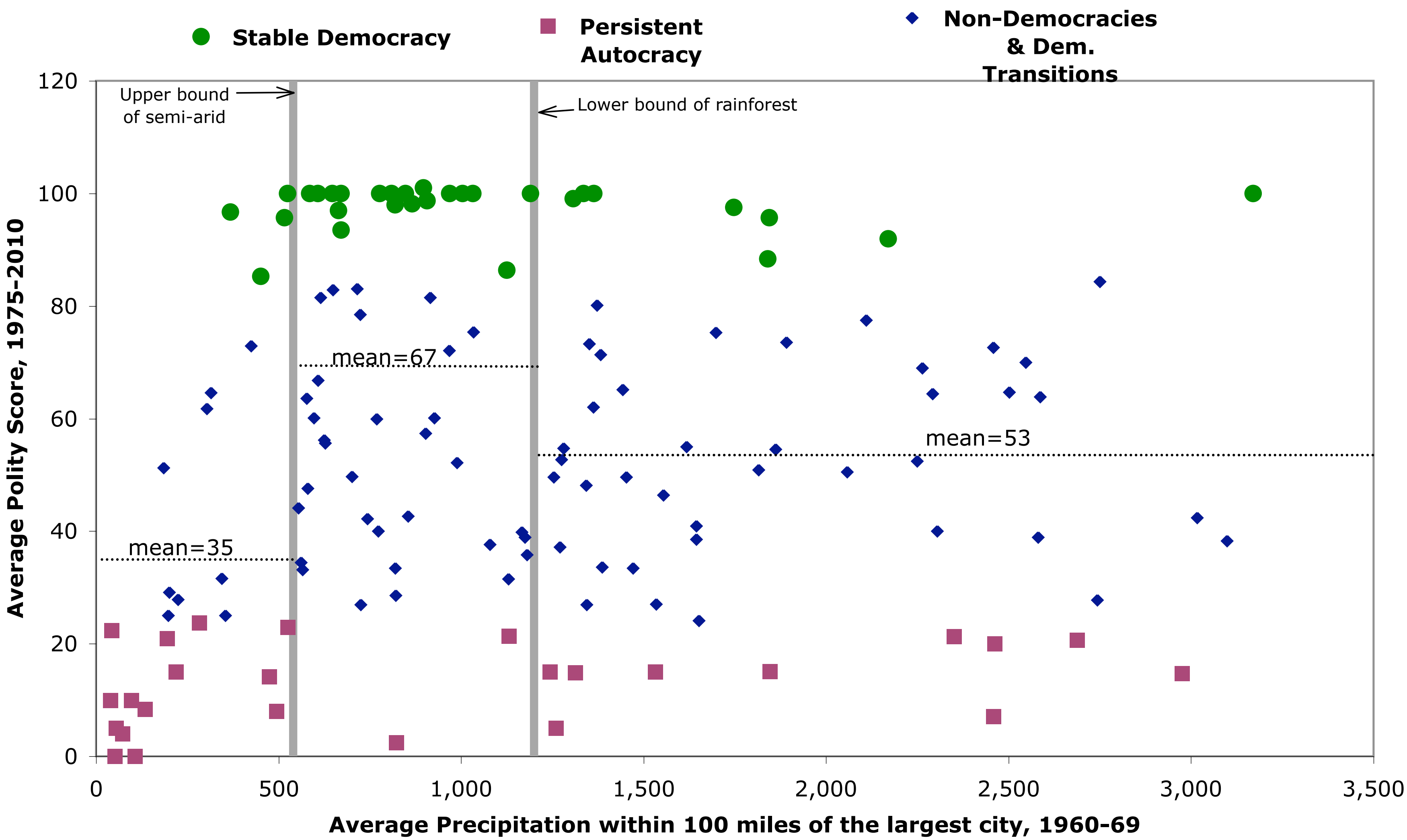

Figure 3
The Relationship between Precipitation Levels and Soils Suitable for Growing Rainfed Cereals

