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On the Human Capital of Inca Indios before and after the Spanish Conquest.
Was there a "Pre-Colonial Legacy"?

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Abstract:

Not only the colonial period, but also the pre-colonial times might have influenced later development patterns. In this study we assess a potential "pre-colonial legacy" hypothesis for the case of the Andean region. In order to analyze the hypothesis, we study the human capital of Inca Indios, using age-heaping-based techniques to estimate basic numeracy skills. We find that Peruvian Inca Indios had only around half the numeracy level of the Spanish invaders. The hypothesis holds even after adjusting for a number of potential biases.

Moreover, the finding has also crucial implications for the narrative of the military crisis of the Inca Empire. A number of explanations have been given as to why the Old American Empires were not able to defend their territory against the Spanish invaders in the early 16th century. We add an economic hypothesis to the debate and test it with new evidence: Were the human capital formation efforts of the Inca economy perhaps too limited, making it difficult to react appropriately to the Spanish challenge?

Key words: Human Capital, Age-Heaping, Inca Empire, Peru, Inequality, Growth

JEL: I25, N30, N36, O15

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Introduction

One commonly accepted view on the genesis of Latin America's economic backwardness blames mainly the legacy of colonial institutions for today's underdevelopment (Engerman and Sokoloff, 2000; Engerman et al., 1999; Acemoglu et al., 2001, 2002; Coatsworth, 1998, 2008; Bulmer Thomas et al., 2006). Acemoglu et al. claim that bad institutions originated in areas in which small European elites exploited large populations of Native or African descent. These so-called "extractive institutions" – favoring the concentration of power by a small fraction of the population, hampering property and human rights, and restricting public investment in schools and other growth-inducing infrastructure – have tended to persist until today, hindering GDP growth. Engerman and Sokoloff argued that geography and initial factor endowments at the time of the conquest – both natural resources and labor supply (the latter determined by population density) – defined the later inequality of the colonies. Where climate and soils were suitable for cultivating highly valued commodities and indigenous population was dense, they argue, extractive institutions were more likely created in order to facilitate exploitation in form of large plantations or cattle and grain haciendas. This was the case in the Andes and Mexico, for example.

While we agree with the role of colonial development obstacles, we argue in this study that there might also have been an additional legacy of pre-colonial societies for economic success. Especially low human capital investment in the Inca Empire might have initiated a path-dependent process of agriculture which was not human-capital intensive in the following centuries. Recently, Comin, Easterly and Gong (2010) constructed a measure of technological adoption at a regional level reaching back to 1500 AD. Applied to Latin America and specifically to Peru, they find that the Inca Empire not only lagged far behind most of Eurasia and Northern Africa, but was also outperformed by the Aztecs in terms of the utilization of a set of basic technologies (communications, agriculture, military, industry, and transportation). Using this measure they report a positive correlation between pre-colonial technology history

and per capita income today. Thinking of human capital as a core determinant of economic development, in this paper we contribute to the literature on the genesis of underdevelopment in the Andean region by constructing a data set that permits us to measure pre-colonial educational levels and compare it with European and Asian values. We also argue that educational inequality was substantial in Peru before the Spanish Conquest.

As a second contribution, we add to the understanding of a paradox in military history. One of the most crucial moments in history was the contact of "Indios" of the ancient American cultures with the European invaders of the 15th and 16th centuries. The meeting soon turned into a military defeat of the Indio cultures. A number of explanations have been provided for the failure of the Old American Empires to protect themselves against the small European military groups. However, in the case of the Inca Empire, it still remains astonishing that a small group of only 168 Spanish soldiers around Pizarro succeeded in capturing the Empire despite the obvious numerical inferiority when compared to the vast Inca army of 80,000 members. One of the most prominent explanations of this puzzle in the last decades was provided by Jared Diamond, who stresses the fact that Europeans brought not only guns and steel, but also infectious diseases such as smallpox and measles from which the American Indians died in large numbers.[1] The Europeans had developed resistance against those diseases over the centuries, partly due to their close contact with domestic herd animals from which these diseases originated (Diamond, 1997; but see McCaa et al., 2004). This factor in combination with superior military techniques of using horses, guns and other equipment, the fact that Indians could not comprehend fast enough the threat they were facing – sometimes even believing the Spanish being gods – and the alliance with some Indian tribes opposing the Inca rulers helped the Spanish to succeed (and similar mechanisms were at work in Mexico and elsewhere in the New World). Bakewell (2004) gives an excellent summary of the potential factors contributing to the victory of the Spanish. Yet, the question remains

[1]For an extensive discussion on the "demographic collapse" caused by epidemics and diseases brought in by the European colonizers to the New World, see also Denevan (1976), Cook (1981) and Cook and Lovell (1991).

whether some of these issues could not have been solved by the Inca Indios, given their enormously large population numbers even after diseases took their toll. Why were they not able to defeat the Spanish later on? The aim of our study is to assess the base of the native economy and society. One of the core elements of each economy is human capital, even in the agricultural economies before the Industrial Revolution. Were the human capital formation efforts of the Inca economy perhaps too limited, and hence making it more difficult to react appropriately to the Spanish challenges?

How can human capital of the "Inca" Indios be measured?[2] Obviously, no school enrollment or literacy rates are available for this early period of human history. However, a considerable number of studies have recently used an innovative measure of basic numerical skills, which takes the share of people who report an exact age as an indicator. In historical populations (as well as in the poorest countries today), a substantial share of the people was not able to state their exact age and hence reported a rounded age, such as "I am 40", when they were in fact e.g. 39 or 41. In hundreds of samples and dozens of studies, it has been proven that there is a significant correlation between the share of exact reported ages and other human capital indicators (see section 2 and Appendix A for longer methodological treatment). For example, one population register on a remote Andean region (Huanuco) contains both age statements of Indios born before the Spanish conquest and thereafter. Another register of Indios in the capital of Peru reflects the birth cohorts of the later 16th century and is therefore an interesting source for the history of numeracy under Spanish colonial rule. We also study a census of the population of Lima born during the 17th century, which allows us to perform a comparison between urban Peruvians of indigenous, European, black and mixed ancestry.

[2] "Inca" Indios are used here in citation marks, because the Inca Empire consisted of nearly 200 tribes, and only the family of the ruler was called Inca. But as the Habsburg Empire was named after the ruling family, it seems reasonable to name the whole group "Inca Indios". Hence, we will drop the quotation marks in the following.

Of course, our study faces a number of challenges. Cultural counting differences, selective mortality, and other human capital components apart from numeracy are all potential lacunae of our research design and hence will be discussed in detail below. But before doing so, we will give a brief history and chronology in section 1, discuss our sources and the methods of basic numeracy measurement in section 2, and present the main results in section 3. After the "Potential Objections section" we will dig slightly deeper and assess social and regional differences in section 5, before ending with a conclusion.

1. History and chronology

Sources used by historians writing about pre-Columbian Peru comprise the legacy from officers of the Crown – like the visitas from which we derive information for our dataset, often conducted on the basis of detailed questionnaires and including remarks of the visitor –, Spanish travelogues and native chronicles.[3] Most important travelogues of conquistadors told from a Spanish point of view include Pedro Pizarro's (brother of Francisco Pizarro). Other authors like Pedro de Cieza de León were more interested in the Indian world and cross-referenced their evidence with information provided by natives (Esteban, 1997; p.112). Works from mestizo and Peruvian writers such as Garcilaso de la Vega and Felipe Guaman Poma de Ayala, both descendants of the Inca nobility, brought up in close contact to Quechua culture and language, provide a valuable insight into the Inca history and culture, though probably also positively exaggerating their advance (Esteban, 1997; p.118).

The date of creation of the Inca Empire in the city of Cuzco is assigned to the early thirteenth century, about three hundred years before the Spanish arrived in Peru (Bakewell, 2004; p. 25).[4] At the time of its greatest expansion, the beginning of the 16th century, the Inca Empire included today's Ecuador, Peru, Bolivia and a large part of Chile, as well as smaller

[3] As the Incas knew no writing, their oral tradition was written down in the early colonial time often in a mixture of Quechua and Spanish language (Wachtel, 1977; p. 5). Members of the intellectual elite soon adopted cultural opportunities as the written language, offered by the interaction with the Spanish.
[4] Their own creation myths link their point of origin to the Lake Titicaca, 300 kilometers south-east of Cuzco.

territories in Argentina and Colombia.[5] The Spanish conquistador Francisco Pizarro reached Inca territory arriving from Panama in 1526. Three years later he obtained the permission from the Spanish crown to conquer the region and become governor of New Castile –as the administrative unit reaching from Ecuador in the north to Cuzco in the south would be called until 1542. At that time, the smallpox epidemic that had already devastated the population in the Caribbean and Mexico, had also reached Inca territory, causing a population catastrophe in this Empire as well, as a number of studies reported (Lockhart, 1968; Denevan, 1976; Cook, 1981; Cook and Lovell, 1991).[6] McCaa et al. (2004) argue, however, that smallpox epidemics and disease factors in general were probably less important, whereas the effects of civil war and of exploitation were rather more decisive for the demographic catastrophe of the Andean region. Huayna Capac's eldest son and designated heir died a short time after him, leaving no selected successor (Livi Bacci, 2008, p. 55; Steckel and Rose, 2002, p. 349). Subsequently, the nobility of Cuzco would choose Huascar, the second legitimate son of Huayna Capac and his sister, as new Inca ruler. However, his half-brother Atahualpa, son of a princess of the newly conquered Quitu tribe who governed today's capital of Ecuador and was the main head of the Inca army, claimed the position for himself. Soon after, a civil war broke out between the supporters of each of the two brothers, Huascar and Atahualpa (Bakewell, 2004; p. 31). When the Spanish troops arrived in Ecuador with the intention of conquering the Inca Empire, Atahualpa had just defeated Huascar and his supporters in a bloody assault of Cuzco. In 1532 the Spanish soldiers led by Pizarro captured Atahualpa at the Battle of Cajamarca. This was the first step of a long fight to subdue the Inca Empire. The Inca ruler was held as a prisoner for eight months. During this time Pizarro received a ransom of "enough gold to fill a room 22 feet long by 17 feet wide to a height of over 8 feet" (Diamond,

[5] The territory of the Inca Empire was then called Tahuantinsuyu, which can be translated into "the four regions", including Chinchay Suyo (the north), Anti Suyo (the Amazon jungle in the east), Colla Suyo (the south) and Conti Suyo (the west). The word Tahuantinsuyu derives from the Quechua tawa (meaning "four"), to which the suffix –ntin ('together' or 'united') is added, followed by suyu ("region" or "province"), which roughly renders as 'The four lands together'.

[6] Following Crosby (1976, p. 207), the smallpox epidemic reached Inca domain in 1525 or 1526.

1997; p. 68) in exchange for the promise to free Atahualpa (which was never fulfilled). The Inca was sentenced to execution in a mock trial because the Spanish suspected he was plotting his rescue by a large troop under the Inca general Rumiñahui. The charges against Atahualpa were polygamy, incestuous marriage, and idolatry – all common rites in the Inca culture – and having killed his brother Huascar. Following Huascar's and Atahualpa's deaths, further Spanish troops arrived in their mission to conquer Ecuador and Peru. Benalcázar's soldiers defeated the great Inca warrior Rumiñahui in Ecuador and occupied the city of Quito with the help of Cañari tribesmen who served as allies against the Incas (Prescott, 1847). The Indio resistance continued for the next forty years with frequent attacks against Pizarro, who was based in Cuzco, until the last Inca Tupac Amaru was murdered in Vilcabamba in 1572.

