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Was the Wealth of Nations Determined in 1000 B.C.?
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ABSTRACT

We assemble a dataset on technology adoption in 1000 B.C., 0 A.D., and 1500 A.D. for the predecessors to today's nation states. We find that this very old history of technology adoption is surprisingly significant for today's national development outcomes. Although our strongest results are for 1500 A.D., we find that even technology as old as 1000 BC matters in some plausible specifications.

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1. Motivation

The study of economic development usually emphasizes modern determinants of per capita income like quality of institutions to support free markets, economic policies chosen by governments, human capital components such as education and health, or political factors like violence and instability. Could this discussion be missing an important, much more long run dimension to economic development? To the extent that history is discussed at all in economic development, it is usually either the divergence associated with the industrial revolution or the effects of the colonial regimes.[1] Is it possible that precolonial, preindustrial history also matters significantly for today's national economic outcomes?

This paper assembles a new dataset on the history of technology over 2500 years of history prior to the era of colonization and extensive European contacts. It finds that there were important technological differences between the predecessors to today's modern nations as long ago as 1000 BC, and that these differences persisted to 0 AD and to 1500 AD (which will be the three data points in our dataset). These precolonial, preindustrial differences have striking predictive power for the pattern of per capita incomes across nations that we observe today. Although our strongest results are for the detailed technology dataset we assemble for 1500 AD, we also find surprisingly significant effects under plausible conditions for cruder measures of technological sophistication going back to 1000 BC. Moreover, technological history affects not only per capita income but also population size and thus total GDP (not surprisingly, since greater technological productivity could either support a larger population, or a higher income for the same size population, or – as we find – both).

We do not claim to definitively resolve WHY technology in 1000 BC or 1500 AD still matters so much today, a question on which we hope to gain insight from further research. We think that the simplest explanation is that technological experience has an important effect on the ability to adopt the new technologies that have come along since the industrial revolution.[2]

These results also may be consistent with several well known models of very long run development. To give some selected examples, Kremer 1993 has a dynamic story for population (since 1 million BC!) in which better technology makes possible a larger population (a la Malthus), and a larger population yields more inventors to make further technological advances. Galor and Weil 2000 (see also Galor 2005) have a related story of

[1] A notable, honorable, and famous exception is Jared Diamond (1997) Guns, Germs, and Steel, however, this work did not systematically test the effect of ancient technologies on modern incomes as we will do here. Perhaps for that reason, the Diamond work did not change much the tendency of development economics to focus on the modern period or at most the colonial period.

[2] This is much debated in the economic history literature. Mokyr (1990, p. 169) stresses the importance of technology for growth but argues that technological experience has limited importance for new technology adoption: "It is misleading to think that nothing leads to technological progress like technological progress." Rosenberg and Birdzell (1987) also minimize the role of previous technological experience for explaining "how the West grew rich." Greene (2000) argues that, in the West, Greco-Roman dynamism was part of a long continuum from the European Iron Age to medieval technological progress and the industrial revolution.

very long run development with the critical added feature that advances in technology raise the rate of return to human capital, which causes the dynamic process to eventually switch over from extensive growth (output and population growth at the same rate) to intensive growth (per capita income growth). Jones (2005) emphasizes even more the non-rival nature of technological ideas, which inevitably generates increasing returns to scale (also featuring the feedback loop between population and ideas). If societies evolve in isolation through many eons, those who started out ahead would be even further ahead in both population and income today.

We do not test the technology-population dynamics explicitly (lack of data on ancient population corresponding to today's nations makes this impossible) Moreover, we don't have enough data on non-technology variables to test these stories against rival hypotheses, To consider a very popular current hypothesis for the determinants of economic development, for example, it could also be that technological history may be proxying for institutional history. Unfortunately, we lack the detail on ancient institutions that we have on ancient technologies, so we cannot resolve this definitively. The aims of this paper are more modest than sorting out these rival models, leading to a simple conclusion: for long run development: history matters --even ancient history.[3]

2. Description of technology data set

The datasets presented in this paper measure the cross-country level of technology adoption for over 100 countries in three historical periods: 1000 B.C., 0 A.D. and the pre-colonial period around 1500 A.D. Each dataset acts as a "snap shot" in time, capturing the levels of technology adoption by country throughout the world. In each time period, we determine a country's level of technology adoption in five distinct sectors: communications, agriculture, military, industry, and transportation. By aggregating these values, we determine a country's overall level of technology adoption.

Technology adoption is measured on the extensive margin by documenting whether a country uses a particular technology at all, not how intensively it is used. For example, in the dataset for 1000 B.C., we consider two transportation technologies: pack animals and vehicles. A country's level of technology adoption in transportation is then determined by whether vehicles and/or draft animals were used in the country at the time. The technologies

[3] Spolaore and Wacziarg (2006) have a fascinating exploration of the effect of genetic distance on log-income distance. They take genetic distance as a difference between all characteristics vertically transmitted from parents to children (not only genetic, but even more importantly cultural), and suggest that differences in these characteristics act as a barrier to technology/development diffusion . They find that countries populated by more genetically distant cultures also have more different per capita incomes. This finding is complementary to ours because genetic distance is very persistent and was determined in a distant past. It differs, however, in at least two respects. First, we explore the effects of technology adoption history on current development. Our left hand side variable has a direct effect on development, while genetic distance surely does not have a direct effect on development. It is a proxy for costs of transferring technology. Second, by exploring a relationship in levels we are able to preserve the transitivity of our measures. This is not the case when looking at distances.

that we examine change between the ancient period (1000 B.C. and 0 A.D.) to the early modern period (1500 A.D.) to reflect the evolution of the technology frontier.

Our focus on the extensive margin of technology adoption is motivated by data availability constraints. It is much easier to document whether a technology is being used in a country (the extensive margin) rather then measuring the degree of its adoption (the intensive margin). It is well documented that the Chinese were using iron for tools by 0 A.D; what is more difficult to assess is the share of tools constructed from iron at the time.

Since our main objective is to analyze the effects that historic technology adoption has on the current state of economic development, our datasets are partitioned using present day countries. We use the maps from the CIA's *The World Factbook* (2006) to put into concordance the borders of present day countries with the cultures and civilizations in 1000 B.C., 0 A.D. and 1500 A.D. For example, the technologies used by the Aztecs and their predecessors during pre-colonial times are coded as the ones used by Mexico in 1500 A.D. In cases where a country had multiple cultures within its borders during a certain time period, we take the culture with the highest level of technology adoption to represent that country. This technique is justified since we are measuring the extensive margin of technology adoption in a country. For example, in 1000 B.C. there were multiple cultures residing within Canada's modern day borders. The Initial Shield Woodland was the most technologically sophisticated of these cultures and we therefore use its level of technology adoption to represent Canada in 1000 B.C.

Our datasets are primarily influenced by the work that ethnologists such as George Murdock and others have done on cross-cultural analysis (Murdock 1967; Carneiro 1970; Tuden and Marshall 1972; Barry and Paxson 1971). Murdock and others were interested in compiling data on multiple cultures and comparing their traits using analytical methods.[4] A work that exemplifies this is "The Measurement of Cultural Complexity" (Murdock and Provost 1973). In that paper, 186 cultures are ranked by their level of cultural complexity. Cultural complexity was measured using ten variables; these variables included the type of transportation a culture uses, the level of political integration and urbanization of a culture, and the degree of technological specialization. Using these rankings, one can conclude that the Roman Empire was culturally more complex than the Masai of East Africa (Murdock & Provost 1973: 304).

Since our interests lie in technology adoption within a specific time period, the ethnographic data described above hold little value for our analysis. Therefore, we adapt the methodology used in the cross-cultural analysis work to develop our own technology adoption datasets. Murdock & Morrow (1970) in their work "Subsistence Economy and Supportive Practices", provide a detailed description of the methodology that is commonly used to code a cross-cultural dataset (Carneiro 1970; Tuden and Marshall 1972; Barry and Paxson 1971; Murdock and Wilson 1972). In their work, Murdock and Morrow use over 400 sources to evaluate 180 cultures. A team of researchers survey multiple sources for each culture, take detailed notes in the form of direct quotations, record page numbers of references, and then code and rank each culture. Inference is used by all of the authors to assist in their coding. In

[4] See the Human Relations Area Files at Yale University for an extensive collection of source material for over 150 cultures.

Carneiro's appendix to his dataset, he notes (1973: 854), "the presence of the trait, while not directly observable, may nevertheless be inferred from the presence of certain other traits which are themselves directly observable." All of our technology adoption datasets are coded following this described methodology.

The datasets for 1000 B.C. and 0 A.D. are derived from the "Atlas of Cultural Evolution" (Peregrine 2003), while we coded the dataset for 1500 A.D. in its entirety. We include a detailed discussion about each dataset in the following sections.

2.1 Technology Datasets for 1000 B.C. and 0 A.D.

The datasets for 1000 B.C. and 0 A.D. measure the level of technology adoption for agriculture, transportation, communications, writing, and military on 113 and 135 countries respectively. In each sector, we examine the same technologies for the two periods. The datasets for 1000 B.C. and 0 A.D. are based on Peter Peregrine's (2003) "Atlas of Cultural Evolution"[5] (henceforward abbreviated as "ACE"). In this work, Peregrine evaluates the traits (i.e. writing and records, agriculture, transportation, urbanization) of 289 prehistoric cultures that existed before 1000 A.D. following closely the same methodology as Murdock & Provost (1973).