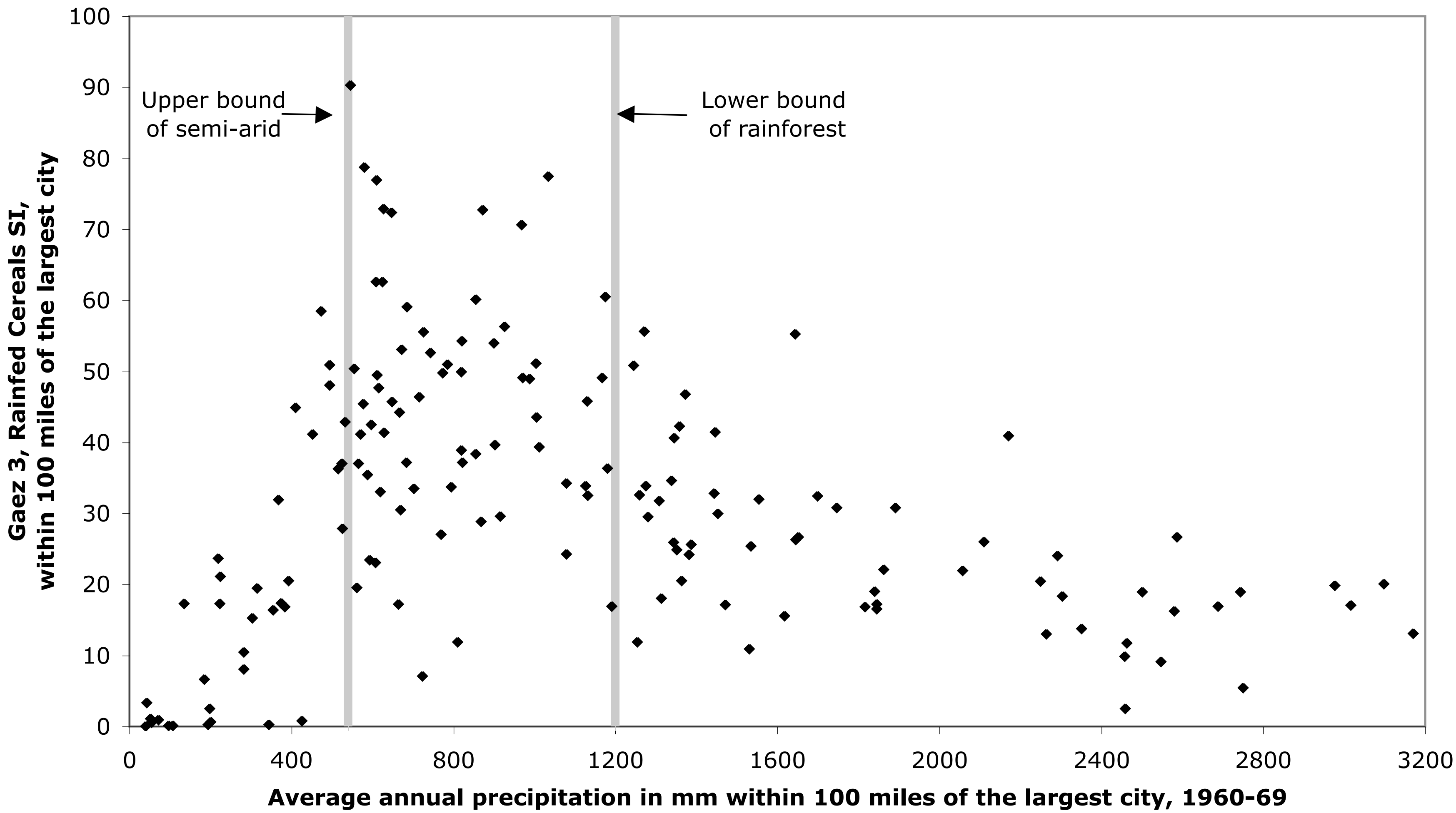

Figure 4
The Relationship Between Precipitation Levels and the Suitability of Soils for Growing Rainfed Sugarcane