The fact that such a small number of Spanish troops (168 soldiers) was able to defeat the 80,000 Inca warriors[7] and capture Atahualpa at Cajamarca has been frequently subject of speculation (Lockhart, 1968; Diamond, 1997; Bakewell, 2004). Some widely accepted arguments include that the Spanish had horses and mastiffs, which caused great fear among the indigenous people, as well as cannons and guns, while the Inca warriors were not armed with such weapons and also not sufficiently protected against them. The very strict hierarchical organization of the Inca army has also been discussed as a possible explanation (after the death of the Inca brothers, no clear leadership existed for a while). Others like Crosby (1976), Cook (1981) and, most forcefully, Diamond (1997) have complemented the military superiority as a reason for the Spanish victory with the weakening of the Indio population via infectious diseases. The political division of the population and the alliance of numerous Indian tribes which had been conquered previously by the Incas, as well as the native's conception of the appearance of the Spanish as the return of gods[8], certainly

[7] This number has been adopted by Diamond (1997) and derives from eyewitness accounts by Pizarro's companions and brothers.

[8] In Peru, the myth of the god Viracocha, who disappeared walking over the sea to the west and was supposed to return during the reign of the twelfth emperor – turning to be Atahualpa –, lead the superstitious Incas to confound the foreigners arriving from Europe with deities (Wachtel, 1977; p. 21).

contributed to the conquerors' success. The military historians Hanson (2002) and Parker (2005) have argued that there was a "Western culture of war", which proved ultimately superior over the last 2,500 years. Hanson, a specialist in ancient Greek military history, stresses the civic liberties and democratic participation culture of "the West", which increased the effectiveness of Western armies, such as the 10,700 Greek soldiers hired by Cyrus the Younger before the battle of Cunaxa against his brother Artaxerxes II. The Greek brought their phalanx back to their home country across thousands of kilometers of Persian Imperial territory and after many battles against numerically superior enemies. This was only possible with their special "shock-fighting" technique, which required a special motivation and education of each soldier. Reviewers have criticized Hanson's definition of "the West": Ancient Greece, then Rome, France in the 8th and Spain in the 16th century, then Northwest Europe, the United States, and finally selected countries on six continents.[9] In other words, the definition covers those who fitted quite well into the model. It has also been criticized that the Spaniards who conquered Mexico were not exactly prototypes of citizens praising civic liberties, freedom and participation culture. Also the Spartiates had a very special way of civic participation culture. Parker (2005, 2009) in contrast does not stress the civic participation culture. He emphasizes that the Western culture of war (apart from the obvious technology factor) implies the major aim of "decisive battles", which was not typical of all other world regional cultures. Parker also mentions long-term credit as a "secret weapon" of the West, and perhaps most decisively in our context, he stresses the training abilities of Western societies. Here his arguments are very consistent with Hanson's, who also emphasizes the well-trained behavior of each individual soldier in decisive moments of battles. This element of the "Western Culture of War" theory has some similarities, albeit it is not identical with our view of human capital being a decisive element also enabling the victory of military groups of small relative size. Clearly, human capital for military purposes and human capital for

[9] For example, Chris Bray in the Reason Magazine's April 2002 issue.

industrial and agricultural production are not the same. But there is some overlap. For the English mariners who fought the Spanish Armada of the late 16th century, their superior human capital clearly helped them in the military conflict (before the North Sea storms came to help further). For ancient Roman soldiers their education to understand signals of relatively complex nature was decisive to win battles against enemies far larger in number, but lacking training and education. Creating the "shock" effects which were often decisive in battles depends on the trained performance of educated soldiers. This training is more important than cruelty and savagery of, for example, the "Barbarian" enemies of the Roman legions. There are many examples like this, which motivate us to assess the human capital difference between the Spanish and the Inca Indios during the 16th century and their military implications. Thus, we argue that human capital and its inequality might additionally have determined the Spanish success over the Inca Empire.

One particularly important aspect of pre-contact history is the inequality of education. The Inca culture had a comparatively advanced social system for the 16th century. The Inca Indios were great architects and developed an admirable sophistication in advanced agriculture (Klein, 2011). But while some advanced cultures in the world were characterized by a relatively broad participation of middle and sometimes even lower classes, other advanced cultures were mainly based on a thin upper class and a large quantity of uneducated people. We will argue in the following that the Inca culture was more of the latter type, with an extremely high educational inequality. The 16th century chronicler of Inca origin, Garcilaso de la Vega, described the elitist attitudes of the 15th century Inca ruler Tupac Inca Yupanqi in the following way: *"*Science was not intended for the people; but for those of generous blood. Persons of low degree are only puffed up by it, and rendered vain and arrogant. Neither should such meddle with the affairs of government; for this would bring high offices into

disrepute, and cause detriment to the state*"*.[10] This view reflects the ideology of the Inca monarchy, which would take care of their people, but not educate them or let them participate in any decision-taking process.

The majority of the population received a very modest education under the Inca Empire, while the small ruling Inca cast and those who dominated the military and the religious sectors would receive training by the amautas (wise people) in order to be prepared for their future positions in the administration of the government or as priests. They were trained in different disciplines according to their future profession, which was most often hereditary, like military competence, religious rites or basic mathematics (Julien, 1998). Though it was the common people who were in charge of moving earth and stones in order to build the irrigation systems, the massive stone buildings, fortress temples and the rest of the impressive architectural and engineering marvels for which the Inca Empire is known, the state would not provide education to them.[11]

Concerning the level of economic development reached in the Andes before the arrival of the Spanish, Comin et al. (2010) have noted that a number of economically useful and important inventions were missing in the Inca Empire, making it technologically inferior to Eurasia and even to the Aztec Empire. They construct a dataset on technological adoption – determined by the utilization of a set of basic technologies (communications, agriculture, military, industry, and transportation) –, which allows to show persistence of technological differences between the predecessors to today's nation states over long periods. In their study on the persistence of technological differences between nations over long periods, they find that their pre-colonial technology measure of 1500 AD is a statistically significant predictor of per capita income and technology adoption at the present.

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[10] Note: translated by Prescott (1847, p. 39) from Garcilaso de la Vega, Inca (1609, part 1, book 8, chapter 8)
[11] People in charge of building palaces and other buildings in Cuzco were part of the coerced rotating labor system called mita (Julien, 1998; p. 85).

Not only education, but also income was distributed very unequally during the Inca Empire. Engerman and Sokoloff (2000) argue that in pre-conquest Peru (and similarly in Mexico) extreme inequality was already latent before the Spanish conquerors arrived. These regions were geographically blessed with a dense population and abundant mineral resources. The strictly hierarchical organization of the Native American societies allowed the powerful elite to take profit of these factors. Europeans to some degree adopted the social organization in which small Indio Elites extracted tribute from the general population, contributing to the path-dependency of inequality. Also the institution of coerced labor called the mita[12], on which mining relied during colonial times, already existed in a similar version for the native population ruled by the Incas. It was reintroduced in the 1570s by the Viceroy Francisco de Toledo among other territorial and tax reforms in order to allow a more profitable exploitation of the Potosí silver mines. It required Indians to work by force in return for wages well below the existing market rate (Bakewell, 1984). About 16 percent of the male native population from communities lying between Cuzco and Potosí were sent to mine and refine silver (or mercury in Huancavelica) on a rotating basis during one year (Bakewell, 2004; p. 202). Despite Toledo's efforts to protect mitayos from the abuses of overwork and severe punishments, these evils combined with harsh natural conditions are supposed to have taken a heavy toll of the native conscripts. However, it would be difficult to know whether the mita reintroduced by the Spanish colonial regime was more or less extractive than the previously existing. The colonial version distinguished itself from the pre-Hispanic one in some key factors. The Spanish only employed this institution for mining and not for other sectors of the economy, as it was done during the Inca Empire (Julien, 1998). Further, the colonial mita was a source of coerced, albeit salaried, labor and it coexisted with a free, comparatively expensive workforce. In the late 1500s the demand for labor rose because of the decimation of the indigenous population due to disease, war, civil war, exploitation and the Spanish

[12]Mita is derived from the Quechua word *mit'a*, meaning "turn" or "period of service" (Cole, 1985; Dell, 2010).

newcomers needing native workers for their encomiendas (Bakewell, 2004; Tandeter, 2002).[13] Thus, many mitayos preferred to remain in Potosí selling their skilled mining labor at the end of their stints, rather than turning back to the more deprived community life in the rural sector (Bakewell, 1984). By the early seventeenth century, as suggested by Bakewell, more than half of the Potosí labor force of some 10,000 consisted of free workers. A very interesting fact is that, for all its imperfections, a market for labor appeared ex novo after the Spanish Conquest and increased in importance over time in the Andes during the colonial period. This has implications for numeracy, because the return to this basic human capital investment increased after a market for labor was created.[14]

Does this imply that the well-being of the native population improved with the change from the Inca to the Spanish colonial regime? The arrival of the Spanish clearly increased the speed of technological progress (see, for example, Comin et al., 2010) and also offered new cultural opportunities, which were soon adopted by members of the Inca elite, such as written language. On the other hand, Klein (2011) suggests that the Inca Empire "functioned as a major distributer of goods and services in a nonmarket manner and probably created a well-being and wealth among all the population unmatched from those times to the present".[15] This very positive view of the late Old American Indio empires does not harmonize with anthropometric and other health evidence presented by Steckel and Rose (2002). They found that South Americans' health deteriorated since the switch from hunter gathering to the agricultural system and the creation of the Inca Empire (and thereafter). For the post-conquest period, Dobado and García (2010) recently argued that Andean and Mesoamerican people were "not so short" during the colonial period, although the evidence of well-being directly before and after Spanish conquest is not based on a large number of observations.

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[13] But see McCaa et al. (2004) on the limited role of disease until the 1560s.
[14] At this point we thank an anonymous referee for his comments.
[15] Klein (2011), p. 19.

2. Sources and methods of basic numeracy measurement

The Incas of Peru made regular counts of the population in order to raise tribute, and to know the number of potential warriors and defenders of the community (Cieza de León, 1609). They recorded the numbers on knotted-string mnemonic devices called quipus. Within a short time after the conquest, Spanish administrators also conducted a number of surveys of the native population in order to learn about the number of tribute-paying subjects being granted to colonists. The Spanish administrators of Peru generated a number of population lists, of which some have survived and contain valuable information for our study. The population list of Huanuco 1562 includes only indigenous people of this province, which was situated some 400 km northeast of Lima in a valley of the Andean mountains (Table 1). The population centers of Huanuco lie between 250 and 6,631 meters over the sea level. This information is particularly valuable for our study, because the administrators documented this district already in 1562, i.e., only three decades after the Spanish conquest of Peru. Hence, many surveyed persons were born when the Inca Empire was still independent. They also confirmed directly if somebody did not know his or her age. As most basic numeracy is acquired during the first decade of life, their age heaping behavior should reflect the educational investment during the Inca Empire. We also mention in Table 1 whether we would expect a bias relative to the overall population of the country. In the case of Huanuco, there might be a negative bias due to its remote and rural geography.