The source for the coding of the "ACE" dataset is the *Encyclopedia of Prehistory* (Peregrine & Ember 2001a), which is a nine volume work that documents over 250 prehistoric cultures. *The Encyclopedia of Prehistory* was compiled from contributions of over 200 authors and covers every geographic region of the world (Peregrine & Ember 2001b:3). The *Encyclopedia of Prehistory* contains a profile of each prehistoric culture and summarizes the culture's environment, settlements, economy, and social political organization. Using the information from each profile, Peregrine codes the traits of each culture to construct the "ACE" dataset.

It is important to note that the "ACE" limits its survey to prehistoric cultures; prehistory refers to the time period that precedes written records (Rouse 1972: 3). Once a culture introduces written records, it is considered part of the historic period and excluded from the "ACE." Since written records were introduced at different times throughout the world, cultures have varying dates on when they entered the historic period. For example, China, Greece, and Mesopotamia had written records during the first millennium B.C. (Rouse 1972: 8) and are coded as historic regions in the "ACE" (Peregrine 2003). Since most of the world in both 1000 B.C. and 0 A.D. is prehistoric, the "ACE" provides data that covers most of the world. We then make inferences on the historic regions of the world at 1000 B.C. and 0 A.D. to complete our datasets.

The "ACE" provides us with data documenting the cultural traits of prehistoric societies; our task was to convert this data in order to measure each country's level of technology adoption. The "ACE" dataset contains four variables of particular interest: "Writing and

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[5] Peregrine (2003) uses BP (Before Present) as the time variable when coding his datasets. We convert the BP time periods to either B.C. or A.D. Peregrine's 3000 BP dataset is used for our 1000 B.C. dataset and Peregrine's 2000 BP dataset is used for our 0 A.D. dataset.

[7] And in even more detail in a second appendix available from the authors that documents the information used to code each technology for each country.

Records," "Agriculture", "Technological Specialization", and "Land Transportation." We use these four variables to code the adoption of the technologies in communications, agriculture, industry, and transportation. Table 1 documents the concordance between the "ACE" and our technology adoption datasets.

Each of the variables in the "ACE" dataset takes on one of three values as shown in the first column of Table 1. For example, the variable "technology specialization," can take on one of three values: a "3" indicates that metalwork is done by a culture; a "2" indicates that pottery is produced by a culture, and a "1" signifies an absence of both metalworking and pottery. We take these values and convert them to signify the presence or absence of a technology. In our technology adoption dataset, the presence of a technology was awarded a "1" while the absence was awarded a "0".

Table 1: Coding Concordance Between "ACE" Dataset and the Technology Adoption Dataset

"ACE" Dataset	**Technology Dataset for 1000 B.C. & 0 A.D.** (0 = indicates absence of technology, 1 = presence of technology)
Writing & Records	**Communication**
1 = None	
2 = Mnemonic or nonwritten records	0,1
3 = True Writing	0,1
Technological Specialization	**Industry**
1 = None	
2 = Pottery	0,1
3 = Metalwork (alloys, forging, casting)	0,1
Land Transport	**Transportation**
1 = Human Only	
2 = Pack or draft animals	0,1
3 = Vehicles	0,1
Agriculture	**Agriculture**
1 = None	0
2 = 10% or more, but secondary	1
3 = Primary	2

Technology adoption in the agriculture sector is measured indirectly, as the "ACE" dataset did not code the actual technologies being used. We infer that the greater the role that agriculture plays in a culture's subsistence the more likely that advanced agricultural technologies were employed. The appendix contains a more detailed discussion on how the agriculture sector is coded.

An example of how we code a country in 1000 B.C. and 0 A.D will best illustrate our methodology.

Korea was inhabited by the Mumun peoples in 1000 B.C. The Mumuns had no tradition of either writing or non-written records. The Mumuns however did rely on agriculture as its primary form of subsistence and used pack animals for transportation. In addition the Mumuns produced metalwork and used bronze for tools (Rhee 2001). The coding for the Mumun entry in the "ACE" dataset (Peregrine 2003) therefore is:

Writing and Records = 1
Technology Specialization = 3
Land Transportation = 2
Agriculture = 3

Based on this data, we code Korea in 1000 B.C. as:

Communication: Mnemonic or nonwritten records = 0; True Writing = 0
Industry: Pottery = 1; Metalwork = 1
Transportation: Pack or draft animals = 1; Vehicles = 0
Agriculture: 10% or more, but secondary = 1; Primary = 1

We aggregate the technology adoption measures at the sector level by adding all the individual technology measures in the sector and dividing the sum by the maximum possible adoption level in the sector. In this way, the sectoral adoption level belongs to the interval [0,1]. The overall adoption level in each country and time period is the average of the adoption level across sectors. Obviously, the overall adoption level also belongs to the interval [0,1].

The adoption levels in the four sectors just reported in Korea in 1000 B.C. are the following:

Communications = 0
Industry = 1
Transportation = 0.5
Agriculture = 1

Coding for the historic regions of the world in 1000 B.C. and 0 A.D. relied on a combination of inference and additional documentation. Cultures with written records were the most technologically sophisticated at the time. A survey of the historic regions during these periods confirms this assumption. In 1000 B.C., the historic regions include China, Egypt, Greece, and Mesopotamia, while in 0 A.D. the historic regions expand to encompass Western Europe and Persia. All of these regions had advanced civilizations that were highly innovative relative to the rest of the world. For example, by 1000 B.C., Egypt, China, Greece, and Mesopotamia had growing city populations which relied on high productivity agriculture (Scarre 1988:122,144; O'Brien 1999:30,36). Wheeled chariots were invented in Mesopotamia around 3000 B.C., and were used in Egypt, Greece, and China by 1000 B.C.(Encyclopedia Britannica 2006h). Jewelry and decorative ornaments constructed out of gold and silver are also evident in these cultures (Scarre 1988; O'Brien 1999). We therefore code the historic regions in our dataset as having the highest level of technology adoption in agriculture, communications, transportation, and industry.

The "ACE" did not contain any variables that correspond to technologies used for military purposes. To assess a country's level of technology adoption for the military we use the "ACE" dataset to determine which metals were available for each culture. Metallurgy is integral for the development of more advanced weapons (Macksey 1993:216; Scarre 1988; Collis 1997:29). The progression from stone to bronze and finally iron corresponded to a progression of more powerful weapons; stone weapons were replaced by bronze swords and daggers; iron weapons were considerably stronger than their bronze predecessors (Hogg 1968:19-22). The "ACE" dataset defined many cultures by the type of metals they were using for tools. Neolithic cultures are coded as having stone weapons, while Bronze and Iron Age cultures were coded as having bronze and iron weapons respectively. Prehistoric cultures not adequately described in the "ACE" dataset are coded through inference. Since the people of the New World did not use bronze until near the time of European contact, all countries in North and South America are coded as not having bronze or iron weapons in 1000 B.C. and 0 A.D (Diamond 1997:259; Kipfer 2000).

The historic regions of 1000 B.C. (Mesopotamia, Northern Africa, Greece, China) did not all use iron for weapons. We therefore differentiate iron producing regions from those that did not use the metal. Asia Minor and Mesopotamia are coded as using iron since the Hittites became major producers of iron in the 3rd millennium B.C. (Collis 1997:32; Kipfer 2000:257). Greece also had iron objects by 1200 B.C and is coded accordingly. The two most prominent historic regions not possessing iron technology by 1000 B.C. are Egypt and China. Both regions first used iron in the 6th century B.C. (Wager 1993; Lucas 1934:198). Egypt and China however both used bronze well before 1000 B.C. (Kerr & Wood 2004:7; Erman 1971: 461) and our dataset in 1000 B.C. reflects this.

The coding of historic regions in 0 A.D. proved much easier as iron technology had diffused throughout Europe, the Middle East, North Africa, and China during the 1st millennium B.C. (Kipfer 2000:258). We therefore code all historic regions as using iron weapons in the 0 A.D. dataset.

2.2 Technology Dataset for 1500 A.D.

The technology dataset for 1500 A.D. encompasses 113 countries and evaluates the level of technology adoption across the same five sectors (agriculture, transportation, military, industry, and communications) as the previous datasets. The technology adoption dataset for 1500 A.D. differs from the prehistoric datasets in that it is not based on an existing work. While the datasets for 1000 B.C. and 0 A.D. relied on the "ACE" (Peregrine 2003) for a preponderance of data, the dataset for 1500 A.D. is coded using over 170 source materials.

Our technology measures outside Europe are estimated before European colonization. It is important to stress, therefore, that our technology measures in 1500 A.D. do not incorporate the technology transferred by Europeans to the rest of the world after European exploration began around 1500.

Obviously, there is a larger number of sources covering the technology adoption patterns in 1500 A.D. than in 1000 B.C. or 0 A.D. This allows us to collect adoption data for 20 technologies in the four sectors other than agriculture vs. the eight technologies covered in the data sets for 1000 B.C. and 0 A.D. As a result, our estimate of the level of technology adoption in 1500 A.D. is likely to be more precise than for the earlier periods. Table 2 presents the various technologies measured in 1500 A.D.

Our technology datasets for 1500 A.D. involve surveying multiple sources (atlases, history books, journal articles) and determining whether a technology was used in a country. However, as with our datasets for 1000 B.C. and 0 A.D, the dataset for 1500 A.D. does include a proxy for the level of agricultural technology adoption.

