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IMPOVERISHED, BUT NUMERATE? EARLY NUMERACY IN EAST ASIA (1550–1800) AND ITS IMPACT ON 20TH AND 21ST CENTURY ECONOMIC GROWTH

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ABSTRACT

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JEL Classification: I21, N30, N35, O15 and O40
Keywords: china, development, growth, human-capital, japan, korea and numeracy

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Impoverished, but Numerate? Early Numeracy in East Asia (1550–1800) and its Impact on 20th and 21st Century Economic Growth

This paper first draws on a unique data set, *hojok* (household registers), to estimate numeracy levels in Korea from the period 1550–1630. We add evidence from Japan and China from the early modern period until 1800 to obtain a human capital estimate for East Asia. We find that numeracy was high by global standards, even considering the potential sources of upward bias inherent in the data. Therefore, the unusually high level of numeracy in East Asia in the early 21st century was already present in the early modern period. However, East Asia had low national income levels during the 19th and early 20th centuries. We assess this phenomenon in the last section and find that "Impoverished Numerates", i.e., countries that were poor despite high early numerical human capital formation, had substantially higher growth rates during the late 20th and early 21st centuries.

Keywords: Human-Capital, Development, Growth, Numeracy, Korea, China, Japan

JEL: O15, O40, I21, N35, N30

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I. Introduction

This paper first employs Korean household registers (*hojok*) to measure numeracy levels during the period 1606–1717.[1] Additionally, we compare Japanese and Chinese numeracy figures to obtain general estimates of early East Asian numeracy. We find

[1] No prior attempt has been made to measure numeracy in Korea during such an early period.

that numerical human capital was quite high in East Asia in the early modern period (1550–1800). Why did this not result in early economic growth in East Asia? After all, the relationship between human capital and growth in GDP per capita is well established in modern growth regressions (Hanushek and Woessmann 2012). This impact of human capital on income growth has also been confirmed for historical periods. For example, in a study on the second half of the 18th century, Baten and van Zanden (2008) found that higher human capital (measured by books per capita) caused higher GDP growth over the following period (Figure 1).[2] Countries with low levels of human capital formation were unable to participate in the industrialization process that transformed the global economy, whereas countries with better starting positions managed to catch up with Great Britain or even overtake it.

It is important for our study on East Asia that China is clearly an outlier in this type of growth regression for the 18th and 19th centuries. China had already accumulated a substantial stock of human capital, but it did not manage to grow in the

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[2] Baten and van Zanden (2008) examined whether human capital—proxied by an indicator of advanced human capital, 'book production'—can account for economic growth in the 19th century. Their data set included a number of European and non-European countries. Relatively reliable GDP estimates were available for the period 1820–1913 (Figure 1). Using regression analyses, Baten and van Zanden also examined whether a higher rate of book production in the 18th century implied more rapid GDP growth in the 19th century. To address this question, they controlled for the initial level of GDP per capita, which was available for 15 countries, and tested the book variable against this initial level effect (their Table 4). Book production was positive and significant.

period from 1820 to 1913. However, China has grown substantially since 1978. Japan already started its impressive catch-up growth around the mid-20th century, and South Korea followed shortly thereafter. It appears that Japan was able to transform human capital into growth relatively early, whereas the process occurred later in China. We discuss below the institutional and cultural factors that prevented these East Asian countries from participating early in the club of rapidly growing countries, despite their high numerical human capital. Our findings imply that in East Asia, the foundations for human capital-based rapid catch-up growth were laid very early. More broadly, we argue that Korea, Japan, and China returned to the growth path at different points of the 20th century and that this return was possible because of their early numeracy development.

In the following Section, we first explain the age-heaping methodology. In Section II, we discuss the new evidence on Korea, and Section III discusses the results. Section IV presents new evidence on Japan and compares it with existing studies on China and Europe. We then compare our results with the literature on East Asian education and human capital. In section V, we discuss the institutional and cultural-rhetoric factors that might have allowed Western Europe to convert its numerical human capital earlier into GDP growth and those that hindered East Asia (Section VI). In Section VII, we develop and test a model of "Impoverished Numerates", and we present our conclusions in Section VIII.[3]

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[3] "Impoverished Numerates" alludes to "impoverished sophisticates" in the title by Sandberg (1979).