Our second source, the census of Indios in Lima 1613, was taken under the viceroyalty of Juan de Mendoza y Luna. The Viceroy sent a copy of this Indio census to Spain, and this copy is the only one surviving.[16] Lima was newly founded by the Spanish in 1535. Hence, the indigenous population structure in 1613 is characterized by immigration of Indios from the countryside, who worked as craftsmen and servants in the capital. The male population was about twice as large as the female population. Indios represented only eight percent of the

[16] Unfortunately, the population records of whites, blacks, mulattos and mestizos have been lost.

total population of Lima at the time. The age group of 23-32 was by far the largest age group.[17] The officials asked every person for his or her name, age, occupation, and birthplace. Most people came from today's Peru and Ecuador, and some were immigrants from other Latin American regions. In total this sample consists of 749 individuals aged 23 to 72.

The inquisition of Lima provides another small source for people born in Peru and Spain (N=64). A part of it was published by Ricardo Palma in 1897, containing the documents of the Sacred Court in Lima from 1625 to 1761.[18] 42 percent of the inquisition victims were female, who were mostly judged for heresy. Men were mostly accused of bigamy, trigamy and similar reasons.[19]

A fourth source that provides a list of all male household heads in Lima from 1700, also recorded a (small) number of Indios. The source contains 2,946 household heads in total and lists 76 persons of (at least partly) Indio origin, as well as a small number of mulatto and black persons. Hence, this source actually informs us better about the numeracy of the white household heads of Lima. Unfortunately, there is no information given about the place of birth of the inhabitants in this census. We assume that the majority was either born in, or close to the capital, or moved quite early to the capital. Thus, we assigned in the following regression the value 1 to the control variable 'large capital'.

These four sources can inform us about the situation in the Andean region, and particularly about the Indio numeracy. For better comparison, we obtain four sources on the European side, as we want to place our argument into a comparative perspective. As for Peru, we work with population censuses and also with inquisition sources, although the latter might be upwardly biased, as we will discuss below. For Portugal and Spain, we have evidence on

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[17] This structure could also be observed at the time in mining towns as Potosí or Huancavelica. Furthermore, the great majority of the households have two children or less. More than fifty percent had no children. The age groups running from end figure 3 to 2 are standard in the age heaping literature.

[18] Other original documents are not available anymore, because they were burnt during an occupation of Lima by Chilean soldiers in 1881. The first edition of Palma's "Anales" was published before the fire when he could still have access to those documents.

[19] The Tribunal of the Santo Oficio was not occupied with the cases of Indios in Peru. There were during the colonial times other institutions that accounted for this purpose (Moreno de los Arcos, 1990).

the four inquisition places in Évora (southern Portugal), Logroño, Cuenca and Llerena (north, east central and western Spain, respectively).[20] The Llerena data set (N=259) consists of a large proportion of Portuguese immigrants, whereas some Spanish immigrants can be located in the Évora data set (N=2,368). We have one source stemming from other sources than inquisition, namely a tax list of 1717 from the city of Badalona in Catalonia in north-eastern Spain (N=359). It is one of the early population registers that survived until today. For the 16th and 17th century in contrast, the inquisition files are relatively abundant, but it is clear that we will need to control for possible biases below.

In Table 2, we provide some comparative characteristics of the data sets. The share of Jewish accusations is important for the inquisition-based data sets, and is as high as 88% for the Portuguese data set from Évora. For the census-based data sets, we assume that the Jewish share was close to zero, because the Jewish were expulsed and persecuted in the Spanish and Portuguese Empires under study here.[21] The female share was particularly high in the Logroño data set, because this inquisition case was mainly directed against witches. Some of the sources contained only males (Badalona 1717, Lima 1700), whereas in most data sets the share was between one fifth and one half. The Huanuco data set of 1562 had also a quite high female share, which might be caused by the fact that males had died in larger numbers from the infectious diseases or suffered from the violence during conquest.

We also define the variables 'large city' and 'migrant' which assign these characteristics to the sample for which the information was given and relevant. Sources from Lima were naturally quite urban, whereas migrants were numerous in the Llerena and Lima inquisition files. Finally, the "age 23-32" variable controls for the age structure in our

[20] The Cuenca data set (N=475) was kindly provided to us by Sara Nalle, for which we cannot thank enough, and for the Portuguese data entry we thank Rosemarie Triebe. We have no information on place of birth and accusation; hence we will insert dummy variables in the regressions below which will control for "partly Jewish", 'partly migrant' and "partly large city".

[21] Following the Alhambra Edict, an Edict of Expulsion against the Jews issued by Ferdinand and Isabella in 1492, about half of the Jewish population living in Spain emigrated and the other half stayed and converted to Christianity. Thus, there were practically no more 'official' Jews in Spain and, since 1497, neither in Portugal.

samples. This is particularly important because younger individuals in their twenties round sometimes on multiples of two rather than five, and as the heaping index employed here does not capture this rounding, we need to control for this as well. The share of young adults was normally in the range of 25-35 percent, but in Lima 1604 it was substantially higher.

How is the heaping index calculated? The ratio between the preferred ages and the others can be measured by several indices, one of them being the Whipple index.[22] To calculate the Whipple index of age heaping, the number of persons reporting a rounded age ending with 0 or 5 is divided by the total number of people, and this is subsequently multiplied by 500. Thus, the index measures the proportion of people who state an age ending in a five or zero, assuming that each terminal digit should appear with the same frequency in the 'true' age distribution.[23]

$$(1)\ \mathrm{Wh} = \left(\frac{(\mathrm{Age}25 + \mathrm{Age}30 + \mathrm{Age}35 + \ldots + \mathrm{Age}60)}{1/5 * (\mathrm{Age}23 + \mathrm{Age}24 + \mathrm{Age}25 + \ldots + \mathrm{Age}62)} \right) \times 100$$

For an easier interpretation, A'Hearn, Baten, and Crayen (2009) suggested another index, which we call the ABCC index.[24] It is a simple linear transformation of the Whipple index and yields an estimate of the share of individuals who correctly report their age:

$$(2)\ \mathrm{ABCC} = \left(1 - \frac{(\mathrm{Wh} - 100)}{400} \right) \times 100 \text{ if } \mathrm{Wh} \geq 100 \text{; else } \mathrm{ABCC} = 100 .$$

The share of persons able to report an exact age turns out to be highly correlated with other measures of human capital, like literacy and schooling, both across countries, individuals, and over time (Mokyr, 1983; A'Hearn et al., 2009; Crayen and Baten, 2010).

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[22] A'Hearn, Baten and Crayen (2009) found that this index is the only one that fulfils the desired properties of scale independence (a linear response to the degree of heaping), and that it ranks samples with different degrees of heaping reliably.

[23] A value of 500 means an age distribution with ages ending only on multiples of five, whereas 100 indicates no heaping patterns on multiples of five, that is exactly 20 percent of the population reported an age ending in a multiple of five.

[24] The name results from the initials of the authors' last names plus Greg Clark's, who suggested this in a comment on their paper. Whipple indexes below 100 are normally caused by random variation of birth rates in the 20th century rich countries. They are not carrying important information, hence normally set to 100 in the ABCC index.

3. Regression estimates of numeracy trends

The aim of the following figures and regression tables is to estimate the numeracy trends for the Indio and white population of the Andean region under study, as well as those of Spain and Portugal during the 15th to early 18th century. However, we identified above a number of potential biases that could create positive or negative selectivity and hence need to be controlled for. The variables which should be taken into account in order to avoid biases are the following:

1. Inquisition sources. One could imagine that victims of the inquisition were not a random sample of the underlying population. We assume that individuals included in inquisition samples are positively selected, especially because the accused were to a great part 'major heretics', including Judaists, Protestants and other spiritual devotees. Arguments for our assumption of Jewish and converts' superiority in terms of education are given in the next paragraph. Concerning Protestants, many studies have shown a better performance in education, especially in literacy, compared to Catholics (Becker and Woessmann, 2010). Illuminists, "Erasmians", Lutherans and other Protestants, were usually individuals who had thought critically about theological (and political) issues and adopted innovative views on spiritual and intellectual life. They were often familiar with devotional literature censored by the inquisition (Rawlings, 2006; pp. 90-113). Moreover, it has been argued that the Inquisition profited from persecuting heretics by confiscating the goods of the accused (Rawlings, 2006; p. 42). In fact, expropriation was a common conviction besides wearing the sanbenito (penitential cloth)[25], scourge, exile, jail and death. For this reason, one could imagine that victims of the inquisition were relatively wealthy – and probably on average more educated –, so that the Sacred Tribunal could make larger profits from condemnations. Even if we control for the effects of birth in large cities and being of Jewish religion separately (see below), the remaining victims of the inquisition might have been more

[25] The sanbenito or 'sacred cloth' was a penitential tunic worn by the condemned during the public penance and sometimes for a certain time afterwards in public (Rawlings, 2006; p. 159).

educated, hence we include a dummy variable for age statements from this source, as opposed to census data and other population lists.

2. Jewish religion. Being accused of practicing Jewish religious activities could generate a bias for various reasons. Firstly, the Jewish community in the Middle Ages – and the converts' afterwards[26] – had acquired important positions in the Spanish society thanks to their excellent educational preparation. They kept posts in medicine, universities, in the church and in public administration. Furthermore, they were active in the world of finance and the economy, working as bankers, merchants and tax collectors (Prado Moura, 2003; p. 18). Secondly, accusations of practicing Jewish religious activities could focus on the relatively rich and educated, even if their connections to Jewish belief were remote or non-existent. Therefore, we expect that this group has a higher numeracy.[27]

3. Female. During most of history, female children received less education than males. Given that our samples feature different gender shares, we control for this and adjust the estimates below to represent the male numeracy level, because in some sources exclusively males were included.

4. Large cities. In large cities, it is typically less costly to organize schools than in the countryside or in small towns, because the pupils have to walk shorter distances (Bouccekine et al., 2007). Moreover, the decision makers of the central administration were living mostly in the capitals and large cities, and they preferred to finance schools which their own children could attend. In contrast, very rural regions like Huanuco in the 16th century were certainly educationally disadvantaged. Hence, we controlled for a possible urban or rural bias by including an indicator variable.[28]

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[26] Since after the edict of expulsion was issued in 1492, about half of the Jewish population converted to Christianity, the Inquisition sued against 'New Christians' accused of practicing Jewish rites.

[27] As the share of Jewish was quite low, our estimates below refer to the non-Jewish population (and they refer to non-inquisition sources).

[28] This variable is one for the following large cities which were included in our sample: Berlin, Bordeaux, Cadiz, Cartagena, Coimbra, Cuzco, Cordoba, Geneva, Granada, La Paz, Lima, Lisbon, Madrid, Malaga, Manila, Naples, Porto, Quito, Santiago de Chile, Seville and Toledo.

5. Migrants. Individuals migrate to other countries if they expect a higher income and a higher standard of living in the new location. However, migration requires an investment, both in terms of money and psychological cost. In the early modern period, travel costs were very high, thus relatively rich and educated individuals might have been overrepresented.

6. Age 23-32. We organized our age-heaping-based numeracy estimates by age group, because those in their twenties normally displayed a different heaping pattern: Similar to the older persons, they reported ages rounded on multiples of five, but some of their rounding was also on multiples of two, such as 24, 26, 28 etc.[29]

The results are reported in Table 3. Column 1 displays the marginal effects of a logistic regression in which the dependent variable is 1, if the individual reported an age that was not a multiple of five, and zero otherwise. We run a logistic regression because our dependent variable is a binary. The marginal effects were multiplied by 125, so that they can be interpreted as percentage changes of numeracy, taking into account that 20% of ages would correctly end on 0 or 5.[30] For example, age statements that come from the five inquisition sources are characterized by an additional numeracy of 13.4 points, even when controlling for urban bias and religion separately.