We must of course stress that there are many possible weak links in the chain to go from the source material on old cultures to our dataset corresponding to today's nation states – such as the possibly tenuous link between ancient cultures and the territories of modern day nation states, and the possible errors of commission and omission on whether technologies are present given incomplete records, just to mention two. There also is likely to be selection bias in that more technologically advanced cultures are likely to leave better records.

Despite these caveats, there are also important reasons to believe in the quality of our data. First, as we describe below, it builds on the methodological contributions of the existing literature. Second, it is based on a very extensive documentation described in detail in a separate appendix.[7] Third, it is much easier to code extensive than intensive measures of technology adoption for pre-colonial periods. The former is feasible, after a significant effort such as ours. The latter is just impossible. Third, as we shall see below, our technology adoption measures for 1500 A.D. are highly correlated to the technology adoption measures for 1000 B.C. and 0 A.D. from ACE. We find this supportive of the quality of our data given that they were constructed in a completely independent way. Finally, as we shall show below, the overall technology adoption measure is highly correlated to contemporaneous measures of the development of societies such as the urbanization rate. These arguments lead us to persist nevertheless in making the best of the always shaky nature of very old data in order to see whether our measures have any signal along with the noise.

Table 2: Variables in the 1500 A.D. dataset

Variable	Description	Values
	Military	
Standing Army	An organization of professional soldiers.	0,1
Cavalry	The use of soldiers mounted on horseback.	0,1
Firearms	Gunpowder based weapons	0,1
Muskets	The successor to the harquebus (the common firearm of European armies) was larger and a muzzle-loading firearm.	0,1
Field Artillery	Large guns that required a team of soldiers to operate. It had a larger caliber and greater range than small arms weapons.	0,1
Warfare capable ships	Ships that were used in battle are considered "warfare" capable.	0,1
Heavy Naval Guns	Ships required significant advances in hull technology before they were capable of carrying heavy guns.	0,1
Ships (+180 guns), +1500 ton deadweight	Large warships that only state navies had the capability of building.	0,1
	Agriculture	
Hunting & Gathering	The primary form of subsistence.	0
Pastoralism	The primary form of subsistence.	1
Hand Cultivation	The primary form of subsistence.	2
Plough Cultivation	The primary form of subsistence.	3
	Transportation	
Ships Capable of Crossing the Atlantic Ocean	Any ship that had successfully crossed the Atlantic Ocean.	0,1
Ships Capable of Crossing the Pacific Ocean	Any ship that had successfully crossed the Pacific Ocean.	0,1
Ships Capable of Reaching the Indian Ocean	Any ship that had reached the Indian Ocean from either Europe or the Far East.	0,1
Wheel	The use of the wheel for transportation purposes. The most common use was for carts.	0,1
Magnetic Compass	The use of the compass for navigation.	0,1
Horse powered vehicles	The use of horses for transportation.	0,1
	Communications	
Movable Block Printing	The use of movable block printing.	0,1
Woodblock or block printing	The use of woodblock printing.	0,1
Books	The use of books.	0,1
Paper	The use of paper.	0,1
	Industry	
Steel	The presence of steel in a civilization.	0,1
Iron	The presence of iron in a civilization.	0,1

The methodology for coding 1500 A.D. datasets follow the works mentioned previously by Murdock and Morrow (1970), Murdock and Provost (1973), Peregrine (2003), and Carneiro (1970). We rely on two principal inference techniques while coding the dataset: 1) technological continuity (Basalla 1988) and 2) temporal extrapolation (Murdock & Morrow 1970: 314). Technological continuity is the idea that innovations are a result of previous antecedents; innovations typically do not spontaneously arise without preexisting technologies.[8] Technological continuity allows us to infer that countries with advanced technologies also have more primitive ones. The use of military technology in 1500 A.D. illustrates this technique. Large warships with over 180 guns on deck were considered the pinnacle of military technology in 1500 A.D. (Black 1996). We find that many countries with large warships also had advanced land weapons such as muskets and field artillery. It is not unreasonable to assume a country must first acquire land-based arms technology before producing ships with large naval guns. Therefore, in cases such as Portugal and Germany, where large warships were present we infer that these countries also had advance land weaponry.

Temporal extrapolation is an inference technique we frequently use in the 1500 A.D. dataset. This technique assumes that once a technology is introduced into a country it is not forgotten. When a technology's presence cannot be documented in a country in 1500 A.D., we look at preceding and following time periods. If a technology is used by a country before 1500 A.D. we infer that it was used during 1500 A.D. as well. An example of this is our coding of transportation technology in China. We were unable to document the presence of the magnetic compass in China during 1500 A.D., but could do so in the 2nd century A.D. (Adshead 1988:156). By temporal extrapolation, we infer that the magnetic compass was still used in China in 1500 A.D. We also use temporal extrapolation to infer the absence of a technology in a country if something at a point in time is documented as a "first." Since the first printing press in the Arabic world was established in Lebanon in 1706 (Stearns 2001: 357), we infer that all Arabic countries did not have printing press technology in 1500 A.D.

Country concordance for the 1500 A.D. dataset follows the methodology we described in the introduction. We assume that a technology used by a civilization diffuses throughout the regions it controlled. An example is the Ottoman Empire. The Ottomans controlled a wide swath of territory during 1500 A.D., including but not limited to modern day Egypt, Libya, Greece, and Iraq. Technologies used by the Ottoman Empire were assumed to have diffused from Turkey to all the countries we cited as being under Ottoman control.

The following passages briefly describe the process of determining levels of technology adoption for the military, agriculture, communications, transportation, and industrial sectors. Further discussion on our coding methodology is in the appendix.

Military technology in 1500 A.D.

We measure a country's level of military technology adoption by documenting the presence of land and sea based weapons in a country. In total, we document the presence of eight variables for each country.

The variables that represent technology for land weaponry include: the presence of a standing army, the use of firearms, muskets, cavalry, and field artillery. Sea based weapons are measured by the presence of naval warships and their armaments. The types of sea

[8] See Basalla (1988:30-57) for a number of case studies documenting technological continuity or technological evolution.

based weapons we document are: warfare capable ships, ships with heavy naval guns, and heavy warships that have over 180 guns and weigh over 1500 tons.

Agricultural Technology in 1500 A.D.

As with the datasets for 1000 B.C. and 0 A.D., we use a country's primary form of subsistence (hunting and gathering, pastoralism, agriculture) as a proxy for technology adoption in 1500 A.D. This measure is rationalized by the fact that the adoption of some important agricultural technologies is necessary for a country to move from a hunter and gathering society to an agrarian one. In addition to this indirect measure, for those countries whose primary form of subsistence was agriculture, we also measure the adoption of plough cultivation.

Transportation Technology in 1500 A.D.

A country's level of transportation technology adoption is measured by the forms of naval and land based transportation. We examine six variables, four of which measure a country's naval technology, while the remaining two measure land-based technology. Land-based technologies include the wheel and animals used for transportation. Naval-based transportation technology adoption is measured by whether a country's seamen used magnetic compasses for navigation and the distances that a country's exploration fleet sailed.

Communications Technology in 1500 A.D.

We measure a country's adoption of communications technologies by examining the technologies used to disseminate written information. We directly measure these technologies by documenting in a country the presence of the following items: paper, books, woodblock printing tools, and movable type printing presses.

The technologies we document represent the stages that many countries went through as they developed their communications technology. By 1500 A.D., paper and books had diffused throughout most of Asia and Europe. These technologies were also adopted in parts of North Africa. More advanced technological countries adopted means of more rapid reproduction of written communication, such as the moveable type press.

Industrial Technology in 1500 A.D.

Industrial technology measures a country's adoption of metallurgical technology. We measure a country's extensive margin of technology adoption by documenting the presence of iron and steel production in the country.

By 1500 A.D., iron and steel were being produced in Europe, the Middle East, and East Asia. While iron was being used for tools throughout Africa in 1500 A.D., steel was not present in Sub-Saharan Africa before contact with the Europeans. Also, the technology used to produce iron and steel was not present in the New World until after European contact.

3. Descriptive statistics

We start the data analysis by presenting in Table 3 some descriptive statistics for the overall technology adoption level in 1000BC, 0 A.D. and 1500 A.D. The descriptive statistics for the technology adoption measures at the sector level are relegated to Table A2 in the appendix.

_________________INSERT TABLE 3 HERE____________________________

The increase in the cross-country average of the overall technology adoption level between 1000 B.C. and 0 indicates the diffusion of the technologies described in the ACE. Recall that the technology adoption data set for 1500 A.D. contains different technologies than the first two periods. The decline in the average level of adoption in 1500 A.D. indicates that these technologies had diffused less than the technologies from ACE in 0 A.D.

An important question that the descriptive statistics can answer is how large is the cross-country dispersion in technology adoption. The binary nature of our measures of technology adoption for individual technologies provides two benchmarks to interpret the cross-country dispersion in technology adoption.[9] First, the maximum range for the average adoption level across countries is the interval [0,1]; 0 for a country that has not adopted any of the technologies and 1 for a country that has adopted all the technologies. Second, the maximum cross-country dispersion in adoption would occur when half of the countries have adopted all the technologies and the other half has adopted none. In this case the standard deviation of the average adoption level across countries would be 0.5.

In Table 3 we can observe how the range of the average adoption level across countries was [0, 1] in all three periods. The fact that these ranges are the maximum possible signals a large cross-country dispersion in overall technology adoption.