II. Age-heaping

How should we obtain insights on numerical abilities of Koreans living during the period 1550–1800? The so-called age-heaping strategy serves this purpose.[4] This approach employs a set of methods that developed around the phenomenon of "age-heaping," i.e., the tendency of poorly educated people to erroneously round their ages. For example, less educated people are more likely to state their age as "30" if they are actually 29 or 31 years old compared with people who have a greater human capital endowment (Mokyr 2006).[5] The most widely used numerical index to measure this is the Whipple index:

$$(1)\quad Wh = \left(\frac{(Age25 + Age30 + Age35 + ... + Age60)}{1/5 * (Age23 + Age24 + Age25 + ... + Age62)} \right) \times 100$$

A'Hearn et al. (2009) suggested an index called the ABCC index.[6] It is a simple linear transformation of the Whipple index that is easier to interpret and yields an estimate of the share of individuals who report their ages correctly:[7]

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[4] Mokyr (2006) pioneered their use, and Duncan-Jones (1990) applied them to study ancient economies.

[5] Among demographers, this specific type of age misreporting constitutes "one of the most frustrating problems" (Ewbank 1981, 88). It is treated as a source of distortion in age-specific vital rates that needs to be removed, or at least minimized, to study family or household variables.

[6] The name results from the initials of the authors' last names plus that of Gregory Clark, who suggested the name in a comment on their paper.

[7] We will exclude those ages below 23 and above 72, as a number of possible distortions affect those specific age groups, leading to age reporting behavior different

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

A'Hearn et al. (2009) found that the relationship between illiteracy and age-heaping for Less Developed Countries after 1950 is very close. The correlation coefficient with illiteracy was as high as 0.7. The correlation with the PISA results for numerical skills was as high as 0.85; hence, the age-heaping measures are strongly correlated with numerical skills.

III. Data on Korea

Measuring Korean numeracy for the early period of 1550–1800 requires age statements in sufficient numbers. The data for this paper were collected through a system of household registers implemented for the purposes of taxation and corvee labor service, called *hojok* (Table 1). The system attempted to collect data from all individuals, including slaves. The registration was supposed to be conducted every three years, but only fragments of *hojok* remain. Individual-level data for the county of Dansung were digitized by the Daedong Institute for Korean Studies. Dansung was a rural county, and literati sharing the same family names resided alongside ordinary people. The digitized data irregularly cover the years from 1606 to 1888, but we decided to use only the first two years for reasons that are explained below.

However, some caveats regarding the data source are in order. One issue is whether household heads reported ages with or without asking the other household members. The procedure for collecting the census information was that local officials distributed the form to each household. The household completed the form, and the

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from that of the intermediate adult group.

local officials then collected the completed form. Given the absolute authority that the head of household commanded in Korea during this period, it is likely that the head of household completed the forms. However, we do not know whether the head of household asked for the ages of other household members before reporting such numbers on the form. If the other household members were not asked, in most cases, this could imply an upward bias because the head of household likely had higher basic numeracy. Calculating the ABCC index for household heads alone, instead of doing so for all household members, we obtain values that are 4–5 percentage points higher for the former (Table 2). Therefore, the estimate for the whole population of approximately 89–90 percent should be considered as a lower bound, whereas the 94 percent estimate for the heads of household likely reflects an upper bound. We considered only including the heads of household in our statistics because those persons were most likely to correctly report their own ages. However, because our main argument in the present study is that East Asian basic numeracy was high in the early modern period, we include the "lower bound" estimate of the whole population in the following figures because it represents a "conservative" value that does not risk providing inappropriate support for our argument.