We further find that those who were persecuted for practicing Jewish religious elements were 7.7 percent more numerate.[31] The occupational constraint of the Jewish to some money-related activities and the religious demand to acquire reading abilities might have caused this advantage. In contrast, females were less educated than males during this early period, by as much as 16.9 percent, and inhabitants of large cities displayed higher education (by 12.8 percent). All these coefficients are statistically significant at the 5 percent level, and we will see below that they are also economically significant, i.e., that their size is

[29] This part of the age heaping is not reflected in the ABCC index, which focuses on heaping on multiples of five. Hence, we need to control for these young age groups and expect to see a seemingly positive bias of this age group, relative to the age groups 33-72.
[30] We included a note in Appendix C explaining the derivation of the multiplication with 125 for estimating numeracy.
[31] This effect is even higher if we do not control for inquisition sources, as in Table 3 Model 3.

relevant relative to overall differences of numeracy between countries. The coefficient of migrants was positive as expected, but not statistically significant. The adjustment of those aged 23-32 in contrast, is highly significant and should be definitely taken into account.

We also estimated two different specifications in order to assess the robustness of our results. In column 2, we removed the inquisition of Cuenca, for which we have no information about the accusation[32] and place of birth. Most of the coefficients are relatively stable, except for Spain in the late 15th century, which had rested mostly on this data set (the remaining few observations from other sources are too few for a reasonable estimate). As a second robustness test, we omitted the source-specification variable "inquisition", which again resulted in fairly robust coefficients.

In order to estimate numeracy trends, we created a large set of coefficients that refer to each country, ethnic group and birth period. We have chosen half centuries as birth periods, in order to estimate the long-run trends and assess the difference between the Inca Indios before and after the Spanish conquest, as well as to compare their human capital with that of the European samples.

In order to calculate adjusted ABCC levels for all these groups, we run a regression of "not reporting a multiple of five" as the dependent variable. The independent variables are those country-ethnicity-period indicator variables and the full set of control variables (Table 3, column 4). We use a linear probability model due to the fact that this tool provides a constant, which we need for the calculation of ABCCs.[33]

As a result, we obtain here the first human capital estimates for Spain and Portugal for the late 15th century and thereafter. In Figures 1 and 2, we can compare the raw values and the adjusted estimates, which were calculated with the coefficients of Table 3, column 4. The

[32] The explanatory variable "Partly Jew" is only relevant for the Cuenca inquisition source because of this. Thus this variable is not included in Model 2.

[33] The correlation between coefficients of the logistic and the linear probability model is 0.96 and the slope in a scattergram comparing the two is equal to one (Figure available from the authors), hence there is almost no difference.

adjusted Spanish and Portuguese numeracy values were between 20 and 30 percent in the late 15th century, and started a slow, but steady increase from this level until the early 17th century, when they reached between 50 and 70 percent. The 17th century was characterized by a stagnation or slight decline in Spain, and a temporary increase between the early and late 17th century in Portugal, but this was lost again in the early 18th century.

We estimate numeracy for Peruvian Inca Indios for the early 16th century, i.e., mainly before the Spanish conquerors arrived. The Peruvian Inca Indios had only about half the numeracy level of the Spanish invaders. This holds true even after adjusting for the downward bias, which might have been typical for the remote and isolated area of Huanuco, on which our early Peruvian data is based. The values during the late 16th century seem to have converged strongly towards Spanish and Portuguese levels. In fact, the numeracy estimate of Indios from Ecuador was even higher than Portuguese levels in the late 16th century. The high numeracy during this period might be slightly biased by the fact that we can only observe Inca Indios who had moved to the newly founded city of Lima and who might have been a quite particular selection of Indios. This view is supported by the fact that the numeracy of 17th century Indios fell back to substantially lower values. It could also be that Indios living in the capital exploited the cultural opportunities offered by the colonial society in form of numerical skills, the way members of the new intellectual elite – Garcilaso de la Vega and Guaman Poma de Ayala – did with the written language.

Nevertheless, it is interesting that the Ecuador Indio values were the highest, because the Indio collaboration with the Spanish conquerors was concentrated in the region that later became Ecuador.[34] This was the area of the Cañari Indios, some of the most decided collaborators of the Spanish. The high levels of numeracy of the Cañari could have been a positive consequence for them of the Spanish rule, which might have implications for the

[34] The specification "Ecuador Indios 1550" refers to migrants coming from the area of today's Ecuador shown up in the Indio population list of Lima in 1613.

colonial legacy. However, the levels of the late 16th century might be overestimated due to the immigration selectivity to Lima.

In the Lima census of 1613, those were explicitly identified as Cañaris, because belonging to this tribe was associated with a privileged position. In fact, it seems that this group of Indios was exempt from tribute and the mita as a reward for their help during the Indio's siege of Cuzco in 1536 (Cook, 1981, p. 83; Livi Bacci, 2008, p. 162). It is not astonishing that they could provide somewhat better education to their children than the Peruvian Indios, or the Southern Indios, which we indicated with the label "Chile/Bolivia/Argentina" (most of them were born in what is today Chile). [35]

The numeracy of white Peruvian household heads that we obtained from the 1700 census of Lima was situated in the middle between Peruvian Indios and Iberians in the 17th century. In contrast, the relatively few mulattos and blacks in Lima during this period reported only rounded ages. As a caveat, we should note that it might have been possible that census enumerators did not even bother asking them, as they did not expect a true age statement. The temporary increase of Indio numeracy during the late 16th century, even if it might have been partly caused by selectivity that we could not capture in our adjustment regressions above, also proves that Indios were not generally unable to reach numeracy levels which were comparable to Spanish or Portuguese levels during the 16th century. There was no cultural or perhaps even genetic hurdle which would have kept them from developing substantial age numeracy, if the educational level and other context parameters would have been sufficient.

How high was Spanish and Inca Indio numeracy in comparison with other populations in Europe and Asia (Figure 3)? In the late 15th century, the Dutch, Italians and Germans had reached a higher numeracy than Iberians, and the gap between Northwest and Southwest Europe might have remained roughly constant thereafter, although numeracy grew in both regions. For the late 17th century, we have the first evidence for China, which had a very high

[35] Individuals included in the variable "Chile/Bolivia/Argentina 1550" are also Indian migrants to the city of Lima captured in the Lima Indio count of 1613.

numeracy. During the early 19th century crisis of China, its numeracy fell back below the European Northwest (see also Gupta and Ma, 2010; pp. 274-275).[36] Summing up, we found that our sources based on inquisition records were upward-biased, not only because the inquisition victims were often of Jewish origin (or were so numerate that the accusers thought they might be Jewish) or urban, but also because inquisition victims per se were more educated than the average population. Moreover, and crucial for the main question of this study, we find that among the adjusted figures, Spanish and Portuguese had a moderate numeracy during the late 15th and early 16th century, but it was at least twice as high as the numeracy of the Inca Indios. Hence, the low human capital level of Inca Indios might have been an additional reason for the military defeat of the Inca Empire.

4. Potential objections

We are aware that this study might be confronted with a number of possible objections. Objection 1: Is the age heaping technique informative in the case of the Inca Indios? Or did they have culturally determined number preferences which were different from European ones, perhaps partly based on their knot-based counting method? Are the sources used reliable and valid for estimating numeracy of the aboriginal population in the late pre-Hispanic period? Our response to this objection is: It seems that all human beings start to count with the fingers of their hands, hence there is a strong preference to express numbers as multiples of five and ten. This is also observable when the Inca Indios were asked for their age, i.e., the data do not point to a preference for another digit. Some additional insights about number preferences can be gained from considering the Inca number system, which relied on the science of the quipus. Quipus, which translated means “knots”, were fabricated by civil servants who were in charge of compiling and reporting information on the population structure or the agricultural inventories and the provisions delivered to the royal storehouse.

[36] Gupta and Ma (2010) report that literacy in the early 19th century was quite low.

They registered births, deaths, marriages and the number of tributaries as well as the number of people who could be recruited for war.[37] The distance between the knots represented the numbers and the colours of the cord were meant to identify the different counted units (Livi Bacci, 2008; p. 161). Quipus were the only system of written numerals and, though little is known today on this system, it was used for a decimal order, with knots that represented singles, tens, hundreds, and higher numbers (Menninger, 1943, p. 196; Espinoza Soriano, 1997, p. 422). Hence, we would argue that it is consistent to assume that the Inca Indios would, as other cultures do, have a preference for multiples of five, and not for any other digit.

Another answer to this question is the fact that within the responses of the Indios, we see a clear stratification between richer and poorer, and presumably more and less educated Indios, as indicated by their taxation records. This provides credibility to the indicator (see section 5 for a more detailed treatment). Finally, we observed special groups of Indios in the previous section – the Cañari Indios of Ecuador – who were as numerate as the Europeans.

Thus we argue that the sources and the technique used here are valid for estimating numeracy of the aboriginal population in the late pre-Hispanic period and early colonial time and that the results can be compared directly with other samples, i.e. those of Indios born after the Conquest and of Europeans.

Objection 2: What about selective mortality? Who survived the infectious diseases and hence could be asked for the age later-on? Our answer to this question is: we do not know exactly. The nature of most epidemics is that mortality is not very selective, rich and poor both die from it. It is slightly different in the case of mortality after bad harvests, when it is more selective. But even if the native mortality from the imported epidemic diseases were selective, our argument would be strengthened: as better educated Indios would have survived

[37] After the new census was planned, the official counters were sent by the Inca to the places in question. Quipu records of the previous count were brought and after noting deaths and births, new divisions of the population into age categories were recorded.

in this scenario, our numeracy estimate for the pre-Spanish period would even be over-estimated. However, the findings of McCaa et al. (2004) suggest that this might not be a major issue.

Objection 3: But is the Inca culture not famous because they had achieved such a high cultural level? Is this not a reflection of a high human capital? Yes, indeed, the Inca culture had many fascinating elements, including their architectural achievements -- such as impressive stone buildings --, a broad infrastructure of paths connecting the whole Empire and a highly developed agricultural system. However, as discussed in section 1, the overall impression is that educational inequality was very high in the Inca Empire. A small elite group received training and education (as described in section 2), but the majority of the population did not.

Moreover, the overall scientific and technological development in the Andes was not very impressive, as suggested by Diamond (1997) and recently supported by Comin et al. (2010). Diamond stresses the fact that the Spanish conquerors – even though poorly educated themselves[38] – were coming from a culture with a certain share of literacy, whereas the Inca Indios had not developed a comparable literacy culture.[39] Measured in terms of technological adoption, Comin et al. (2010) find out that Incas not only lagged far behind most of Eurasia and Northern Africa, but were also outperformed by the Aztecs in terms of the utilization of a set of basic technologies (communications, agriculture, military, industry, and transportation).

Objection 5: Are the samples used here comparable? Is the validity of the sources given? The Huanuco sample of Indians born before Spanish conquest might cover the whole surviving population of this region. But Huanuco had no large urban settlement, which would have been characterized by typically better educational standards, probably also in the Inca

[38] The educational level of the conquerors was mixed, but Pizarro himself could not read and write (Bakewell, 2004; p. 100).

[39] In this context Diamond points out that Peruvians had never heard (or read) of the existence of the Spanish until Pizarro's first landing in Ecuador. They also remained ignorant about Spain's conquest of Central America. Diamond (1997, p. 80) emphasizes that "literacy made the Spaniards heirs to a huge body of knowledge about human behavior and history".

culture. Hence we have worked with multiple regression models which allow to control for a large urban share in order to make the Huanuco sample comparable with the other samples. This is the reason why our numeracy estimate for Inca Indios born in the early 16th century (before the Conquest) increased from 2.4 points to 12.5 points.[40] We applied the same procedure to the "inquisition bias", because otherwise the samples affected by it would have been unrepresentatively high.