This conclusion is strengthened by exploring the cross-country standard deviation of the aggregate adoption level. In 1000 B.C. and 0 A.D. this standard deviation is 0.28 and in 1500 A.D. it increases to 0.32. These represent 56 and 64 percent, respectively, of the maximum feasible dispersion of the aggregate adoption measures. Finally, it is quite remarkable that the cross-country dispersion in overall technology adoption has remained roughly constant over the three periods despite the 2500 years that separate the first from the third.

Figures 1 through 3 and Table 4 explore the cross-country variation in the overall technology adoption level. Table 4 explores the variation across continents in overall technology adoption. Figures 1 through 3 present a world map with the overall technology adoption level in each country and historical period. We use four colors to indicate technology adoption levels between 0 and 0.25, between 0.25 and 0.5, between 0.5 and 0.75 and between 0.75 and 1. Darker colors represent a higher overall technology adoption level. Missing values are represented in white.

[9] The exceptions to this rule are the measures of technology adoption in agriculture.

__________________INSERT TABLE 4 HERE_____________________________

In all three periods, Europe and Asia present the highest average levels of overall technology adoption, while America and Oceania present the lowest.

____________ INSERT FIGURES 1-3 HERE ______________________

A glimpse to the figures suffices to note that there is substantial variance in overall technology adoption both across and within continents. To make observation more precise, we decompose the cross-country variation in overall technology adoption between the variation within continents and the variation across between continents. In 1000BC, about 65 percent of the variance in overall technology adoption is due to variation within continents and 35 percent due to variation between continents. These proportions are reversed in 0 A.D. and in 1500 A.D. the share of total variance due to the between continent component rises to 78 percent.

Table 5 provides a more detailed comparison of the evolution of overall technology adoption in the most advanced countries. These countries correspond to four civilizations: Western Europe, China, the Indian civilization and the Arab people. Western Europe includes Spain, Portugal, Italy, France, United Kingdom, Germany, Belgium and Netherlands. The Indian civilization includes India, Pakistan and Bangladesh. Finally, the Arab civilization includes Saudi Arabia, UAE, Yemen, Oman, Iraq, Iran, Syria, Lebanon, Jordan, Egypt, Libya, Tunisia, Algeria and Morocco.

________________ INSERT TABLE 5 HERE _______________________

In 1000 B.C. the Arab empire and China have an overall technology adoption level of 0.95 and 0.9 respectively, while in India and Western Europe the average adoption level are 0.67 and 0.65 respectively. In 0 A.D. India and Western Europe catch up with China and the Arab empire. In 1500 A.D. Western Europe has completed the transition and is the most advanced of the four great empires with an average overall adoption level of 0.94. China remains ahead most countries with 0.88. But the Indian and the Arab empires have fallen behind. The average overall adoption levels in these empires are 0.7.

4. Technology history and current development

Without more delay, we turn next to the question that motivates our exploration. Namely, whether centuries-old, pre-colonial technology history determines development today. To answer this question, we estimate the following regression

$$y_c = \alpha + \beta T_c + u_c \qquad (1)$$

where y_c is the log of PPP adjusted per capita income in 2002 A.D., T_c is the measure of technology adoption and u_c is the error term.

___________ INSERT TABLE 6 HERE______________

The first three columns of Table 6 report the estimates of regression (1) when T_c is measured successively by the overall adoption level in 1000 B.C., in 0 and in 1500.A.D. (T-statistics are in parentheses.) The technology adoption level in 1000 B.C. is positively associated to the log of per capita GDP in 2002, though this association is only significant at the ten percent level. Technology adoption in 0 A.D. is not significantly correlated to current development. The overall technology adoption level in 1500 A.D. is positively and significantly associated to current income per capita. This measure of technology in 1500 A.D. explains 18 percent of the variation in log per capita GDP in 2002.

In addition to being statistically significant, the effect of technology on development is quantitatively large. Changing from the maximum (i.e. 1) to the minimum (i.e. 0) the overall technology adoption level in 1500 A.D. reduces the level of income per capita in 2002 by a factor of 5.

Figure 4 presents the scatter plot between overall technology adoption level in 1500 A.D. and current development. The positive relationship between these two variables is quite transparent. It is clearly not driven by outliers. In the bottom left quadrant of the plot we can see many African countries that had adopted very few of the technologies in our 1500 sample and that are quite poor today. European countries are in the top right corner.

Countries that roughly correspond to ancient empires such as Egypt, Iran, China, India, and Pakistan were middle-income countries in 2002 and had adopted between 70 and 90 percent of the technologies in our 1500 A.D. sample. These countries are slightly below the regression line in the bottom right quadrant of Figure 4.

___________ INSERT FIGURE 4 HERE______________

Latin American countries were behind the median country in the overall technology adoption level in 1500 but today they are middle income countries. This very likely has something to do with the long period of European settlement in Latin America, even though the European settlers were generally a minority of the population. Finally, in the top left corner of Figure 4 we find the Neo-Europes. That is the US, Canada, Australia and New Zealand. These were among the countries with most primitive technology in 1500 A.D. but are among the World's richest countries today. This is very likely due to the large-scale replacement of the original inhabitants with European settlers.

We would expect that the European settlers in the Spanish and Portuguese colonies and in the Neo-Europes affected quite dramatically the process of technology transfer, human capital accumulation and institutional development in these countries during the colonial period. Another place where there was large scale (albeit still minority) European settlement was southern Africa. Of course, there could be technology transfer in any colonized nation, but the duration and intensity of the influence of the settlement processes in southern Africa, Latin America and the Neo-Europes suggest adding special controls. Further, the difference in the degree to which Europeans colonizers substituted for the local population justifies the distinction between the Neo-Europes and Latin America/southern Africa.

To formalize this intuition, we use the fraction of European settlers in total population in 1900 from Acemoglu, Johnson and Robinson (2001).[10] This fraction was over 90 percent for the Neo-Europes, between 15 percent and 65 percent for South Africa, Lesotho and Swaziland, and most countries in Latin America, and below 15 percent for the rest of non-European countries.

Based on this, we create two dummies. The first captures maximum European influence, and takes a value of one for the US, Canada, New Zealand and Australia and is zero for the rest of the countries. The second dummy reflects lesser European influence than in the neo-Europes, and takes a value of one for the Latin American colonies of Spain and Portugal (see the appendix for a complete list), South Africa, Lesotho and Swaziland, and is zero otherwise. This yields the following regression equation:

$$y_c = \alpha + \beta T_c + Major_c + Minor_c + u_c \qquad (2)$$

_______________ INSERT FIGURE 5 HERE_________________

Columns 4 through 6 in Table 6 report the estimates of equation (2) with T_c measured successively by the overall technology adoption level in 1000B.C., 0 and 1500 A.D.

_______________INSERT FIGURE 6 HERE_____________________

We find that the European influence dummies have a significant positive effect on current per capita income. Further, when including the European influence dummies, the correlation between the overall technology adoption and current development increases. In particular, the effects of the technology adoption levels in 1000 B.C. and 0 on current per capita income become statistically significant, and the effect of technology in 1500 A.D. almost doubles. In other words, once we control for the most obvious historical example of replacement of the indigenous technology by technologies brought by new settlers, technology in ancient times becomes a significant predictor of per capita income today.

_______________INSERT FIGURE 7 HERE_____________________

In addition to being significant, the effect of technology history on current development is large. An increase in the overall adoption level from 0 to 1 in 1000 B.C. or in 0 A.D. is associated with an increase in income per capita in 2002 by a factor of 4. A similar increase in the overall adoption level in 1500 A.D. is associated with an increase in per capita income in 2002 by a factor of 18. This is half of the current difference in income per capita between the top and bottom 5 percent of the countries in the world.

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[10] Similar results are obtained using the share of population from European descent in 1975 from Acemoglu, Johnson and Robinson (2001) or the fraction of European settlers 100 years after first settlement from Easterly and Levine (2006).

Similarly, 20 percent of the income difference between Europe and Africa is explained by Africa's lag in overall technology adoption in 1000 B.C., 7 percent is explained by the technology distance in 0 A.D., and 75 percent is explained by Africa's lag in overall technology adoption in 1500 A.D. This gives a very different perspective on Africa's poverty compared to the usual emphasis on modern governments. It also shifts backward in time the historical explanations for Africa's poverty, compared to the usual emphasis of historians on the slave trade and colonialism.[11]

Figures 5 through 7 display the scatter plots of the current income per capita and overall technology adoption after regressing these variables on the European influence dummies. These figures confirm the significant association between current development and historical technology after conditioning on the European influence dummies. Clearly, the strongest relationship holds between overall technology adoption in 1500 A.D. and current development.

Finally, we explore which sectors' technology are driving the observed association between overall technology adoption and current development. To investigate this question we estimate the following regression for each of the three pre-colonial periods.

$$y_c = \alpha + \sum_i \beta_i T_{ic} + Major_c + Minor_c + u_c \qquad (3)$$

In this specification, *i* indexes each of the 5 sectors.

__________INSERT TABLE 7 HERE______________________________

Table 7 reports the estimates of regression (3) for each time period. The main finding is that different sectors are driving the positive relationship between overall technology adoption and current development for different periods. The sophistication of agricultural technology in 1000 B.C. seems important for current development but the importance of agricultural technology declines for later periods. Technology adoption history in communications and industry in 1000 B.C. and 0 A.D. does not have a positive effect on current development (communication in 1000 B.C. is negative and significant.) In 1500 A.D., however, the degree of technology adoption in communication has a strong positive effect on current development. Military technology adoption history in 1000 B.C. and 1500 A.D. have important positive effects on current development. Finally, technology adoption history in transportation in 1000 B.C. and 0 A.D. has a positive effect on current development but the transportation technology adoption variable in 1500 A.D. does not affect current development. This variation in the conditional correlation of sectoral technology history provides some justification for looking at the overall technology adoption measure as the main variable of interest

[11] There was some slave trade before 1500 A.D. across the Sahara and along the Indian Ocean. However, most accounts of the negative effects of the slave trade stress the Atlantic slave trade, which only became nontrivial after 1500 A.D.