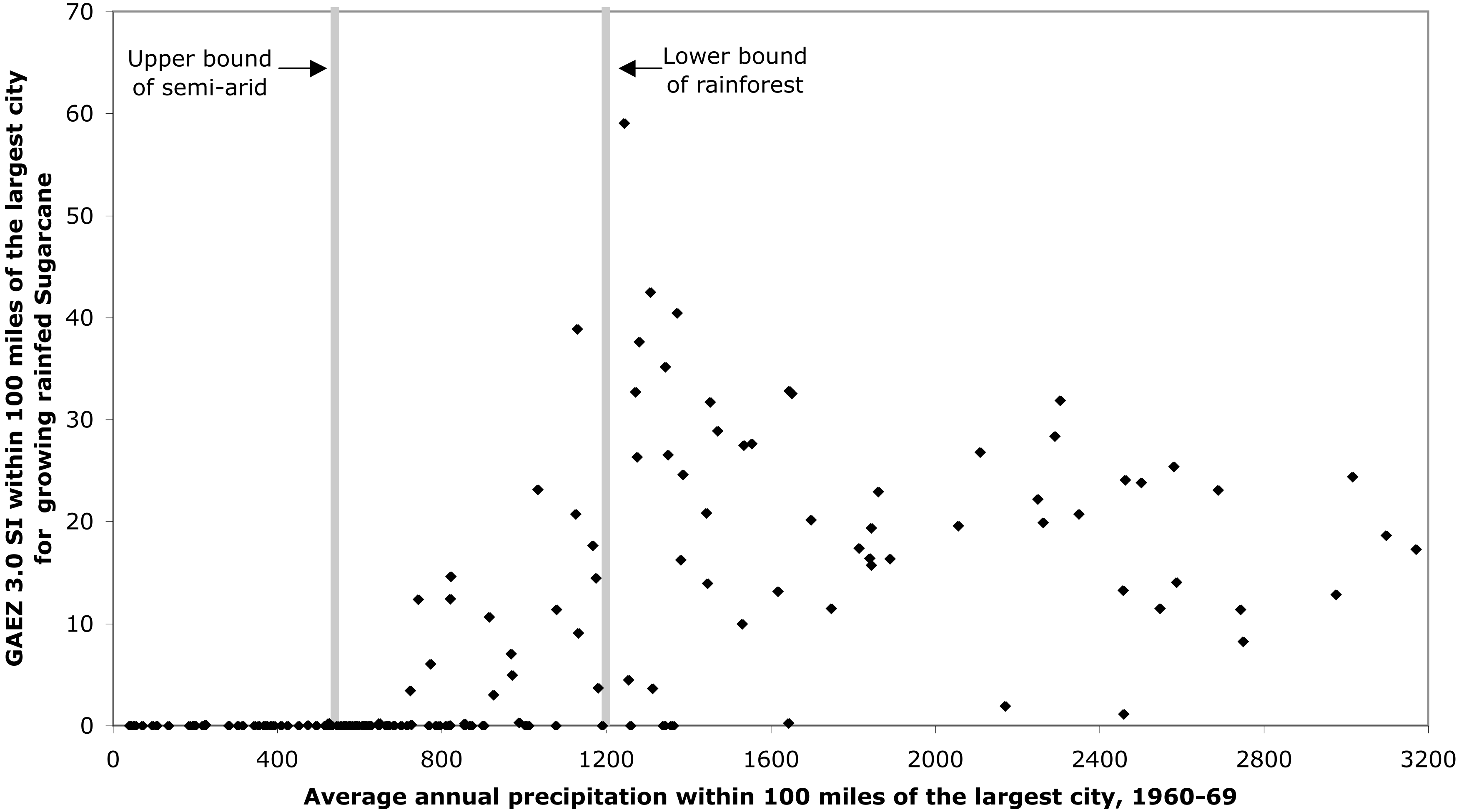

Figure 5
The Relationship Between Soils Suitable for Growing Rainfed Grains and Average Polity (1975-2010)