We have to admit that for the Inca economy before the conquest, we need to work like archeologists who find artifacts and interpret them based on what they know about the context based on other evidence. But the validity and comparability of the samples is given, as argued above.

What would make a source unsuitable for the age heaping methodology?[41] Not asking individuals directly for their age, as well as counterchecking, would be an insurmountable obstacle. We have taken care that the persons listed were indeed asked for their age and that it was not guessed by the counting officials. It is also important that the age statements were not counterchecked with birth registers by the officials. In the introduction of the Lima and Huanuco sources, the explanations given to the counting officials are explicitly to ask them personally for their age (Escobar Gamboa, 1968; Murra, 1967; Cook, 1985). Sources which were counterchecked, typically do not display age heaping.

5. Social and regional differences of numeracy

We will observe in the following whether numeracy differences existed among the social strata of Inca Indios. Our aim is to assess whether the age heaping technique can be applied as a proxy for human capital of the Indio population within their specific culture. If different

[40] Further, a gender bias characterizes some of the sources, such as the Lima Indio count. This is due to the fact that the Indio population of the new Peruvian capital comprised a large share of male working migrants (see Escobar Gamboa, 1968; p. VII).

[41] For caveats discussed in the literature, see also Manzel et al. (2011) and Stolz et al. (2011). In our source, we find direct remarks indicating that even the poorest women were individually asked for their age.

Indio status groups show different age heaping levels, then this would be a hint that the proxy is informative. In the following we assess the differences in education by occupational groups or, in the case of Huanuco, approximated by three social groups and by the tribute paid to the Spanish encomendero.

The Huanuco region lies in the Andean highlands, about 400 kilometers away from Lima. It is thus a very remote region and we assume that the population had had nearly no contact with Spaniards at the time the population count was made. Our Huanuco sample includes three social groups called chupacos, mitimaes and yanaconas. What defines these groups? The first two groups belong to the common rural community, whereas yanaconas were a caste of slaves in service of the privileged classes (Baudin, 2003; p. 390). The rural community lived in small clan groups. A certain amount of land was assigned to each of these clan groups depending on the number of its members. They mainly worked for their subsistence and not for the market, but they gave a part of their agricultural output as a tribute to the royal storehouses.[42] A special group within the rural population was that of the mitimaes, who were forced to move from the imperial centre to other valleys in the Andes for political reasons, especially in order to populate newly conquered regions (Bakewell, 2004; p.15).

Yanaconas were born into slavery as descendants of an ethnic group that had raised great revolts against the colonizing Inca tribe centuries before the Spanish conquest (Espinoza Soriano 1997, p. 287). We could expect this group to be disadvantaged compared to the other social groups.

In order to assess whether we could find differences in numeracy between social groups in Huanuco, we divide our data set into the three categories, chupacos, mitimaes and yanaconas and run a regression with chupacos as reference category. Although the slaves had

[42] A second sort of tribute was paid in form of labour, within the structure of the so-called mita. The mitayos generated income for the state by the cultivation of its land, keeping the cattle, exploiting its mines or fabricating arms and other artisanal objects and buildings or infrastructure. It consisted of a labour service by millions of men between 18 and 50 years old working exclusively for the construction of the state or in service of the elite.

the expected negative sign, our results (Model 1 in Table 4) show no significant effect of the two independent variables representing social groups. This might be explained by the fact that these three groups could have suffered from the same low quality of education.[43] As described above (section 1), the main divide was between the small elite and the rest of the Inca Indio population.

At this enumeration, the visitors took into account the amount and form of the tribute the Indio population paid, which is useful for our purposes. Of the 747 people counted between 23 and 62 years of age, 638 paid some type of tribute to their encomendero.[44] The five different agricultural products in which the tribute was paid were wheat, maize, cotton balls, cotton pieces and poultry. It was not possible to quantify the value of the tributes, but we can assume that the wealthier Indios paid in more diverse items. In order to assess whether the relative wealth could have been a correlate of numeracy, we construct five different tribute categories depending on the amount of items delivered as a tribute, and run a logistic regression, observing marginal fixed effects. In column 2 of Table 4 we build dummy variables for the number of tribute categories: five categories, four categories, and so forth ending with 'no tribute'. Moreover, we control for other variables discussed in section three, such as gender and age structure. Our regression outputs show a positive significant correlation of the four and five tribute category with the numeracy level. There is also a positive significant correlation with paying any various tributes (Column 3).

In a second step we assess whether numeracy differences existed between Indios belonging to distinct social classes. Therefore we divide our complete data set into occupational groups according to the scheme Armstrong suggests for classifying enumerated

[43] Yanaconas lived between the common rural population and could even aspire to social mobility, to a greater extent than the rest (Espinoza Soriano, 1997; p. 287). In our sample we can find a few principales, and they belong to the three of the population groups. Unfortunately, the number of cases of principales in our sample is too small to be included in the analysis of differences in numeracy.

[44] After the Spanish conquest, the people continued paying tributes, but instead of to the Inca state, they paid it to their Spanish landlord, or encomendero. Principales (Indio village chiefs) were still in charge of collecting it.

populations (Armstrong, 1987; p. 214).[45] We first run a logistic regression for the full data set of both Indios and Europeans taking the lowest skill group 0 as a reference category, which refers to the ones with no profession (some of them disabled). Our results in Model 1 of Table 5 show significant positive effects on numeracy for all higher skilled groups, relative to the constant, which refers to having no occupation. In our second model we consider only the Indios included in our data set. Here the reference category is the occupation group of "semi-professionals" and "professionals" together. We opted for pooling both groups, because only four Indios in our data set belong to the professional group, which includes doctors, interpreters, village chiefs, etc. We obtain in Model 2 significant negative effects of the variables "semi-skilled" and "skilled" relative to the most educated group. The "unskilled" also have a negative coefficient. However, it is not significant. This confirms that Indios who are assumed to have benefited from a better education would tend to round their age on multiples of 5 less often than poorly educated Indios, also those born before contact with the Europeans. We therefore conclude that the age heaping methodology is a good proxy for the numeracy of Peruvian Indios that also allows us to establish comparisons with European counterparts.

6. Conclusion

One of the most crucial moments in history was the meeting of Indios of the ancient American cultures and the European invaders of the 15th and 16th centuries. The meeting ended with a military defeat of the Indio cultures. A number of explanations have been given for the failure of the Old American Empires to protect themselves against the small European military groups. However, in the case of the Inca Empire, it remains an astonishing fact how the small Spanish group of soldiers succeeded over the vast Inca army. We have discussed whether education might have been an additional factor along with the obvious ones, such as

[45] Farmers form an extra professional group, because they can belong to a wide range of groups along the social hierarchy depending on if they own the land or not.

the Spanish horses, guns and cannons; the weakening of the native population through diseases introduced by Europeans; their political division at that time and the alliance of some Indian tribes against the Inca regime.

Further, we launched the hypothesis that low educational investments in the pre-colonial Andean region could have influenced later long-term development patterns. We based our argument on the literature about the "colonial legacy" (Acemoglu et al., Engerman and Sokoloff, Coatsworth, Bulmer-Thomas) and argued that also pre-colonial conditions hampered economic growth. Especially, low human capital investment in the Inca Empire might have initiated a path-dependent process of agriculture which was not human-capital intensive in the following centuries.

The human capital of the native Inca society was measured with age heaping methods. The sources employed allow us to gain insight into pre-colonial numeracy levels for the first time and to compare them with European values. We discussed adjustments that were necessary for some types of sources, and some characteristics of the sample, performing a joint logistic regression with these adjustment variables, and a large set of country-half century dummy variables. The results of the adjustment variables were interesting by themselves. For example, age statements which come from the five inquisition sources were characterized by an additional numeracy of 13 percent, even when controlling for urban bias and religion separately. We estimated numeracy for Peruvian Inca Indios for the early 16th century, i.e. mainly before the Spanish conquerors arrived. Crucial for this study is the fact that the Peruvian Inca Indios had only about half the numeracy level of the Spanish invaders. This held true even after adjusting for the downward bias which might have been typical for the remote and isolated area of Huanuco on which our early Peruvian data is based. As for the evolution of human capital in the colonial period, our adjusted figures show that Spanish and Portuguese numeracy remained twice as high as in the Latin American regions of the Inca Empire, though Northwest-Europe had even higher numeracy. Finally, our numeracy

estimates for the indigenous population remain nearly ten points lower than the White Peruvians'.

Our sources and methodology further allowed us to find evidence on inequality in pre-Columbian times. Given the low educational level and the high inequality reigning before the Spanish Conquest in the Andean region, we argue that more attention should be paid the pre-colonial legacies when assessing the genesis of the long-term path of only modest economic growth in the countries of Latin America.

References

Acemoglu, D., Johnson, S. and Robinson, J.A. (2001). The Colonial Origins of Comparative Development: An Empirical Investigation. American Economic Review, 91: 1369–1401.

Acemoglu, D., Johnson, S. and Robinson, J. A. (2002). Reversal of Fortune: Geography and Institutions in the Making of the Modern World Income Distribution. Quarterly Journal of Economics, 117: 1231–1294.

A'Hearn, B., Baten, J. and Crayen, D. (2009). Quantifying Quantitative Literacy: Age Heaping and the History of Human Capital. Journal of Economic History, 68 (3): 783–808.

Bakewell ,P. (1984). Miners of the Red Mountain: Indian Labour in Potosi. The University of New Mexico Press, Albuquerque.

Bakewell, P. (2004). A History of Latin America: c.1450 to the Present. Blackwell Publishers, Malden, USA.

Baten, J., and Mumme, C. (2010). Globalization and educational inequality during the 18th to 20th centuries: Latin America in global comparison. Revista de Historia Económica - Journal of Iberian and Latin American Economic History, 28 (2): 279–305.

Baudin, L. (2003). Daily Life of the Incas. Dover Publications, Mineola, New York.

Becker, S. O. and Woessmann, L. (2010). The Effect of Protestantism on Education before the Industrialization: Evidence from 1816 Prussia. Stirling Economics Discussion Papers, University of Stirling, Division of Economics.

Bulmer-Thomas, V. (2006). The Cambridge Economic History of Latin America. Cambridge University Press, Cambridge, 2 vols.

Boucekkine, R., de la Croix, D., and Peeters, D. (2007). Early literacy achievements, population density, and the transition to modern growth. Journal of the European Economic Association, 5(1): 183–226.

Bray, C. (2002). Torturing History: A military historian abuses the past. Reason Magazine. [Internet: http://reason.com/archives/2002/04/01/torturing-history]

Cieza de León, P. (1609). The discovery and conquest of Peru**:** Chronicles of the New World encounter. Edited and translated by Alexandra Parma Cook and Noble David Cook. Duke University Press, Durham, N.C., 1998.

Coatsworth, J. H. (2008). Inequality, Institutions and Economic Growth in Latin America. Journal of Latin American Studies, 40: 545–569.

Cole, A. (1985). The Potosí Mita, 1573–1700: Compulsory Indian Labor in the Andes. Stanford University Press, California.

Comin, D., Easterly, W., and Gong, E. (2010). Was Wealth of Nations Determined in 1000 BC?. American Economic Journal: Macroeconomics (2): 65–97.

Cook, N. D. (1981). Demographic Collapse, Indian Peru, 1520–1620. Cambridge University Press, New York.