5. Robustness and Discussion

Next we discuss the robustness and interpretation of the main fact uncovered in the previous section, that technology history is positively and strongly associated with current development.

A. Robustness

We start by exploring whether we are identifying the effect of historical technology on current development through the cross-continent variation of also through the within continent variation. To answer this question, the first three columns of Table 8 report the estimates of regression (2) when adding three continent dummies to the control set.

_______________INSERT TABLE 8 HERE______________________

We extract two main conclusions from columns 1 through 3. First, much of the effect of technology history is detected from the cross-continent variation. Adding the continent dummies eliminates the effect of overall technology adoption in 1000 B.C. on current development (column 1), and by 60 percent the effect of technology adoption in 0 A.D. (column 2) and in 1500 A.D. (column 3) on current development. The flip side of this is that a significant fraction of the effects of technology adoption history in 0 A.D. and 1500 A.D. on current development is driven by the within continent variation. In particular, the within continent variation in overall technology adoption in 1500 A.D. can account for cross country variation in current income per capita by a factor of 3.25. This effect is statistically significant.

Galllup, Sachs and Mellinger (1999) have argued that the latitude is an important determinant of income per capita, with the tropics at a disadvantage. Hall and Jones (1999), Acemoglu, Johnson, and Robinson 2002, Easterly and Levine 2003 and Rodrik et al. (2003) argue that the effect of tropical location is through institutions. Columns 4 through 9 in Table 8 report the estimates of regression (2) after controlling for the distance to the Equator (columns 4 through 6) or whether the country is tropical (columns 7 through 9). As emphasized by the previous literature, being far from the Equator tends to be associated with higher levels of current income per capita. Controlling for the latitude of countries, however, does not eliminate the strong positive effect of overall technology adoption in 1500 A.D. on current development. This effect remains statistically significant, though the effect of technology adoption history on 1000 B.C. and in 0 A.D. on current development become insignificant after controlling for the distance to the Equator or after including the tropical dummy.

One natural question to study is whether more advanced technology also made higher population feasible as well as higher per capita income. To answer this question we estimate the effect of primitive technology on the log of real GDP (Y_c) and in the log of population (L_c), both in 2002, as indicated in regressions (4) and (5).

$$\log(Y_c) = \alpha + \beta T_c + u_c \qquad (4)$$

$$\log(L_c) = \alpha + \beta T_c + u_c \qquad (5)$$

_______________INSERT TABLES 9a-9c HERE______________________

Table 9a reports the estimates of these specifications for the measures of overall technology adoption in each of the three periods. In columns 1 through 3 we observe that the measures of primitive technology in 1000 B.C. and in 1500 A.D. have a very significant positive effect on current GDP. The effect of technology adoption in 0 A.D. is positive but insignificant. Columns 4 through 6 show that countries with higher overall levels of historical technology adoption have higher population today. This is the case for each of the three measures of primitive technology. Unlike the regressions for per capita income, the coefficient on technology in 1000 BC for today's GDP and population is significant even without including the European influence dummies.

In columns 7 through 9 of Table 9a we estimate the effect of technology adoption history on land area by estimating the following regression:

$$\log(A_c) = \alpha + \beta T_c + u_c \qquad (6)$$

where *Ac* is the arable land area. Our estimates show that the log of arable land area of today's nation states is also related to historical technology in that area. We interpret this as evidence that countries with more advanced technologies could conquer more land and/or could control more land more easily.

This could also be another mechanism by which advanced technology led to larger populations; conversely countries with larger populations, thanks to more advanced technology, could also conquer or settle more territory. Over the very long period that we are considering, the size of nations in both area and population is endogenous. Our results show that technology is one of the determinants of the size of nations. However, since both land area and population are endogenous and we lack good instruments, we cannot separate out the relationship between these two different dimensions of size.

Table 9b estimates specifications (4) through (6) adding the two European influence dummies. This increases the effects of technology adoption history on current GDP, on current population and on current arable land area. Hence, we conclude that historical technology adoption facilitated both a larger population and a higher average income.

We next check the robustness of this conclusion to controlling for the distance from the Equator which affected the significance of the ancient technology variables in the per capita income regressions Columns 1 through 9 in Table 9c show that controlling for distance to Equator does not affect the strong positive effect of technology adoption history on current GDP, on current population, and on current land area. It is interesting to note that, while distance to Equator is positively and significantly associated with current GDP in the regressions where technology adoption history is measured at 1000 B.C. and 0 A.D., it is insignificantly associated with current GDP when technology adoption is measured in 1500 A.D. Similarly, while distance to Equator is insignificantly associated with current population in the regressions for technology adoption in 1000 B.C. and 0 A.D., it is negatively and significantly associated to current population when technology adoption is measured in 1500

A.D. We interpret these significant changes in the mechanism by which latitude affects current income per capita as a signal that the association of latitude and current development is not causal and direct. In contrast, the effect of technology adoption history on current GDP and population are robust to measuring technology in any of the three periods.

B. Why does old technology matter?

The big question that remains to be addressed is: why does centuries-old, pre-colonial technology matter so much for current development? We cannot resolve this here for lack of data on other crucial variables for these earlier eras, but we offer some suggestive hypotheses.

We think it likely that two related hypotheses will be fruitful for further investigation. First, it seems to us the simplest hypothesis with which to begin is that adopting one technology today makes it much easier to adopt subsequent technologies in the future.[12] As a result, technology adoption is extremely persistent. Countries that adopted new technologies in 1000 A.C. were more likely to be the technology leaders in 0 A.D. Technology leaders in 0 A.D. were more likely to adopt the newest technologies in 1500 A.D. The technological leaders in 1500 A.D. in turn were the ones best suited to implement the industrial revolution and its many technological sequels. Hence, the leader countries in 1500 A.D. are still today the current technology leaders. Second, we suggest (not so controversially) that technology is a principal determinant of a country's level of development. Hence, countries that currently are the technology leaders are the richest countries and countries that fail to use advanced technologies are the poorest. In short, as Mokyr (1990) memorably argued, technology is the "lever of riches."

We start our evaluation of this hypothesis by estimating how autocorrelated technology adoption is over time. Table 10 presents the cross-country correlation of technology adoption across time periods. The cross country correlation of the overall technology adoption level between 1000 B.C. and 0 is 0.62, between 0 A.D. and 1500 A.D. it is 0.71 and between 1000 B.C. and 1500 A.D. it is 0.68. Table 11 shows that technology adoption is also highly persistent after controlling for the distance to the Equator and after adding the continent dummies. This remarkably high persistence of technological differences over 2500 years of human history is another important finding of our paper.[13] (It is also reassuring that the error rate on our technological measures is not disastrously high.)

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[12] We are hypothesizing this as a direct feature of the innovation technology. An alternative and more complex view that is not easy to distinguish with available data is that the dependence of the technology outcome on initial conditions is a consequence of increasing returns arising from the positive feedback loop between non-rival technological ideas and population size (see references mentioned in the introduction – Kremer 1993 and Jones 2005; Galor and Weil 2000 and Galor 2005 also add a dynamic interaction with human capital to generate the transition from extensive to intensive growth).

[13] An important question is how our findings of technology and income persistence relate to the "reversal of fortune"finding of Acemoglu, Johnson, and Robinson (2002). Our results are not inconsistent because the reversal of fortune is most dramatic in those places occupied by European settlers, where we have introduced dummies. Indeed, if we focus on the sub-sample of former colonies we find a negative association between technology history in 1500 A.D. and current development. However, this association disappears when we introduce the major European influence dummy. We interpret the dummies as representing technology transfer in light of our other evidence in this paper, but we cannot necessarily contradict AJR's interpretation of

_________INSERT TABLES 10 AND 11 HERE____________________

We also observe this very high persistence of technology adoption for the sector-level measures. The average correlation coefficient between the technology adoption in a sector in one period and in the subsequent period is around 0.5. Technology adoption is most persistent in military, industry and transportation. In these sectors, the cross-country correlation between technology adoption in 1000 B.C. and in 1500 A.D. it is between 0.6 and 0.69. In Agriculture the correlation is 0.42, while in communications it is only 0.22. This latter correlation is statistically significant at the 5 percent level. All the other correlations reported in Table 10 are significant at the 1/10000 level.[14] As shown in Table 11, the high autocorrelation of overall technology adoption is robust to controlling for the distance to the Equator and for the continent dummies.

In the light of these estimates, technology adoption history seems more persistent than any other determinant of development. Institutions, for example, which have been regarded as highly persistent, have been more volatile than technology over the past two centuries.

To obtain an estimate of the persistence of modern institutions we use the Polity IV measure of democracy. This variable takes values from -10 to 10, 10 being most democratic, and it is available from 1800 until the present. We estimate the coefficient of democracy on democracy 50 years ago using non-overlapping observations to be 0.59. It seems remarkable that this widely used measure of institutions is less persistent over a 50 year period than overall technology adoption over a 2500 year period. Of course, this could be a flawed measure of institutions, and other deeper definitions of institutions could show stronger persistence. For example, there is an influential intellectual tradition that locates the origins of Western democracy and freedom in ancient Greece and Rome. However, this is speculative in the absence of more rigorous measures and tests.