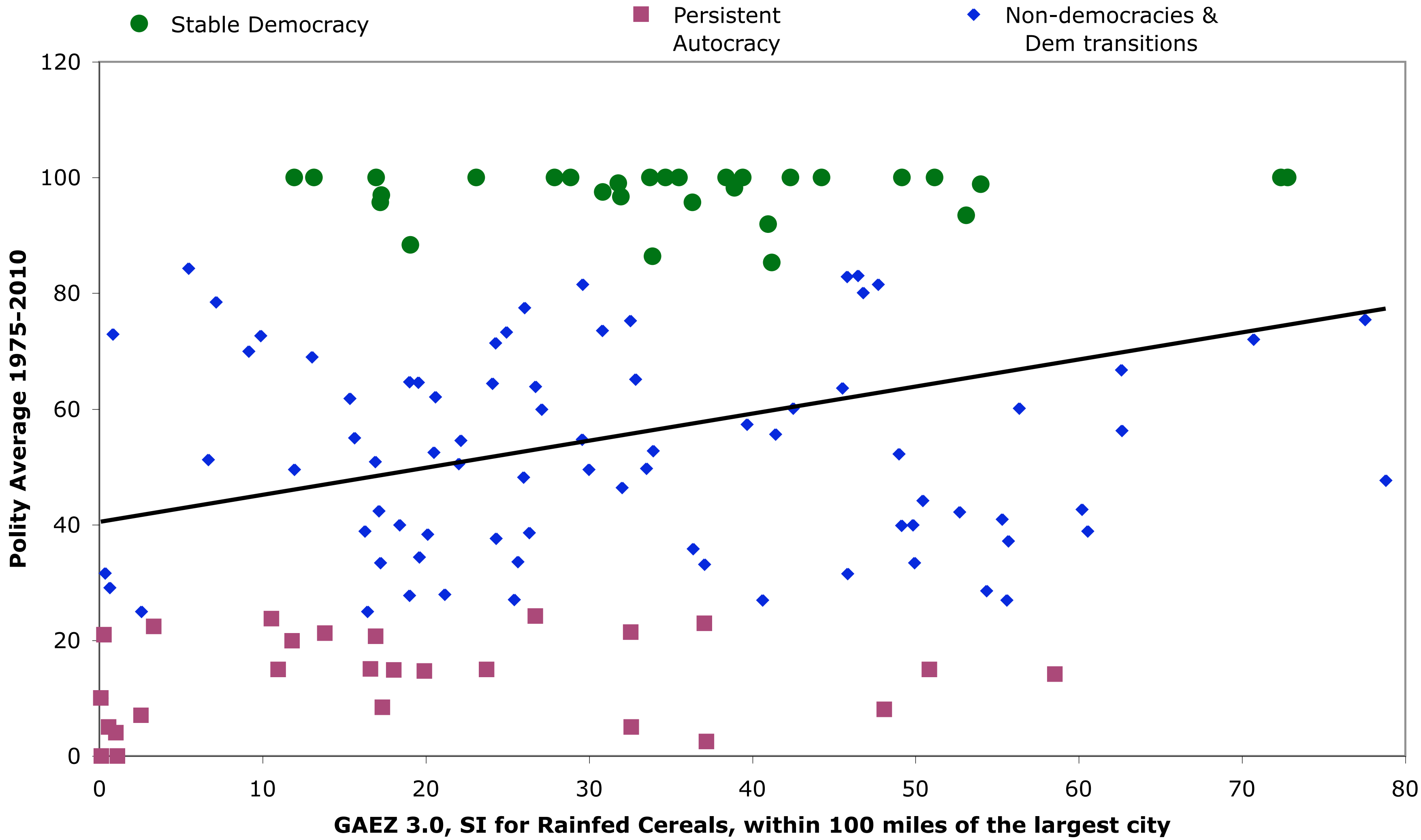

Figure 6
The Relationship Between Average Polity in 1975-2010 and the Whipple Index in 1910