This is also a promising strategy because there are other potential sources of upward bias. For example, some individuals avoided being registered to avoid taxation and corvee labor service despite heavy punishments and monitoring systems. Some hid in the mountains, and others remained transient. If such individuals were less numerate than registered individuals, numeracy would be over-estimated.

Unfortunately, the Korean system of registering individuals every three years might have allowed the possibility for government officials to countercheck age statements. The officials did not have access to independent information, but they could have compared the ages given in 1609 and 1612 to those given in 1606. If an individual stated his age as "I am 30" in 1606, then the officials would not have accepted the answer "I am 35" in 1612. However, they might have written some not rounded number (e.g., 36) which was not directly reported by the individual. Hence, the number reported would not be a rounded number, even if that is what the individual reported. The ABCC index cannot identify such calculated age information because "age 36" simply looks as if the individuals could determine his age with a yearly resolution. Therefore, the best strategy is to focus exclusively on the first year following a massive Japanese invasion during the late 16th century, which destroyed a number of *hojok* registers. Therefore, instead of using data from the whole period ranging from 1606 to 1888, this paper focuses only on 1606 for the regular Korean population. Although Korean household registers were more or less continuously maintained long before 1606, the Japanese invasion had very adverse effects on Dansung, and many official documents, including the *hojok* registers, were destroyed (Kim 2001). Thus, it is likely that the process of household registration was re-started from scratch after 1606. This suggests that more realistic age-heaping values can be obtained after the break in the registration system. In contrast to 1606, authorities were subsequently able to verify responses with age statements from previous years, which could result in an upward bias in the numeracy values for the later years. The Korean example of 1606 is in line with other historical evidence on realistic numeracy values after a "break" in age reporting for various political and economic reasons, e.g., in Japan (Hayami 2001).

We also employed a second data set that allows us to estimate the numeracy of monks. In 1675, King Sook Jong approved the registration of monks in the *hojok* registers. Because the reason for this decision is relevant for numeracy, we provide some historical background. A series of adverse events threw 17th-century Korea into complete disarray. The negative consequences of the Japanese invasion still lingered, and the Manchu invaded Korea in 1627 and 1636. Small and large rebellions were not uncommon across the country, and one of the largest rebellions was that led by Lee Kwal in 1624. To make matters worse, natural disasters, famines, and diseases abounded. All of these adverse events can be understood as part of the general crisis of the 17th century (Parker and Smith 1997). A large number of people died, hid in the mountains, or became vagabonds. The registration system failed to keep pace with the changes. As a result, each individual who had been properly registered suffered more from corvee labor service. One way to circumvent this aggravating situation was to register and recruit monks for the service. This idea was appealing because monks had already experienced corvee labor service on a few occasions (albeit unsystematically). In addition, a growing number of people simply became monks to avoid permanent corvee labor service. Registering them would allow the government to identify, control, and exploit monks more systematically. Hyu Yun proposed the idea of registering monks in the *hojok*, and King Sook Jong approved of the plan on May 9, 1675.

The registration of monks was one aspect of the overhaul of the *hojok* system. In 1675, King Sook Jong issued a law (o-*ga-tong-sa-mok*) according to which five (*o*) households (*ga*) were grouped into a higher level of an administrative unit called a *tong*. The law was an attempt to strengthen the system by correcting inaccurate entries and rebuilding the *hojok* registers that were lost during the Manchu and Japanese invasions. Our data concern the year 1678, which was the first registration year after the law was passed. Hence, the data may include the first registration of monks in Dansung.

Admittedly, monks were most likely an upwardly biased sample of the Korean population in terms of education. However, the data set on monks is useful for our research because it provides numeracy values from the beginning of the registration process and is therefore unlikely to be biased due to authorities being able to countercheck age statements. Moreover, because many ordinary people became monks to avoid corvee labor service, the potential upward bias of this group might not be large.

Because age-heaping reflects a very basic skill that is obtained during the first decade of life, we organize all evidence by birth decades. Using the 1606 *hojok*, we can document the birth decades for the regular Korean population who were born from the 1550s to the 1570s, and we can document the same information approximately for the birth decade of the 1630s for Korean monks (Figure 2). The numeracy values for these observations seem to be quite constant over time and have values of approximately 80 to 90 percent, which is relatively high by historical standards.