The second premise in our hypothesis is that technology has a strong, positive and contemporaneous effect on development. Few would dispute that technology has a large effect on development, but there is some debate about its importance relative to factor accumulation. A very important role for technology has been shown indirectly for the post-war period by Klenow and Rodriguez-Clare (1997) and Hall and Jones (1999). In particular they show the importance of TFP to explain the cross-country variation in income per capita nowadays. More recently, Comin, Hobijn and Rovito (2006) have compiled 100 direct measures of technology covering most sectors of economic activity in 150 countries over the last two centuries. They have shown that there is a strong cross-country association between technology and income per capita and that cross-country variation in physical technology may explain up to 50 percent of the observed cross-country differences in income per capita.

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institutional differences being the explanation for this shift. We plan to investigate this further in future work. In a broader sense, there is no reason to restrict the sample to the group of former colonies. As shown in Table 6, we find that in the whole sample there is a strong positive association between overall technology adoption in 1500 A.D. and current development. In this sense, there is a “persistence of fortune”.

[14] An alternative way to convey the same message is to estimate convergence regressions for the technology adoption measures both for each sector and for the aggregate. The conclusion from this exercise is that there is convergence but at an extremely slow pace.

__________________INSERT TABLE 12 HERE______________________

One difficulty in demonstrating the contemporaneous connection between technology and development is that we do not have historical series for income per capita that go back very far. An alternative route suggested by several authors[15] consists in using the urbanization rate as proxies for development level (they are strongly correlated in the modern data across countries.) This is a particularly good proxy for pre-modern periods such as the ones covered by our technology adoption data set.

The urbanization rate for 1000 B.C. and 0 A.D. come from Peregrine's "ACE",[16] while the urbanization rate for 1500 A.D. come from Acemoglu, Johnson and Robinson (2002). Table 12 reports the estimated contemporaneous effects of overall technology adoption on the urbanization rate. We find that there is a strong and positive contemporaneous association between technology adoption history and the contemporaneous urbanization rates. We extract two conclusions from this finding. First, it provides further support for the quality of our measures of technology adoption in pre-colonial times. Second, if we grant that urbanization is a good proxy for development, it shows that the contemporaneous relationship between technology adoption and development also holds in earlier periods.

In columns 4 through 6 of Table 12 we show that the positive contemporaneous association between overall technology adoption and the urbanization rate is robust to controlling for distance to the Equator. Indeed, distance from the Equator typically does not have a significant effect on urbanization. Since the mechanisms used to justify the effect of latitude on development are atemporal, this finding also weakens the case for a causal role of latitude on development.

This evidence is suggestive that ancient technological prowess facilitated modern technological prowess, which in turn determines modern development. However, there are loopholes due to lack of data that leaves this only suggestive. We do not have data on ancient institutions, so we cannot assess whether technology is proxying for quality of ancient institutions. We obviously don't have data on ancient factor accumulation, so we cannot assess the relative role of factor accumulation and technology in ancient development outcomes.

One thing that we can say more confidently based on our findings is that development is a very long run process. However much institutions, factor accumulation, and technology may have been bound up together in the past, our findings still show that the ancient past – as captured by our technology variable -- matters to a remarkable extent.

[15] Acemoglu, Johnson and Robinson (2002), for example.

[16] Peregrine (2003) constructs a measure of the urbanization rate that can take three values. 1 if the largest settlement is smaller than 100 persons. 2 if it is between 100 and 399 persons. 3 if it is larger than 400 persons.

6. Conclusions

The finding of this paper is a simple one: centuries-old technological history still matters today. The most surprising part of the finding is just how old the history can be and still matter. Our most robust finding is that technology in 1500 AD matters for development outcomes today, itself remarkably old when we consider that most history discussions of developing countries start with European contact and colonization. Even more surprising is that technology in 1000 BC and 0 AD has a significant effect in many specifications. While of course this finding is subject to standard caveats about the quality of data from ancient periods, the finding has important implications to the extent that it survives those caveats.

This finding is at least suggestive that technology is a strong candidate for being a principal determinant of development; this paper increased our prior weights on technology vis-à-vis competing explanations such as institutions and factor accumulation (not to go to the extreme that those latter things don't matter). We consider our findings suggestive of the important role of technology even though missing data on ancient institutions and factor accumulation make this suggestion less than air-tight.

What does seem inescapable from this finding (if it is taken at face value despite the caveats) is that development is a very long run process. The tendency of policymakers and international institutions to overemphasize the instruments under their control may have contributed to an excessive weight being placed on the behavior of modern-day governments and development strategies as a determinant of development outcomes.

This is not to say that history is destiny. Our technology history only explained a partial share of the modern day variance of development outcomes, and so history is obviously not *all* that matters.

Even giving *any* substantial weight to centuries-old history may not be so appealing from a policy-making point of view, but the world is as it is. The world seems to be a place where the long eons of history still matter very much today.

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Figure 1: Overall technology adoption in 1000 B.C.

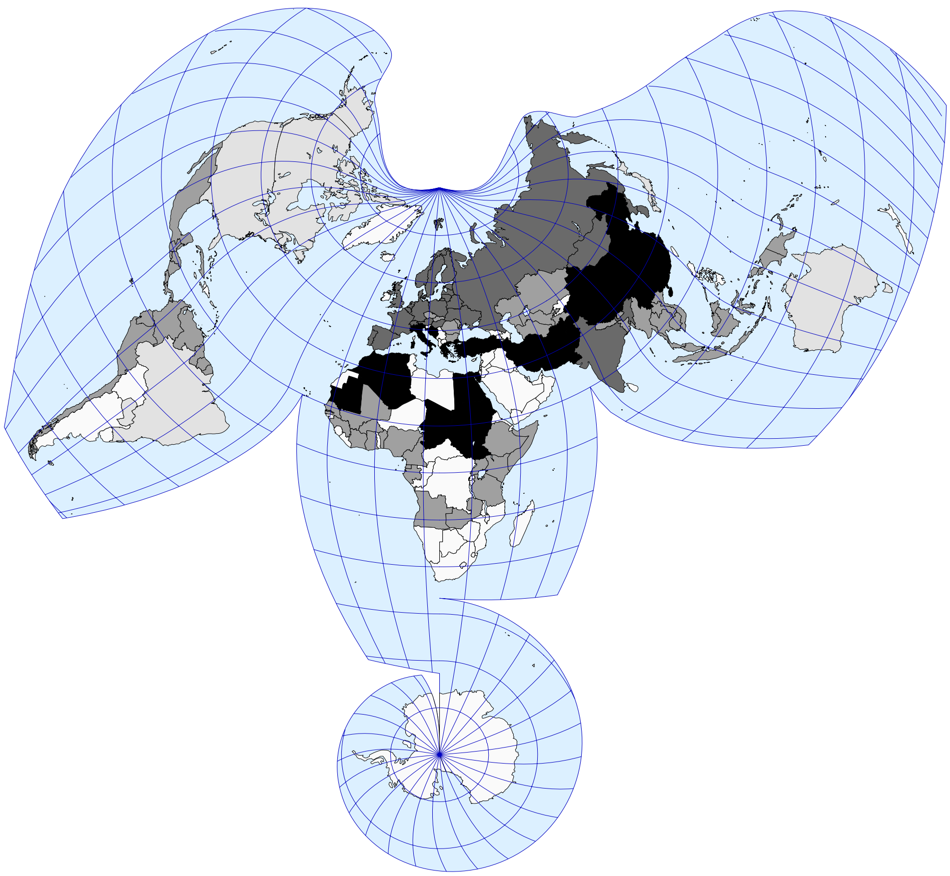

Figure 2: Overall technology adoption in 0 A.D.

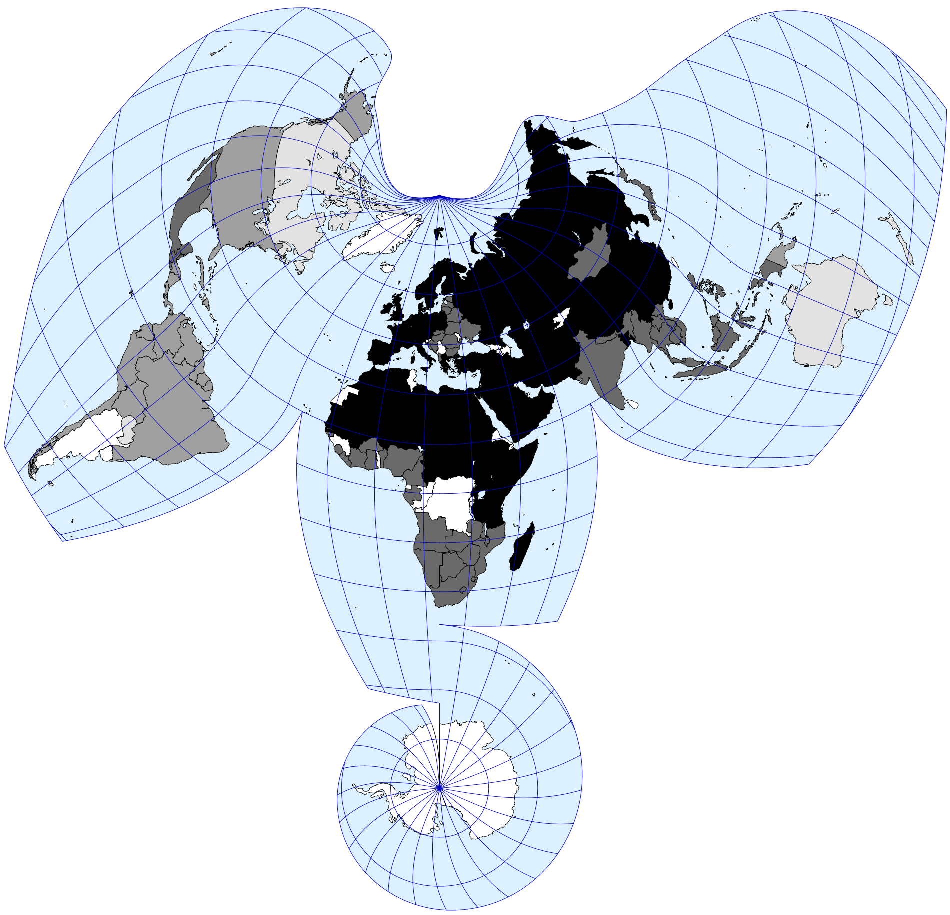

Figure 3: Overall technology adoption in 1500 A.D.