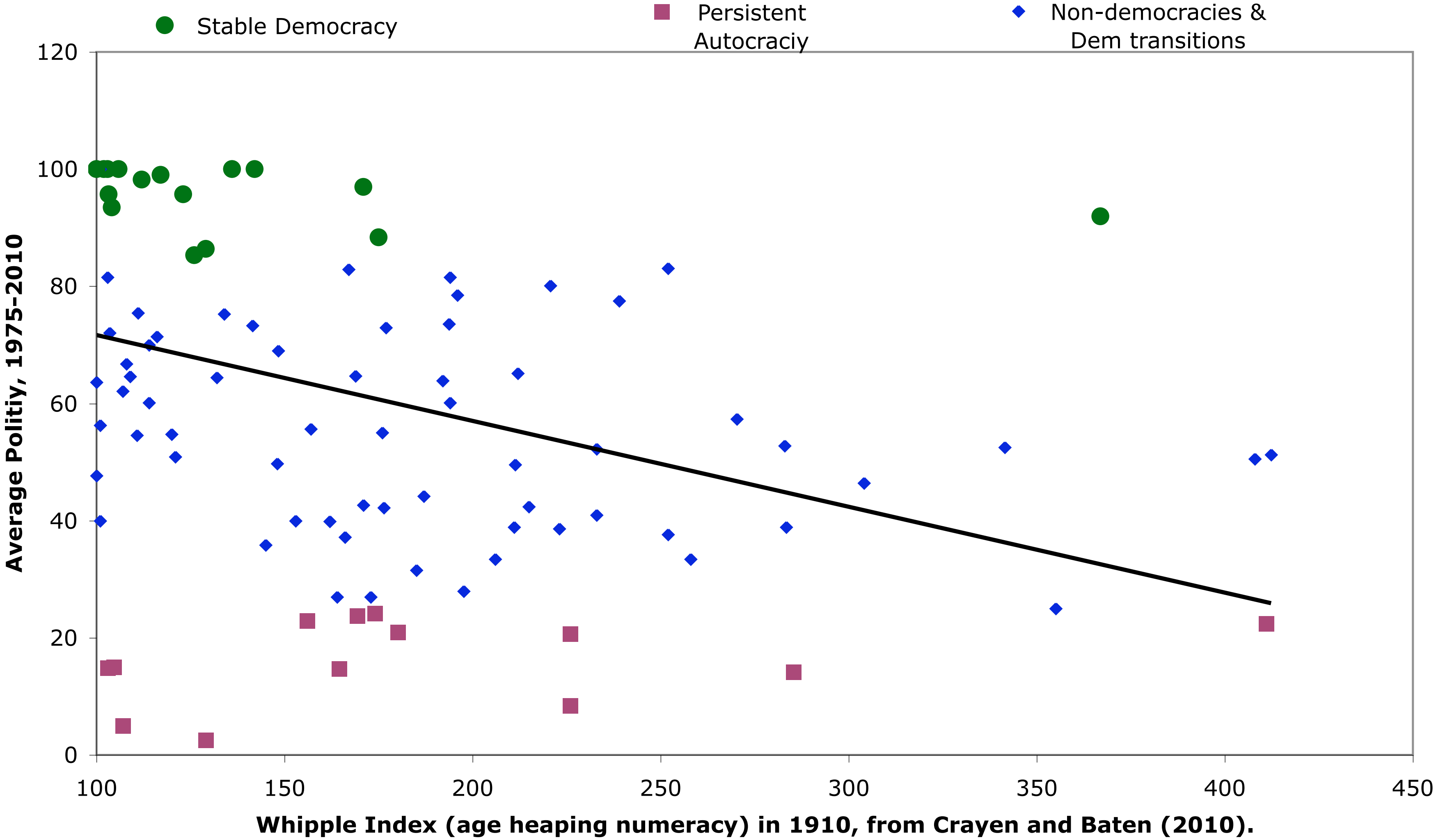

Figure 7
The Relationship between Soils Suited for Rainfed Cereals and the Whipple Index in 1910