Cook, N. D., introd. (1985). Numeración General de todas las personas de ambos sexos, edades y calidades que se ha hecho en esta ciudad de Lima ano de 1700. COFIDE, Lima.

Cook, N. D., and Lovell, W.G. (1991). Secret Judgment of God: Old World Disease in colonial Spanish America. University of Oklahoma Press, Norman, London.

Crayen, D., and Baten, J. (2010). Global Trends in Numeracy 1820-1949 and its Implications for Long-Run Growth. Explorations in Economic History 47 (1): 82–99.

Crosby, A. W. (1972). The Columbian Exchange: Biological and Cultural Consequences of 1492. Greenwood publishing, Westport, CT.

Dell, M. (2010). The Persistent Effects of Peru's Mining Mita. Forthcoming Econometrica.

Denevan, W. M. (1976). The Native Population of the Americas in 1492. The University of Wisconsin Press, Madison.

Diamond, J. (1997). Guns, Germs and Steel: The fates of human societies. W.W. Norton & Co, New York.

Dobado González, R., and Garcia Montero, H. (2010). Colonial Origins of Inequality in Hispanic America? Some reflections based on new empirical evidence. Revista de Historia Económica - Journal of Iberian and Latin American Economic History, 28 (2): 253–277.

Easterly, W., and Levine, R. (2003). Tropics, Germs, and Crops: How endowments influence economic development. Journal of Monetary Economics, 50 (1): 3–39.

Engerman, S. L., Mariscal, E.V., and Sokoloff, K.L. (1999). The Persistence of Inequality in the Americas: Schooling and Suffrage, 1800–1945. Working Paper, University of California, Los Angeles.

Engerman S. L., and Sokoloff, K. L. (2000). History Lessons: Institutions, Factor Endowments, and Paths of Development in the NewWorld. The Journal of Economic Perspectives, 14 (3): 217-232.

Escobar Gamboa, M., transcr. (1968). Padrón de los Indios de Lima en 1613. Seminario de Historia Rural Andina, Universidad Nacional Mayor de San Marcos, Lima.

Espinoza Soriano, W. (1997). Los Incas, Economía, Sociedad y Estado en la era del Tahuantinsuyo. Amaru Editores, 3rd edition.

Esteban, A. (1997). Literatura Hispanoamericana: Introducción y Antología de textos. Comares, Granada.

Garcilaso de la Vega, Inca (1609). Comentarios Reales de los Incas. Edited by Aurelio Miró Quesada. Biblioteca Ayacucho, Caracas. 2 vols., 1976.

Gupta, B., and Ma, D. (2010). Europe in an Asian mirror: the great divergence. In: Broadberry, Stephen and O'Rourke, Kevin H., (eds.) The Cambridge economic history of modern Europe. The Cambridge Economic History of Modern Europe , 1. Cambridge University Press , Cambridge, UK , pp. 264-285.

Hanson, D. V. (2002). Why the West Has Won: Carnage and Culture from Salamis to Vietnam. Faber and Faber, London.

Henningsen, G. (1980). The Witches' Advocate: Basque Witchcraft and the Spanish Inquisition (1609–1614). University of Nevada Press Reno, Nevada.

Julien, C. (1998). Die Inka. Geschichte, Kultur und Religion. Verlag C. H. Beck, München.

Klein, H. S. (2011). A Concise History of Bolivia. Cambridge University Press, Cambridge.

Lea, H. C. (1998). The Inquisition in 17th –Century Peru: Cases of Portuguese Judaizers. [http://www.fordham.edu/halsall/mod/17c-lea-limainquis.html]

Lisón Tolosana, C. (1979). Brujería, Estructura social y Simbolismo en Galicia. Akal editor, Madrid.

Livi Bacci, M. (2005). Conquest: The destruction of the American Indios. Polity Press, Cambridge.

Lockhart, J. (1968). Spanish Peru: 1532–1569: A Colonial Society. The University of Wisconsin Press, Madison, Milwaukee, London.

Manzel, K., Baten, J. and Stolz, Y. (2010). Convergence and Divergence of Numeracy: The Development of Age Heaping in Latin America, 17th to 20th Centuries. University of Tuebingen Working Paper.

Menninger, K. (1934). Zahlwort und Ziffer: Aus der Kulturgeschichte unserer Zahlsprache, unserer Zahlschrift und des Rechenbretts. Ferdinand Hirt Verlag, Breslau.

McCaa. R., Nimlos, A., and Hampe- Martínez, T. (2004). Why Blame Smallpox? The Death of the Inca Huayna Capac and the Demographic Destruction of Tawantinsuyu (Ancient Peru). Working Paper presented at the American Historical Association Annual Meeting, Washington, D.C.

Moreno de los Arcos, R. (1990). La Inquisición para Indios en la Nueva España (Siglos XVI a XIX). Servicio de Publicaciones de la Universidad de Navarra, 1990, Vol. 2: 1471–1484.

Murra, J. V., ed. (1967). Visita de la Provincia de Leon de Huánuco en 1562. Tomo I. Iñigo Ortiz de Zúñiga. Universidad Nacional Hermilio Valdizan, Huanuco.

Nalle, S. T. (1989). Literacy and Culture in Early Modern Castile. Past and Present, Vol. 125, Nov: 65–96.

Palma, R. (1897). Anales de la Inquisición de Lima. Madrid, 3rd edition.

Parker, G. (2005). The Cambridge History of Warfare. Cambridge University Press, Cambridge.

Parker, G. (2009). The Cambridge Illustrated History of Warfare. Cambridge University Press, Cambridge.

Perez Villanueva, J. and Escandell Bonet, B. (2000). Historia de la Inquisición en España y América,Vol. 3. Biblioteca de autores cristianos, centro de estudios inquisitoriales, Madrid.

Poma de Ayala, G. F. (1615). Nueva Corónica y Buen Gobierno. Edition and preface by Franklin Pease.

Porras Berrenchea, R. (1986). Los Cronistas del Perú (1528–1650) y otros ensayos. Lima

Prado Moura, A. (2003). El Tribunal de la Inquisición en España (1478–1834). Editorial ACTAS, Madrid.

Prados de la Escosura, L. (2000). International Comparisons of Real Product, 1820–1990: An Alternative Data Set. Explorations in Economic History 37**:** 1–41.

Prescott, W. H. (1847). History of the Conquest of Peru. 3rd edition, R. Bentley, London.

Rawlings, H. (2006). The Spanish Inquisition. Blackwell Publishing, Oxford.

Shea, D. E. (1976). A Defense of Small Population Estimates for the Central Andes in 1520. In: Denevan, W. M. The Native Population of the Americas in 1492. The University of Wisconsin Press, Madison.

Steckel R. H., and Rose J. C. (2002). The Backbone of History. Cambridge University Press, Cambridge.

Tandeter, E. (2002). Coacción y mercado: la minería de la plata en el Potosí colonial, 1692-1826. Siglo XXI de España Editores, Madrid.

Wachtel, N. (1977). The Vision of the Vanquished: The Spanish Conquest of Peru through Indian Eyes 1530–1570. The Harvester Press, Sussex

Wedin, A. (1965). El Sistema Secimal en el Imperio Incaico. Insula, Madrid.

Williamson, J. (2009). Five Centuries of Latin American Inequality. NBER Working Paper No. w15305.

Tables and Figures

Table 1: Sources, ABCC Indices and possible biases by sample

Label	Source	ABCC	Selectivity hypothesis?
Huanuco 1562	Murra (1967)	2	Negative (remote region, no contact to Spanish)
Lima 1700	Cook (1985)	45	Positive (large city)
Lima Indios 1613	Escobar Gamboa (1968)	36	Positive (large city, migrants)
Lima Inquisition (1625 – 1761)	Palma (1897)	44	Positive (inquisition, large city)
Badalona 1717	National Archive Catalonia	66	Positive (large city)
Cuenca Inquisition (1521 – 1723)	National Historical Archive, Madrid (Nalle, 1989)	60	Positive (inquisition)
Évora Inquisition (1487 – 1894)	National Archive Torre do Tombo, Lisbon	53	Positive (inquisition)
Llerena Inquisition (1695 – 1730)	Pérez Villanueva and Escandell Bonet (2000)	81	Positive (inquisition)
Logrono Inquisition (1609 – 1633)	Henningsen (1980)	49	Positive (inquisition)

Table 2: Characteristics by sample

Source	Cases	% Jew. accus.	Female	Large city	Migrant	Age 23-32	Source inquis.
Huanuco	746	0.00	0.63	0.00	0.00	0.46	0
Lima 1700	2946	0.00	0.00	1.00	0.00	0.38	0
Lima Indios 1613	749	0.00	0.33	0.11	0.10	0.64	0
Lima inquisition	64	0.05	0.42	0.41	0.23	0.38	1
Badalona	359	0.00	0.00	0.00	0.00	0.30	0
Cuenca inquisition	475	0.00	0.19	0.00	0.00	0.32	1
Évora inquisition	2368	0.88	0.52	0.03	0.02	0.36	1
Llerena inquisition	259	0.48	0.44	0.16	0.33	0.29	1
Logroño inquisition	157	0.00	0.80	0.00	0.00	0.22	1

Table 3: Determinants of numeracy (as percentages)

	(1)	(2)	(3)	(4)
Dependent variable	Numerate	Numerate	Numerate	Numerate
Estimation technique	Logit mfx	Logit mfx	Logit mfx	Linear prob. Model
Data included	All	Except Cuenca	All	All
Source: Inquisition	13.38**	13.88**		11.78**
	(0.02)	(0.02)		(0.03)
Accusation: Judaism	7.71**	8.04**	10.05***	7.04**
	(0.03)	(0.03)	(0.00)	(0.03)
Female	-16.88***	-16.88***	-16.13***	-15.13***
	(0.00)	(0.00)	(0.00)	(0.00)
Large city	12.75***	12.46***	14.25***	12.04***
	(0.01)	(0.01)	(0.00)	(0.01)
Migrant	7.36	9.10	9.24	7.33
	(0.25)	(0.17)	(0.15)	(0.20)
Age 23-32	18.63***	18.25***	18.75***	17.13***
	(0.01)	(0.01)	(0.01)	(0.01)
Mulatto and Black 1650	-19.75	-20.13	-9.49	-18.25
	(0.28)	(0.26)	(0.66)	(0.24)
Chile, Bolivia and Argentina 1550	39.00***	37.50***	37.13***	19.75*
	(0.00)	(0.00)	(0.00)	(0.09)
Ecuador Indios 1550	47.63***	46.50***	45.88***	31.00***
	(0.00)	(0.00)	(0.00)	(0.01)
Spain 1450	35.63***	12.39	44.38***	16.00*
	(0.00)	(0.65)	(0.00)	(0.06)
Spain 1500	40.50***	37.13***	49.13***	21.63***
	(0.00)	(0.00)	(0.00)	(0.00)
Spain 1550	51.00***	51.00***	58.75***	34.25***
	(0.00)	(0.00)	(0.00)	(0.00)
Spain 1600	64.75***	64.38***	67.88***	58.75***
	(0.00)	(0.00)	(0.00)	(0.00)
Spain 1650	62.00***	62.25***	64.50***	50.13***
	(0.00)	(0.00)	(0.00)	(0.00)
Peru 1600	36.50***	35.75***	47.63***	17.63
	(0.00)	(0.01)	(0.00)	(0.13)
Peru 1650	44.50***	43.63***	55.75***	26.50**
	(0.00)	(0.00)	(0.00)	(0.02)
Peru 1700	41.00***	40.75***	51.13***	24.00
	(0.00)	(0.01)	(0.00)	(0.13)
Peru Indios 1550	42.88***	42.88***	42.88***	24.13***
	(0.00)	(0.00)	(0.00)	(0.00)
Peru Indios 1600	15.38	14.50	28.50	2.46
	(0.48)	(0.51)	(0.15)	(0.88)
Peru Indios 1650	30.00*	29.25*	41.63***	11.64
	(0.06)	(0.07)	(0.00)	(0.42)
Portugal 1450	29.00**	28.00**	40.00***	11.28
	(0.02)	(0.03)	(0.00)	(0.30)
Portugal 1500	31.38***	30.38***	42.13***	13.25**
	(0.00)	(0.00)	(0.00)	(0.04)
Portugal 1550	42.63***	41.75***	52.13***	24.50***
	(0.00)	(0.00)	(0.00)	(0.00)
Portugal 1600	49.00***	48.25***	57.63***	32.00***
	(0.00)	(0.00)	(0.00)	(0.00)
Portugal 1650	58.50***	58.00***	64.63***	46.38***
	(0.00)	(0.00)	(0.00)	(0.00)
Portugal 1700	54.50***	54.25***	61.25***	41.00***
	(0.00)	(0.00)	(0.00)	(0.00)
Constant				12.75***
				(0.02)
Observations	8124	7649	8124	8124