IV. Comparison of Human Capital Development in Korea, Japan, China, and Europe

A comparison of the results to those of similar studies conducted for Japan and China sheds further light on human capital development in East Asia. Japanese age statements are reported in Table 3, which is taken from Hayami (2001). The data were collected in population registers in the province of Bungo in 1622. Assuming that the median age group in Japan of those 21 and older at that time was the group aged between 30 and 40, the data are centered on those born in the 1590s. This makes the data suitable to compare Japanese human capital formation to the newly estimated numeracy levels for the Korean population in 1550–1570. The reported age statements indicate clear age-heaping on 0 (21.4%) and 5 (13.8%). In addition to heaping on numbers ending in 0 or 5, Table 3 also displays heaping on numbers ending in 8. The reason for this additional heaping is that 8 was considered to be a number associated with luck and fertility. In other Asian societies, the number 8 also stood for prosperity and good fortune (Hayami 2001). Conversely, the digit 4 was avoided because this number sounds similar to the Japanese words for death and suffering; thus, reported ages ending in 4 are relatively rare (Hayami 2001).

A graphical comparison of human capital development in Korea, Japan, and China is displayed in Figure 3. Although the age reports for the Korean population and the monks came from different centuries, the numeracy values indicate similar human capital levels. The Japanese numeracy levels are approximately 10 percentage points lower than the Korean levels.

For China, Baten et al. (2010) used the censorial section of the board of punishment, in which information on age statements can be found for all Chinese administrative regions. Only a small portion of these documents, especially those from the Qianlong period (1735–95), have been published (Historical Archive No. 1, 1981). The ages that we used from these memorials are self-reported by persons in court (i.e., they were still alive at the time).

Baten et al. (2010) analyzed whether these sources can be used in age-heaping studies. For example, they asked whether animal cycles for birth years in China might have caused age-heaping in a form other than stating ages ending in 0 or 5. To measure this impact, they used data on age-heaping for the most popular animal sign, the year of the dragon. They studied the age reporting behavior of Chinese migrants to the US, with the result that a preference for dragon years was visible but much less important than age-heaping on multiples of 5. The same result was obtained for the Chinese preference for 8 and their desire to avoid 4. Using data from the board of punishment for the late 17th and early 18th centuries, it can be observed that the degree of age-heaping was relatively low.

If we compare East Asia with trends in three European regions, we arrive at the conclusion that Korea, Japan, and China were similar to the most advanced European regions in northwestern Europe (Figure 3). In Europe, the centuries between the late 15th and early 19th centuries represent a human capital revolution. European numeracy rates grew from approximately 50% to approximately 95%. This is a true revolution because the nearly 50 percentage point magnitude of change is comparable to the difference between the poorest and the wealthiest economies of the early 20th century (Crayen and Baten 2010b: South Asia had a numeracy rate of 52% in the 1940s, whereas the richest countries had reached full numeracy). Therefore, Europe transitioned from a half-numerate to a mostly numerate continent during this revolution. The differences between the European regions are also interesting: southern Europe was the most advanced region in the late Middle Ages and the early Renaissance, but the well-known ascendancy of northwestern Europe is also visible in the numeracy record. In the 16th and 17th centuries, Korea and Japan had already covered half the distance of this human revolution, even if we consider the potential biases mentioned above. China was even more developed during the late 17th and 18th centuries.