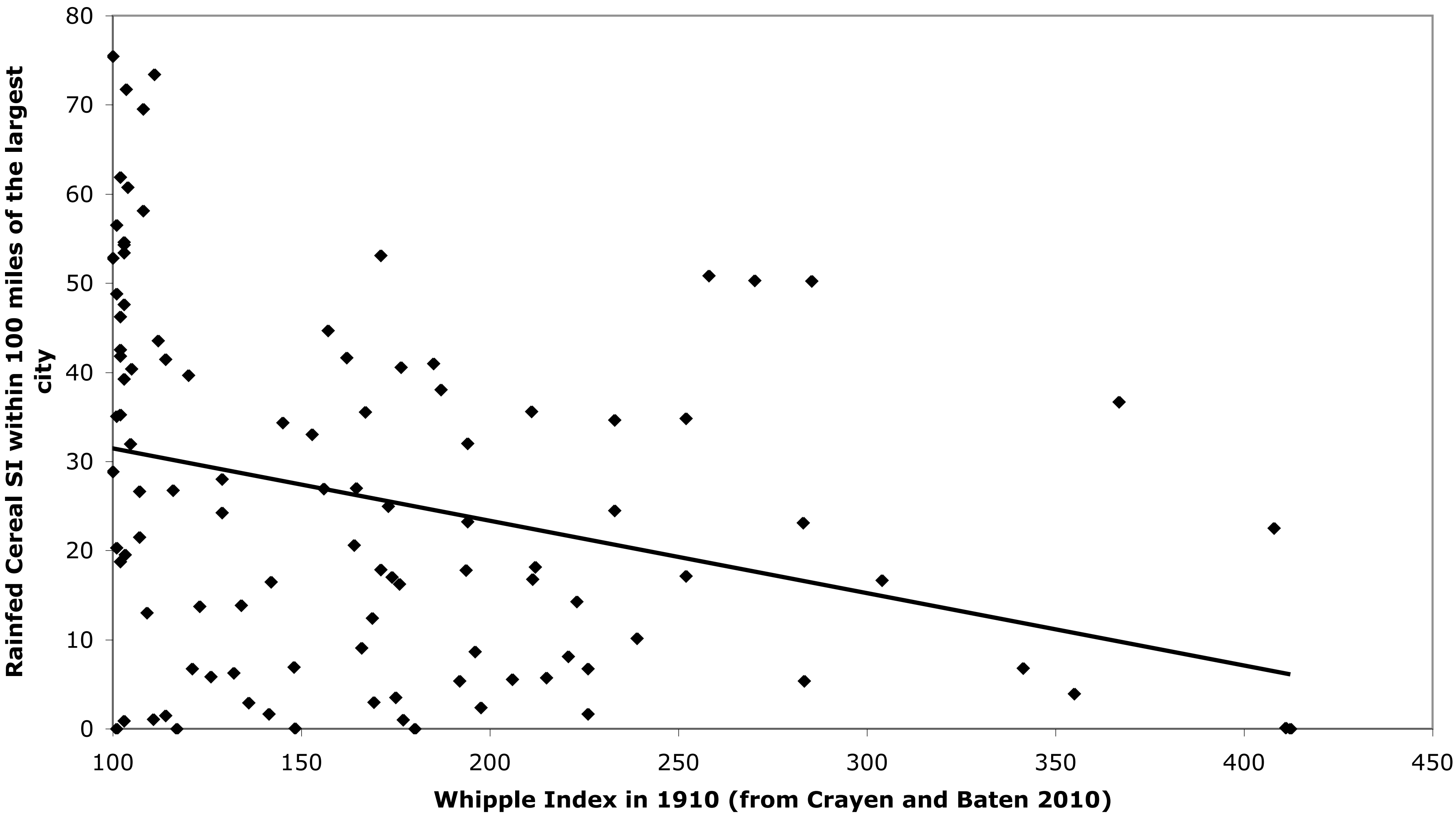

Figure 8
The Relationship Between Average Precipitation and Average Polity in the Former Iron Curtain

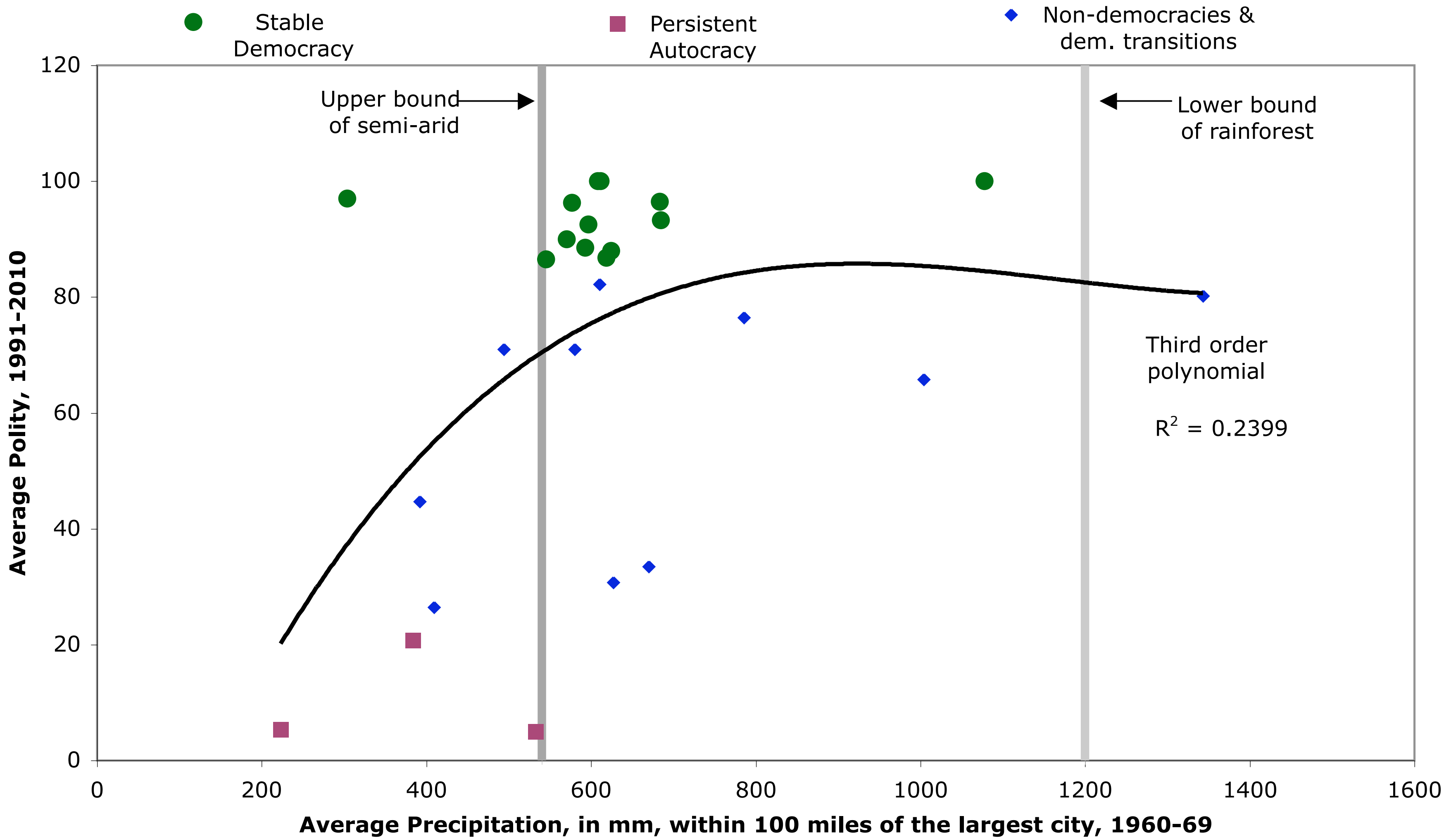

Figure 9
The Relationship Between Soils Suitable for Growting Rainfed Cereals and Average Polity, 1991-2010