Pseudo R-Squared	0.0827	0.0821	0.0822	
Adjusted R-Squared				0.0970

Note: P-Values in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Constant refers to Peruvian Indios born between 1500 and 1549, age 33 to 72, non-migrant, rural, male, other sources, not accused of being Jewish. The year numbers refer to the beginning of a half century of birth (for example "Mulatto and Black 1650" to those born 1650-99). We scaled the coefficients of all independent variables up by 125, for a more convenient interpretation of changes in numeracy (see Appendix C for the details). We also included dummy variables for "Jew partly" and "Large city unknown", which refer to the Cuenca sample only, "migrant unknown" to this one and the Lima 1700 sample. All year statements refer to the beginning of a half century. "Chile, Bolivia and Argentina 1550" refers to migrants to Lima born in those countries. "Ecuador Indios 1550" refers to migrants coming from the area of today's Ecuador, who mainly identified themselves as "Cañari".

Table 4: Logit regression – Social Inequality in Huanuco

Dependent variable	(1) Numerate	(2) Numerate	(3) Numerate
Female	-1.25	-1.40	-1.06
	(0.32)	(0.23)	(0.39)
Five tributes		13.38*	
		(0.09)	
Four tributes		6.01*	
		(0.10)	
Three tributes		4.04	
		(0.19)	
Two tributes		-0.69	
		(0.69)	
One tribute		6.36	
		(0.33)	
Mitimaes (forced migrants)	4.11		
	(0.41)		
Yanaconas (slaves)	-1.04		
	(0.59)		
Any tribute			2.65**
			(0.01)
Observations	746	746	746
Pseudo R2	0.37	0.42	0.38

P-Values in parentheses

*** p<0.01, ** p<0.05, * p<0.1

In Model (1) constant refers to 'chupacos' (common population).

In Models (2) and (3) constant refers to men who do not pay any tribute.

Age group dummies for the youngest group included, which had to cover only age 23 – 27 in this case, because the number of unrounded ages was extremely small.

Table 5: Logit regression – Inequality among social skill groups: full data set and only Indios

	(1)	(2)
Dependent variable	Numerate	Numerate
Population included	All	Only Indios
Reference category	No profession	Semi professionals and professionals
Source: Inquisition	14.63***	
	(0.04)	
Jew	7.26**	
	(0.03)	
Female	-17.13***	-4.05
	(0.02)	(0.03)
Large city	12.05***	8.08
	(0.04)	(0.05)
Migrant	7.00	-42.25***
	(0.05)	(0.02)
Unskilled	15.25**	-7.70
	(0.05)	(0.05)
Semi-skilled and skilled	17.75***	-14.13**
	(0.05)	(0.05)
Semi-professional	18.38***	
	(0.05)	
Professional	26.25***	
	(0.05)	
Farmer	15.75**	-8.3875
	(0.06)	(0.06)
Skill unknown	17.13***	-13.125
	(0.04)	(0.07)
Observations	8124	1558
Pseudo R2	0.08	0.15

P-Values in parentheses

*** p<0.01, ** p<0.05, * p<0.1

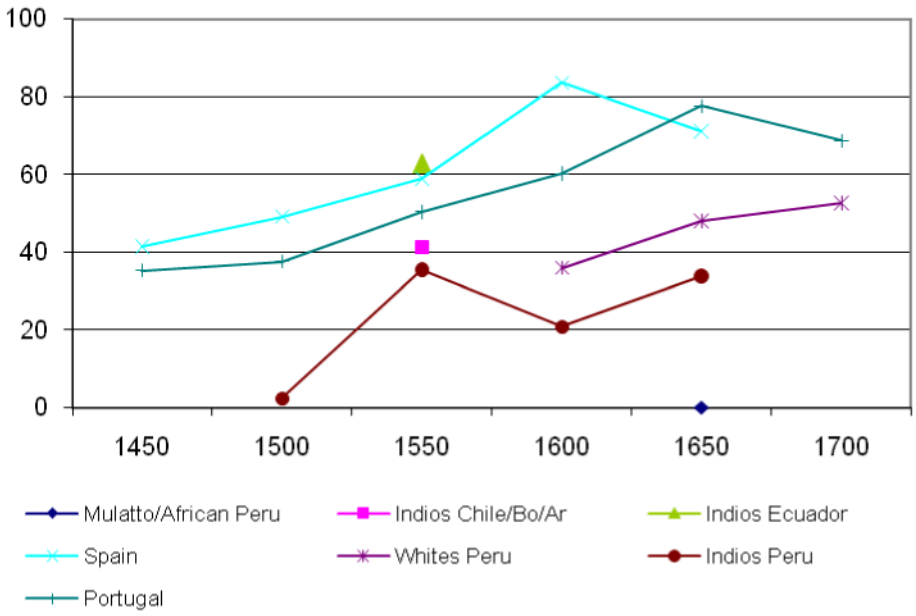
Time and country fixed effects are included in both regressions.

In Model (1) reference category is skill group 0 (no profession).

In Model (2) reference category is skill group 4 and 5 together (semiprofessionals and professionals).

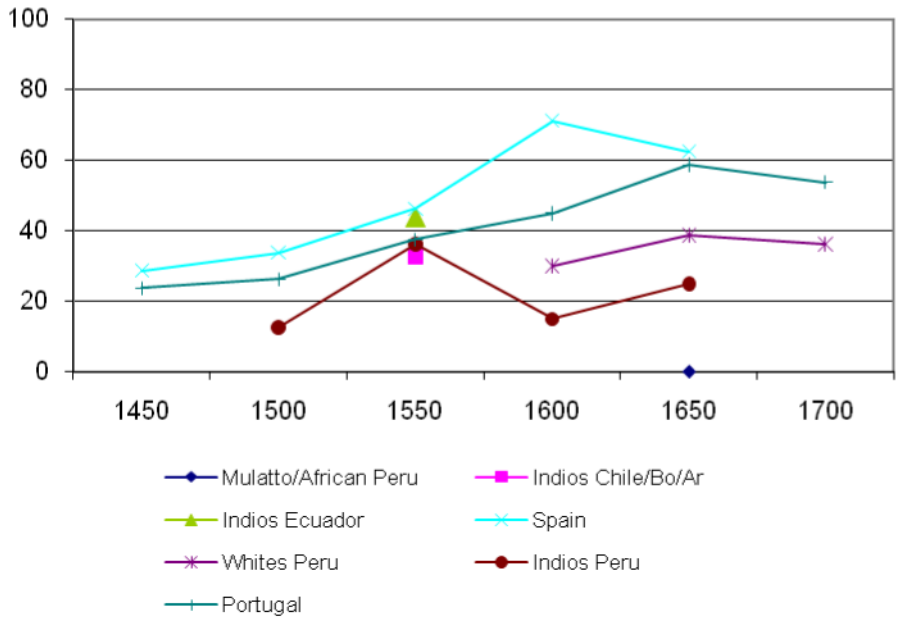
Age group dummies for the youngest group included.

Figure 1: Raw averages of ABCC by half century, country and ethnic group



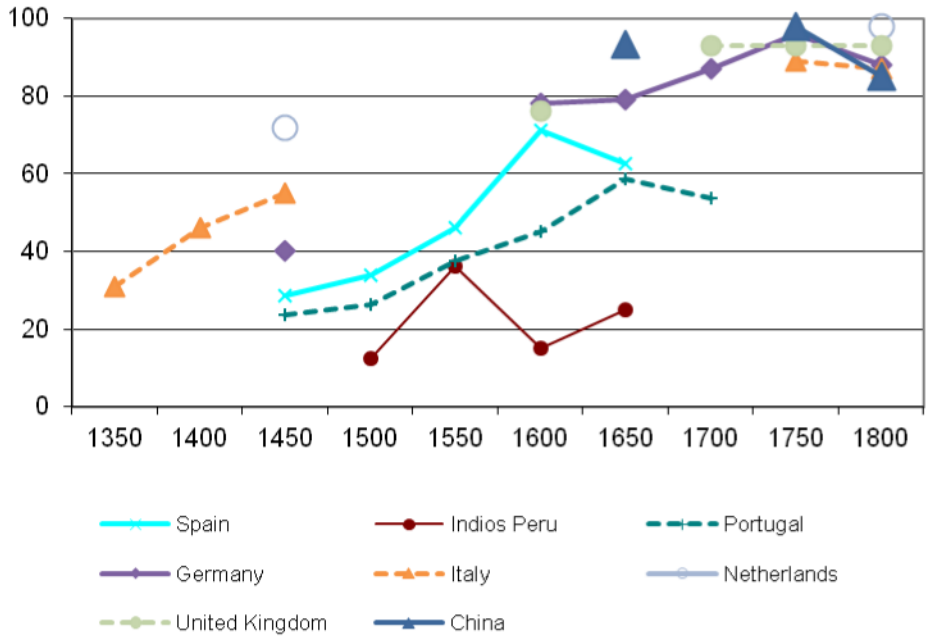
Note: The year on the horizontal axis represents the first year of a half century of birth.

Figure 2: Adjusted estimates of ABCC by half century, country and ethnic group



Note: The year on the horizontal axis represents the first year of a half century of birth.