Figure 4: Technology in 1500 and current development

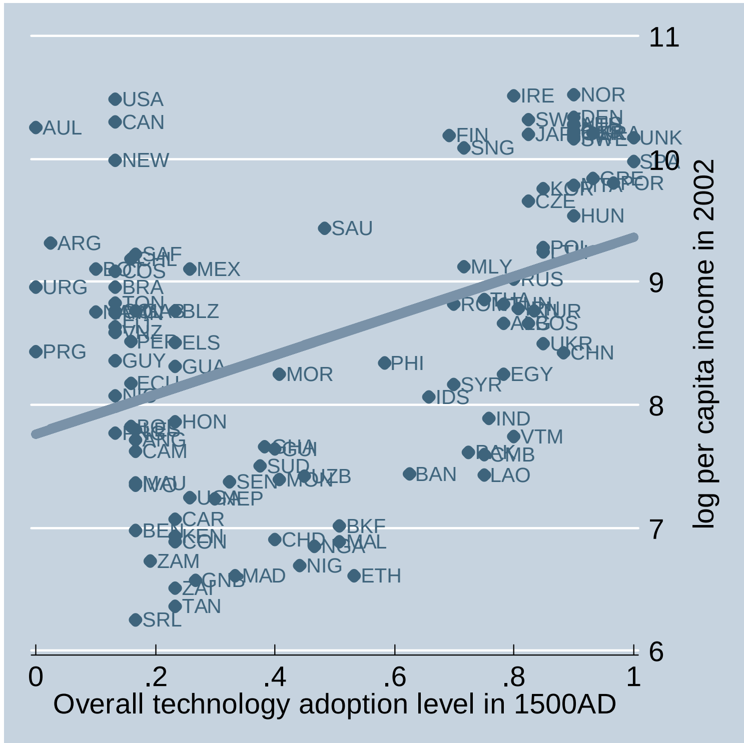

Figure 5: (Conditional) overall technology adoption in 1000 B.C. and (conditional) current development

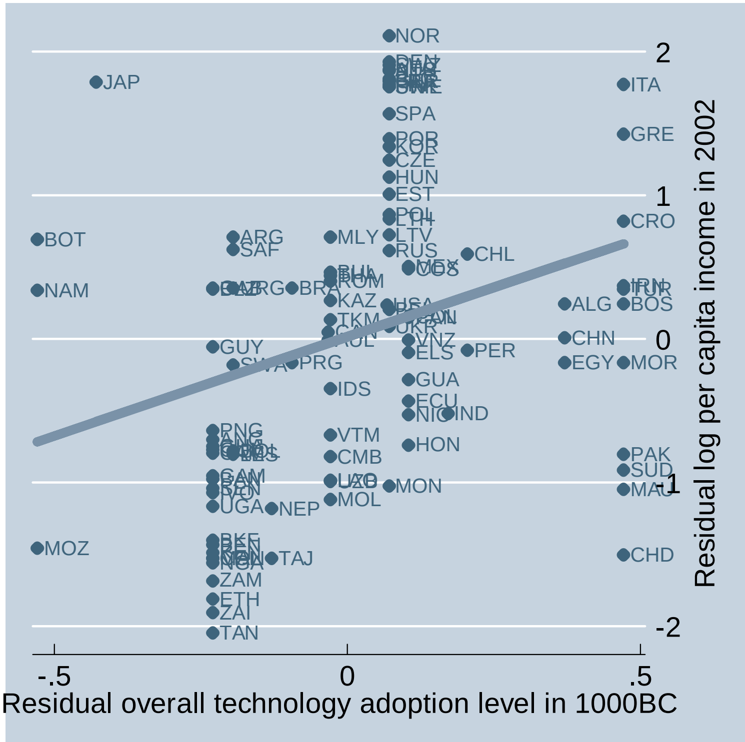

Figure 6: (Conditional) overall technology adoption in 0 A.D. and (conditional) current development

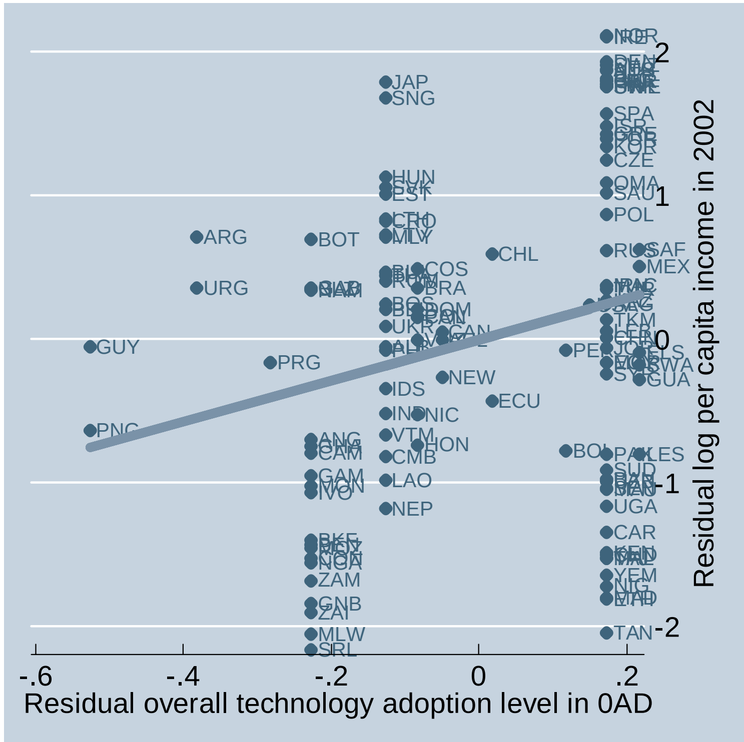

Figure 7: (Conditional) overall technology adoption in 1500 A.D. and (conditional) current development

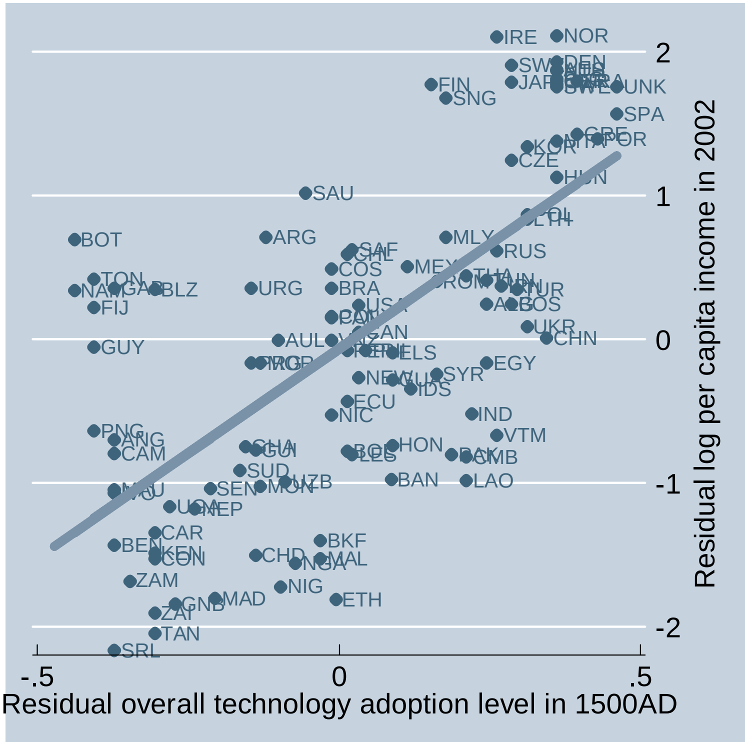

Table 3: Descriptive statistics of Overall Technology Adoption

Period	Number Obs.	Average	Std. Dev.	Min	Max
1000BC	113	0.45	0.28	0	1
0	135	0.73	0.28	0	1
1500AD	123	0.46	0.32	0	1