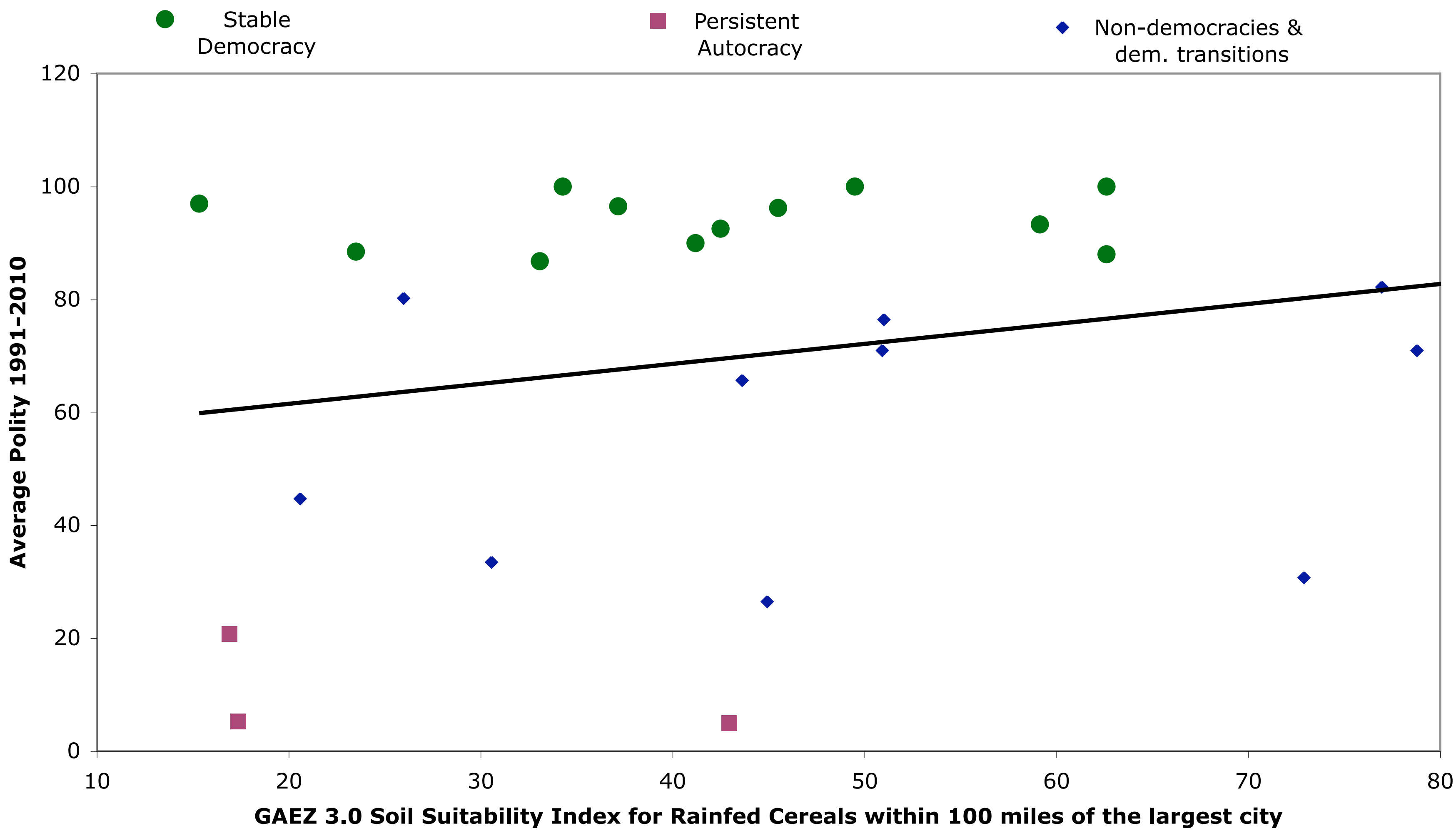

Table 1

The Relationship between Average Precipitation (1960-69) and Average Polity (1975-2010), Tobit Regressions