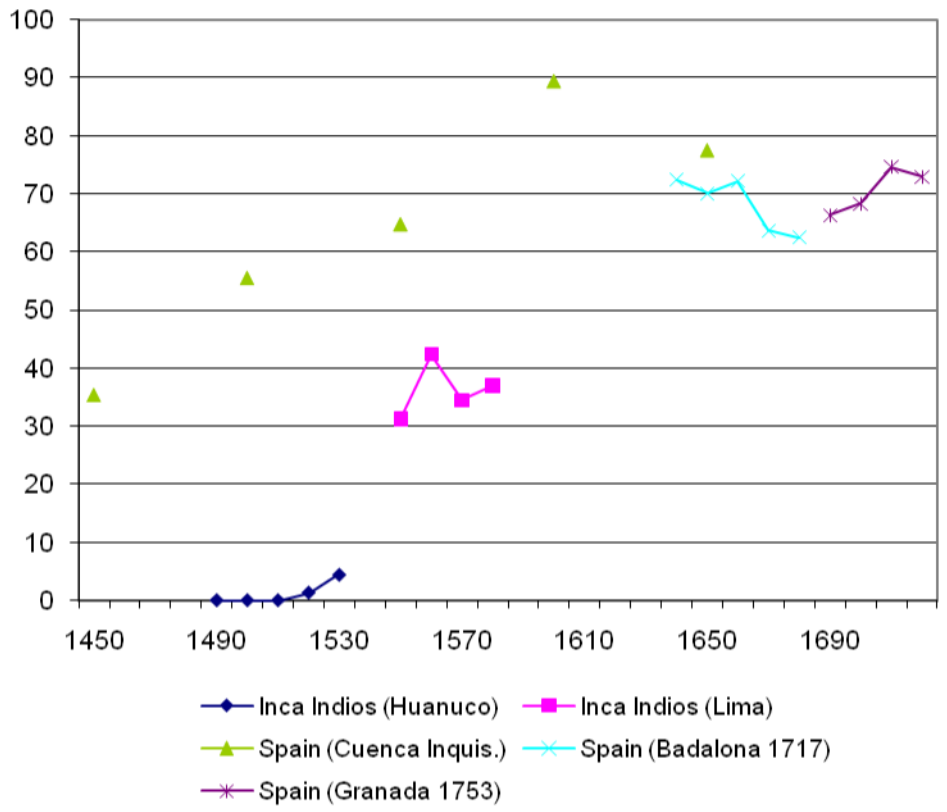
Figure 3: Peruvian ABCC in comparison with other European countries and China



Notes: In general, the years on the axis represent the first year of a half century of birth. China 1650 refers to 1660-1700, China 1750 refers to 150-1759 and China 1800 refers to 1820. Italy refers to Northern Italy before 1750, Germany to Swabia in 1450. The large unfilled circles represent the Netherlands.

Source: A'Hearn et al. (2009)

Appendix A: Figure A.1



Numeracy Trends among "Inca" Indios and various Spanish samples. For each birth decade we obtain plausible ABCC values.

Not for publication: Appendix B: Methodology and basic concepts of age heaping (Internet Appendix)

We study numerical abilities in this article, which are an important component of overall human capital. In order to provide estimates of very basic components of numeracy, we will apply the age heaping methodology.[46] The idea is that in less developed countries of the past, only a certain share of the population was able to report the own age exactly when census-takers, army recruitment officers, or prison officials asked for it. The remaining population reported a rounded age, for example, 40, when they were in fact 39 or 41. In today's world of obligatory schooling, passports, universities, birth documents, and bureaucracy, it is hard to imagine that people did not know their exact age. But in early and less organized societies this was clearly different. The typical result is an age distribution with spikes at ages ending in a five or a zero and an underrepresentation of other ages, which does not reflect the true age distribution. There was also some heaping on multiples of two, which was quite widespread among children and teenagers and to a lesser extent among young adults in their twenties. This shows that most individuals actually knew their age as teenagers, but only in well-educated societies were they able to remember or calculate their exact age again later in life.[47] To give an example of rounding on multiples of five, the census of Mexico City 1790 reports 410 people aged 40, but only 42 aged 41. This was clearly caused by age heaping. Apolant (1975, p. 333) gives individual examples of age misreporting: Joseph Milan, who appeared in February 1747 as a witness in an Uruguayan court, should have been 48 years old, according to one judicial record. However, in the same year, but in another judicial record, he declares his age to be "45 years". Demographers see this age misreporting as a problem when calculating life expectancies and other population statistics. But exactly this misreporting enables us to approximate numerical abilities of historical populations. The ratio between the

[46] For more detailed surveys on the age heaping methodology see A'Hearn, Baten and Crayen (2009).
[47] At higher ages, this heaping pattern is mostly negligible, but interestingly somewhat stronger among populations who are numerate enough not to round on multiples of five.

preferred ages and the others can be calculated by using several indices, one of them being the Whipple index.[48] To calculate the Whipple index of age heaping, the number of persons reporting a rounded age ending with 0 or 5 is divided by the total number of people, and this is subsequently multiplied by 500. Thus, the index measures the proportion of people who state an age ending in a five or zero, assuming that each terminal digit should appear with the same frequency in the "true" age distribution.[49]

$$(1)\ \mathrm{Wh} = \left(\frac{(\mathrm{Age}25 + \mathrm{Age}30 + \mathrm{Age}35 + \ldots + \mathrm{Age}60)}{1/5 * (\mathrm{Age}23 + \mathrm{Age}24 + \mathrm{Age}25 + \ldots + \mathrm{Age}62)} \right) \times 100$$

For an easier interpretation, A'Hearn, Baten, and Crayen (2009) suggested another index, which we call the ABCC index.[50] It is a simple linear transformation of the Whipple index and yields an estimate of the share of individuals who correctly report their age:

$$(2)\ \mathrm{ABCC} = \left(1 - \frac{(\mathrm{Wh} - 100)}{400} \right) \times 100 \text{ if } \mathrm{Wh} \geq 100 \text{; else } \mathrm{ABCC} = 100 .$$

The share of persons able to report an exact age turns out to be highly correlated with other measures of human capital, like literacy and schooling, both across countries, individuals, and over time (Bachi 1951, Myers 1954, Mokyr 1983, A'Hearn, Baten, and Crayen 2009). A'Hearn, Baten, and Crayen (2009) found that the relationship between illiteracy and age heaping for less developed countries (LDCs) after 1950 is very close. They calculated age heaping and illiteracy for not less than 270,000 individuals who were organized by 416 regions, ranging from Latin America to Oceania.[51] The correlation

[48] A'Hearn, Baten and Crayen (2009) found that this index is the only one that fulfils the desired properties of scale independence (a linear response to the degree of heaping), and that it ranks samples with different degrees of heaping reliably.

[49] A value of 500 means an age distribution with ages ending only on multiples of five, whereas 100 indicates no heaping patterns on multiples of five, that is exactly 20 percent of the population reported an age ending in a multiple of five.

[50] The name results from the initials of the authors' last names plus Greg Clark's, who suggested this in a comment on their paper. Whipple indexes below 100 are normally caused by random variation of birth rates in the 20th century rich countries. They are not carrying important information, hence normally set to 100 in the ABCC index.

[51] See A'Hearn, Baten and Crayen (2009), Appendix available from the authors.

coefficient with illiteracy was as high as 0.7. The correlation with the PISA results for numerical skills was even as high as 0.85, hence the Whipple index is more strongly correlated with numerical skills. They also used a large U.S. census sample to perform a very detailed analysis of this relationship. They subdivided by race, gender, high and low educational status, and other criteria. In each case, they obtained a statistically significant relationship. Remarkable is also the fact that the coefficients are relatively stable between samples, i.e., a unit change in age heaping is associated with similar changes in literacy across the various tests. The results are not only valid for the U.S.: In any country with substantial age heaping that has been studied so far, the correlation was both statistically and economically significant.

In order to assess the robustness of those U.S. census results and the similar conclusions drawn from late 20th century LDCs, A'Hearn, Baten, and Crayen (2009) also assessed age heaping and literacy in 16 different European countries between the Middle Ages and the early 19th century. Again, they found a positive correlation between age heaping and literacy, although the relationship was somewhat weaker than for the 19th or 20th century data. It is likely that the unavoidable measurement error when using early modern data caused the lower statistical significance.

Age heaping has also been compared to other human capital indicators, for example, primary schooling rates. The widest geographical sample studied so far was created by Crayen and Baten (2010), who were able to include 70 countries for which both age heaping and schooling data (as well as other explanatory variables) were available. They found in a series of cross-sections between the 1880s and 1940s that primary schooling and age heaping were closely correlated, with R-squares between 0.55 and 0.76 (including other control variables; see below). Again, the coefficients were relatively stable over time. This large sample also allowed the examination of various other potential determinants of age heaping. To assess whether the degree of bureaucracy, birth registration, and government interaction with

citizens are likely to influence the knowledge of one's exact age, independently of personal education, the authors used the number of censuses performed for each individual country for the period under study as an explanatory variable for their age heaping measure. Except for countries with a very long history of census-taking, all variations of this variable turned out insignificant, which would suggest that an independent bureaucracy effect was rather weak. In other words, it is sometimes the case that societies with a high number of censuses had high age awareness. But, at the same time, these societies were also early in introducing schooling and this variable clearly had more explanatory power in a joint regression than the independent bureaucracy effect. Crayen and Baten also tested whether the general standard of living had an influence on age heaping tendencies (using height as well as GDP per capita to serve as a proxy for welfare) and found a varying influence: in some decades, there was a statistically significant correlation, but in others there was none. Cultural determinants of age heaping were also observable, but their strongest influence was visible in East Asia, not in the Latin American countries under study in this article.

In this article, we employ the ABCC measure of age heaping, computing indexes for different countries and birth decades. In order to do so, we use the age groups 23-32, 33-42, etc.[52] we omitted the age range from 63 to 72, as this age group offers too few observations, especially for the 17th and 18th centuries, when mortality was relatively high.[53]

An advantage of the age heaping methodology is that age statements are more widely available than other human capital proxies like signature ability or school attendance. As Reis (2008) argues, the age heaping measure is a very basic measure of human capital. Therefore, it is especially valid to study human capital development in Latin America in the 17th and 18th

[52] An advantage of this method is to spread the preferred ages, such as 25 or 30, more evenly within the age groups and it adjusts also for the fact that more people will be alive at age 50 than at age 54 or at age 55 than at age 59 (Crayen and Baten 2009).

[53] Given that young adults aged 23 to 32 round partly on multiples of two rather than five, we use the adjustment method suggested by Crayen and Baten (2009) to increase the Whipple value (minus 100) by 24 percent, before calculating the ABCC measure.

centuries when more advanced human capital indicators were quite scarce and reflected only the skills of the elite.

Appendix C. Notes on numeracy estimations

Assume that $\frac{1}{m}$ of the population are numerate and that age is uniformly distributed.
$1-\frac{1}{m}=\frac{m-1}{m}$ is not numerate and will state a multiple of five as their age anyway.
$\frac{1}{5}\cdot\frac{1}{m}$ of the population will correctly and non-accidently report a multiple of five.
In total, $\frac{1}{5m}+\frac{m-1}{m}=\frac{1-5m-5}{5m}=\frac{5m-4}{5m}=1-\frac{4}{5m}$ will claim to be a multiple of five years old.
Conversely, $1-\left(1-\frac{4}{5m}\right)=\frac{4}{5m}$ will answer with an age that is not a multiple of five.
The fraction of the population assumed to be numerate is recovered by multiplication with $\frac{5}{4}$, since $\frac{4}{5m}\cdot\frac{5}{4}=\frac{1}{m}$.

<u>References (Appendix)</u>

A'Hearn, B., Baten, J. and Crayen, D. (2009). Quantifying Quantitative Literacy: Age Heaping and the History of Human Capital. Journal of Economic History, 68 (3): 783-808.

Apolant, J. A. (1975). Génesis de la familia uruguaya. 4 vols, Montevideo.

Bachi, R. (1951). The tendency to round off age returns: measurement and correction. Bulletin of the International Statistical Institute 33, 195-221.

Clark, G. (2007). A Farewell to Alms: A Brief Economic History of the World. Princeton University Press.

Mokyr, J. (1983). Why Ireland Starved. George Allen & Unwin, London. Chap. 8.

Myers, R. (1954). Accuracy of age reporting in the 1950 United States census. Journal of the American Statistical Association XLIX, 826-831.