V. Is this High Early Human Capital Level in East Asia Plausible?

Ronald P. Dore's (1965) landmark study offered a remarkably optimistic reassessment of Japanese education in the Tokugawa period (1603–1868). The school enrollment data for 1868 led him to estimate a literacy rate of 43% for males and 19% for females, a remarkably high level by nineteenth-century standards (Hayami and Kitô 2004). Another piece of evidence is provided by studies assessing the existence of a dynamic book publishing industry and book rental market. These studies also conclude that business and private households were familiar with earlier forms of accounting and bookkeeping and the use of farm manuals (Hayami and Kitô 2004; Smith 1988). Rawski (1979) extended these findings to the case of China, although she emphasized that her results were based on fragmentary and circumstantial evidence. She observed a literacy rate of approximately 30–45% for males and approximately 2–10% for females (Rawski 1979). Rawski also reported that educational and schooling opportunities improved during the Ming (1368–1644) and Qing (1644–1911) periods. Due to an increased demand for commerce, local administration, and agricultural production, there was an educational spillover to the broader society, which implied that not only did the elites have access to education but other groups of society could also obtain basic skills (Rawski 1979; Li 2004). Rawski argued that Chinese demand for education and literacy should be greater than, or at least similar to, that of Japan in the Tokugawa period. She based her argument on the fact that Chinese society, in which education was an important condition for upward social mobility, was relatively open compared with the more status-oriented Japanese society.

Rawski (1985) and Li (2004) also addressed the issue of a growing and prosperous publishing industry in China, with book publication ranging from encyclopedias or histories to romance novels or Buddhist sutras. In addition, cities and towns "had an abundance of posted regulations, shops signs, advertisements, and other material to read for profit and amusement" (Naquin and Rawski 1987, 58–59). In addition to other factors, the relatively low cost of paper and woodblock printing helped fulfill the demand from the large reading public, which no longer solely consisted of the literate elite but also included non-elites, such as merchants (Rawski 1985; Li 2001). Furthermore, Li (2004) accounted for the spread of arithmetic textbooks and abacuses and the spread of numerals for bookkeeping and accounting during the Ming and Qing periods, which provided direct evidence of numeracy in this period. More evidence of numeracy can be found in other studies on China and Korea that demonstrated the use of traditional accounting techniques by analyzing the surviving account books (Guo 1982, 1988; Gardella 1992 for China; Jun and Lewis 2006 for Korea). Ronan and Needham (1978) argued that the importance of a lunar calendar, numerology, and number-mysticism in daily life numerically influenced Chinese thinking (Ronan 1978).

If we consider contemporary human capital levels, Chinese students perform very well on international standardized tests and are consistently ranked near the top of all students worldwide. This fact holds even when compared with OECD countries that have higher per capita incomes than China (Hanushek and Woessmann 2008). Baten and Juif (2014) found that early numeracy rates from approximately 1820 were highly correlated with contemporary cognitive skills, especially in the areas of math and science (Figure 4). Moreover, Korean (“kr” in Figure 2) and Japanese (“jp”) math and science test results were among the highest ranked in the figure.

The original cause of the high numeracy levels in East Asia, however, has yet to be thoroughly and quantitatively studied. One factor could clearly be the traditional institutional design of China’s labor market for the selection of high-ranking officials. Civil service examinations were used to identify the applicants who were most suited for the highest posts in government bureaucracy, and this custom created incentives to invest heavily into education. Some of these educational incentives were adopted in Korea and Japan. Second, the very high level of Chinese development during the Middle Ages created cultural customs that conserved high numeracy and education, even after incomes were declining in comparison to those in Europe during the 19th century. For example, the wide-spread use of calendars and astrological calculations was a custom that contributed to basic numerical skills. Third, the East Asian bureaucracies developed great interest in numerical facts because rice planting was highly dependent on accurate decisions being made about the amount of water and fertilizer used. This interest in numerical facts also led to questioning East Asian farmers in greater detail than elsewhere. Hence, institutions were developed to control and discipline the society of an agrarian empire, but a side-effect of these institutional features was an increase in basic numerical skills in early modern East Asia, and these skills were sustained in a relatively exogenous way during the low-income period of the 19th and early 20th centuries.

We conclude from this review section on East Asian educational history that general human capital—and numeracy in particular—was remarkably developed in this world region and that our numeracy estimates are thus not implausible.