	Spec 1 Ave Polity	Spec 2 Ave Polity	Spec 3 Ave Polity	Spec 4 Ave Polity	Spec 5 Ave Polity	Spec 6 Ave Polity
Rain Spline 1	29.92*** (4.326)	28.26*** (5.348)	29.57*** (4.182)	27.81*** (3.589)	13.29*** (3.704)	31.87*** (4.299)
Raiun Spline 2	-35.14*** (7.152)	-33.63*** (7.855)	-26.81*** (5.939)	-30.68*** (6.383	-23.51*** (6.499	-36.15*** (6.432)
Ave Crude Oil PC 1970-2006		0.00 (0.001)				
High Malaria Risk (% Pop)			-38.06*** (5.100)			
Ethnic Frac				-35.59*** (9.682)		
Muslim (% Pop)					-0.398*** (0.064)	
British Colony						-0.738 (7.122)
Dutch Colony						-16.62* (6.793)
Belgian Colony						-42.04*** (6.909)
French Colony						-32.85*** (5.853)
Spanish Colony						7.041 (6.813)
Portuguese Colony						-25.72* (10.39)
Constant	-123.0*** (24.8)	-112.4*** (31.51)	-110.0*** (24.86)	-94.77*** (21.01)	-6.916 (22.63)	-128.6*** (24.37)
Sigma Constant	30.73*** (1.798)	30.72*** (1.798)	26.26*** (1.977)	29.29*** (1.891)	28.13*** (1.857)	26.51*** (1.783)
N	136	136	132	135	132	136

Robust standard errors in parentheses
* p<0.05 ** p<0.01 *** p<0.001

Table 2

The Relationship Between Precipitation Levels and the Ability to Grow Rainfed Cereals (OLS Regressions)

	Soil SI for Rainfed Cereals
Rain Spline 1	21.24***
	(2.460)
Rain Spline 2	-34.41***
	(3.429)
Constant	-99.23***
	-14.7
N	158

Standard errors in parentheses
* p<0.05, ** p<0.01, *** o<0.001

Table 3
The Relationship Between Soils Suitable for Rainfed Production of Cereals and and Average Polity, 1975-2010 (Tobit Regressions)

	Spec 1 Ave Polity	Spec 2 Ave Polity	Spec 3 Ave Polity	Spec 4 Ave Polity	Spec 5 Ave Polity	Spec 6 Ave Polity
Rainfed Cereal SI	0.587*** (0.149)	0.480** (0.143)	0.438** (0.147)	0.503*** (0.142)	0.353** (0.132)	0.537*** (0.1540
Ave Crude Oil PC 1970-2006		-0.003*** (0.0008)				
High Malaria Risk (% Pop)			-31.82*** (5.665)			
Ethnic Frac				-35.59*** (10.14)		
Muslim (% Pop)					-0.410*** (0.0576)	
British Colony						4.941 (8.183)
Dutch Colony						-10.57 (6.659)
Belgian Colony						-21.11** (7.112)
French Colony						-23.79*** (6.679)
Spanish Colony						16.13* (7.702)
Portuguese Colony						-14.68 (13.52)
Constant	43.93*** (4.116)	48.32*** (3.941)	60.72*** (6.196)	62.65*** (7.564)	60.57*** (4.784)	46.56*** (7.156)
Sigma Constant	32.93*** (1.919)	31.83*** (1.879)	29.79*** (2.047)	31.58*** (1.87)	28.61*** (1.849)	29.99*** (1.875)
N	136	136	132	135	132	136

Robust standard errors in parentheses
* p<0.05 ** p<0.01 *** p<0.001

Table 4
The Relationship Between the Whipple Index in 1910 and Average Polity, 1975-2010 (Tobit Regressions)

	Spec 1 Ave Polity	Spec 2 Ave Polity	Spec 3 Ave Polity
Rainfed Cereal SI	0.587*** (0.149)	0.337* (0.155)	0.134 (0.149)
Whipple Index 1910			-0.168*** (0.0432)
Constant	43.93*** (4.116)	55.63*** (4.785)	89.39*** (10.39)
Sigma Constant	32.93*** (1.919)	32.34*** (2.209)	30.11*** (2.13)
N	136	104	104

Robust Standard errors in parentheses
* p<0.05 ** p<0.01 *** p<0.001

Table 5
The Relationship Between the Whipple Index in 1910 and Average Polity, 1975-2010 (Tobit Regressions)

	Spec 1 Ave Polity	Spec 2 Ave Polity	Spec 3 Ave Polity
Rain Spline 1	29.92*** (4.326)	27.80*** (6.871)	14.47 (8.305)
Raiun Spline 2	-35.14*** (7.152)	-33.22*** (9.382)	-16.98 (10.12)
Whipple Index 1910			-0.144** (0.0442)
Constant	-123.0*** (24.8)	-105.3* (41.41)	0.219 (54.6)
Sigma Constant	30.73*** (1.798)	31.08*** (2.194)	29.74*** (2.158)
N	136	104	104

Robust standard errors in parentheses
* p<0.05 ** p<0.01 *** p<0.001