Table 4: Descriptive statistics of Overall Technology Adoption by Continent

Period	Continent	Number Obs.	Average	Std. Dev.	Min	Max
1000BC						
	Europe	30	0.66	0.16	0.5	1
	Africa	34	0.36	0.31	0	1
	Asia	23	0.58	0.25	0.1	1
	America	24	0.24	0.12	0	0.4
	Oceania	2	0.2	0.14	0.1	0.3
0AD						
	Europe	33	0.88	0.15	0.7	1
	Africa	40	0.77	0.2	0.6	1
	Asia	34	0.88	0.15	0.6	1
	America	25	0.33	0.17	0	0.6
	Oceania	3	0.17	0.11	0.1	0.3
1500AD						
	Europe	26	0.87	0.074	0.69	1
	Africa	39	0.32	0.2	0.1	0.78
	Asia	25	0.66	0.19	0.07	0.88
	America	24	0.14	0.07	0	0.13
	Oceania	9	0.12	0.04	0	0.13

Table 5: Average Overall Technology Adoption in Advanced Civilizations

Civilization	1000BC	0 AD	1500 AD
W. Europe	0.65	0.96	0.94
China	0.9	1	0.88
Indian	0.67	0.9	0.7
Arab	0.95	1	0.7

Note: W. Europe includes Spain, Portugal, Italy, France, United Kingdom, Germany, Belgium and Netherlands. Indian Empire includes India, Pakistan and Bangladesh.
Arab Empire includes Saudi Arabia, UAE, Yemen, Oman, Iraq, Iran, Syria, Lebanon, Jordan, Egypt, Libya, Tunisia, Algeria and Morocco

Table 6: Technology History and Current Development

Dependent Variable	Log Income per capita in 2002						
	I	II	III	IV	V	VI	VII
Overall Technology adoption level in 1000BC	0.67				1.38		
	(1.75)				(2.89)		
Overall Technology adoption level in 0		0.04				1.43	
		(0.11)				(2.74)	
Overall Technology adoption level in 1500AD			1.6				2.92
			(4.98)				(8.17)
Major European Involvement				1.9	2.46	2.82	3.21
				(11.71)	(10.69)	(8.1)	(12.86)
Minor European Involvement				0.24	0.61	0.85	1.42
				(1.37)	(2.67)	(3.22)	(5.89)
Constant	8.21	8.47	7.76	8.02	7.7	7.21	6.75
	(39.37)	(30.35)	(37.49)	(65.07)	(27.13)	(17.27)	(27.06)
N	103	122	106	124	103	122	106
R2	0.03	0	0.18	0.09	0.17	0.13	0.5

Note: t-statistics in parenthesis computed using robust standard errors.
Major European Involvement is a dummy that is 1 for US, Canada, New Zealand and Australia.
Minor European Involvement is a dummy that is 1 mostly for Latin American, Caribean Countries and southern Africa.

Table 7: Sectoral Primitive Technology and Current Development

Dependent variable		log GDP/capita 2002	
Technology adoption in	1000BC	0	1500AD
Agriculture	0.82	0.47	-0.69
	(2.06)	(1.29)	(1.79)
Communications	-2.48	-0.21	1.31
	(3.59)	(0.68)	(3.53)
Industry	-1.38	-0.83	0.08
	(1.52)	(1.38)	(0.15)
Military	2.54	-0.15	1.2
	(2.4)	(0.34)	(2.71)
Transportation	1.69	1.28	0.54
	(3.51)	(3.36)	(0.94)
N	103	122	106
R2	0.4	0.2	0.56

Note: All regressions include major European and minor European dummies and a constant
t-statistics in parenthesis

Table 8: Primitive Technology and Current Development, Robustness

Dependent Variable	Log Income per capita in 2002								
	I	II	III	IV	V	VI	VII	VIII	IX
Overall Technology adoption level in 1000BC	0.09			0.2			0.52		
	(0.22)			(0.24)			(1.17)		
Overall Technology adoption level in 0		0.58			0.04			0.45	
		(1.38)			(0.09)			(0.96)	
Overall Technology adoption level in 1500AD			1.18			1.46			2.3
			(1.94)			(2.8)			(4.99)
Europe dummy	1.74	1.58	0.68						
	(7.67)	(5.17)	(1.27)						
Africa dummy	-0.34	-0.66	-1.09						
	(2.03)	(2.39)	(3.44)						
Asia dummy	0.36	0.34	-0.55						
	(1.31)	(1.03)	(1.23)						
America dummy	0.19	0.15	-0.22						
	(1.04)	(0.84)	(0.69)						
Distance to equator				3.9	4.14	2.91			
				(8.48)	(9.02)	(4.1)			
Tropical dummy							-1.13	-1.21	-0.52
							(5.49)	(6.42)	(2.3)
N	103	122	106	97	114	103	103	122	106
R2	0.6	0.62	0.67	0.54	0.45	0.6	0.37	0.36	0.52

Note: t-statistics in parenthesis computed using robust standard errors.
All regressions include major and minor European involvement dummies and a constant.

Table 9a: Technology History, Current GDP, Population and Arable Land

Dependent Variable	Log GDP 2002			Log Population 2002			Log Arable Land		
	I	II	III	IV	V	VI	VII	VIII	IX
Overall Technology adoption level in 1000BC	1.75			1.23			1.48		
	(2.43)			(2.28)			(2.66)		
Overall Technology adoption level in 0		0.87			0.97			0.43	
		(1.36)			(2.1)			(0.68)	
Overall Technology adoption level in 1500AD			3.77			2.42			1.45
			(6.14)			(4.13)			(2.54)
Major and Minor european involvement dummies		NO			NO			NO	
N	103	122	105	112	134	117	109	131	114
R2	0.06	0.02	0.27	0.05	0.03	0.14	0.06	0	0.06

Note: t-statistics in parenthesis computed using robust standard errors.
All regressions include a constant.

Table 9b: Technology History, Current GDP, Population and Arable Land, European Influence Dummies

Dependent Variable	Log GDP 2002			Log Population 2002			Log Arable Land		
	I	II	III	IV	V	VI	VII	VIII	IX
Overall Technology adoption level in 1000BC	2.86			1.85			2.18		
	(3.76)			(2.99)			(3.67)		
Overall Technology adoption level in 0		3.63			2.39			2.03	
		(4.78)			(3.6)			(2.31)	
Overall Technology adoption level in 1500AD			5.91			3.51			2.66
			(11.23)			(5.09)			(4.14)
Major and Minor european involvement dummies		YES			YES			YES	
N	103	122	105	112	134	117	109	131	114
R2	0.22	0.21	0.54	0.11	0.12	0.23	0.2	0.11	0.2

Note: t-statistics in parenthesis computed using robust standard errors.
All regressions include a constant.

Table 9c: Technology History, Current GDP, Population and Arable Land, Distance from Equator

Dependent Variable	Log GDP 2002			Log Population 2002			Log Arable land		
	I	II	III	IV	V	VI	VII	VIII	IX
Overall Technology adoption level in 1000BC	2.31			2.47			1.98		
	(2.56)			(3.18)			(3.07)		
Overall Technology adoption level in 0		2.33			2.57			1.55	
		(2.78)			(3.49)			(1.77)	
Overall Technology adoption level in 1500AD			5.43			4.66			2.53
			(7.23)			(5.68)			(2.18)
Distance from Equator	2.96	3.5	-0.073	-0.52	-0.46	-3.2	1.38	2.1	0.44
	(2.56)	(4.33)	(0.08)	(0.6)	(0.71)	(3.06)	(1.56)	(2.46)	(0.27)
N	97	114	103	105	125	113	104	124	111
R2	0.3	0.28	0.54	0.13	0.11	0.3	0.23	0.15	0.2

Note: t-statistics in parenthesis computed using robust standard errors.
All regressions include major and minor European Influence dummies and a constant.

Table 10: Correlation of technology adoption measures over time

	Overall	Agri.	Military	Industry	Comm.	Transport.
Correlation (1000BC, 0AD)	0.62	0.39	0.51	0.39	0.32	0.64
p-value	0	0	0	0	0	0
Correlation (0AD, 1500 AD)	0.71	0.41	0.51	0.64	0.51	0.71
p-value	0	0	0	0	0	0
Correlation (1000BC, 1500AD)	0.68	0.42	0.69	0.6	0.22	0.6
p-value	0	0	0	0	0.03	0

Table 11: Correlation of technology adoption measures over time

Dependent Variable Overal technology adoption in:	0 A.D.	1500 A.D.	1500 A.D.	0 A.D.	1500 A.D.	1500 A.D.
Overall Technology Adoption in 1000 B.C.	0.63		0.58	0.39		0.33
	(8.03)		(5.44)	(6.01)		(3.1)
Overall Technology Adoption in 0 A.D.		0.63			0.39	
		(12.22)			(4.46)	
Distance from Equator	0.17	0.7	0.72			
	(1.45)	(7.03)	(5.77)			
Continent dummies		NO			YES	
N	103	106	94	110	106	94
R2	0.44	0.67	0.6	0.64	0.7	0.71

Table 12: Urbanization rate and technology adoption history

Dependent Variable: Urbanization rate in	1000 B.C.	0 A.D.	1500 A.D.	1000 B.C.	0 A.D.	1500 A.D.
Overall Technology adoption level in 1000BC	2.08			1.96		
	(19.38)			(22.57)		
Overall Technology adoption level in 0		1.69			1.68	
		(13.59)			(12.77)	
Overall Technology adoption level in 1500AD			8.4			9.5
			(3.46)			(4.24)
Distance from Equator				0.39	0.16	-2.83
				(1.25)	(0.84)	(0.57)
N	113	135	52	106	126	50
R2	0.5	0.58	0.2	0.48	0.59	0.21

Note: t-statistics in parenthesis computed using robust standard errors.
All regressions include a constant