VI. The Context of the Late Growth of China, Japan, and Korea: Institutional and Rhetorical Hurdles

Various models of economic growth emphasize the importance of human capital in economic growth (for a review, see Aghion and Howitt, 2009). However, high levels of human capital in a country do not automatically cause economic growth unless the capital is productively employed. Acemoglu, Johnson, and Robinson (2005) provided a conceptual framework to understand the historically unprecedented economic growth of Western Europe between 1500 and 1800, the "First Great Divergence" (for different interpretations, see Li and van Zanden 2012, Allen 2012). Acemoglu et al. argued that when the power of royal principals had already been constrained to some extent, as in Britain and the Netherlands, Atlantic traders and other merchants were able to demand and establish institutions that protected property rights and were conducive for early economic growth. Hence, according to those authors, Atlantic trade facilitated the First Great Divergence both directly by providing opportunities to trade via the Atlantic and the associated profits from colonialism and slavery and, more importantly, indirectly through "good", growth-promoting institutions. In contrast, when the power of the crown was less constrained, as in Spain, Portugal, and France, Atlantic trade instead benefited the royal principals and their allies, further weakening the protection of property rights. They argued that alternative sources of the First Great Divergence such as religion, war-making, Roman heritage, and geography were less plausible.

From a different perspective, McCloskey (2010) offered another explanation, namely that the main source of early growth was based on “talk”. Specifically, in seventeenth- and eighteenth-century Europe, talk about private property, commerce, and the bourgeoisie was radically altered; the bourgeoisie was both appreciated and allowed to pursue commercial activities. Moreover, she argued that securing property rights was not the primary source of the Industrial Revolution because the institutions of property rights were established in China long before European industrialization. The primary source of European growth was enthusiastic and encouraged rhetoric about markets and free enterprise. If there is a positive interaction between foreign trade and favorable rhetoric—not medieval political institutions, as Acemoglu et al. (2005) argued—it is possible to explain why China, Japan, and Korea grew later than Europe did and at different times from one another.

In contrast to models of economic growth, sustained economic growth did not occur in East Asia to the same extent that it did in Western Europe and the European settlement colonies in North America and Australia until the late 20th century. When the arguments of Acemoglu et al. (2005) and McCloskey (2010) are synthesized as mentioned above, the reason could be traced to self-imposed isolation and Confucianism-inspired prejudices against the bourgeoisie. Extending back to the period after Zheng He’s naval expedition (1405–1433) ended, which was the largest up to that time, foreign trade was discounted as a minor issue in China. This situation largely remained the same until the economic liberalization policies and economic opening of the country towards international trade were implemented in 1978. At the same time, the government and Chinese society redistributed social prestige in favor of entrepreneurs and tradesmen, allowing McCloskey’s rhetoric to prosper. Of course, this does not mean that pre-modern China was isolated and self-sufficient. Deng

(1997) presented evidence, limited though it may be, that the scale and scope of China's staple trade with other countries was substantial. However, he acknowledged that "whatever the effect of the foreign staple trade on China's economy, one thing is clear: in the Chinese case, the trade, despite its in-built economic incentives and rewards, was not the sufficient condition to generate modern growth (p. 283)."

Similarly, Japan also persisted in isolation policies, called *sakoku*, and opened only one port in Nagasaki for foreign trade until Commodore Perry forcefully opened Japan with the Convention of Kanagawa in 1854. Even Kazui (1982), who argued that foreign trade during the Edo period was not as restricted as previously thought, could count only four trading partners: China, Korea, the Ryukyus, and the Dutch East India Company. Also influenced by Confucianism, the bourgeoisie occupied the lowest position in society, below samurais, peasants, and artisans.

The situation was similar in pre-modern Korea. Private foreign trade was prohibited, as it was in China, and official foreign trade was confined mainly to China (Lee and Temin 2010). These isolation policies remained until Japan forcefully opened Korea with the Convention of Kanghwado in 1876. However, unlike Japan, Korea failed to take advantage of foreign trade. It was formally colonized by Japan in 1910. Foreign trade in Korea substantially grew only after Chung-hee Park promoted exports as one of the main driving forces of economic growth in the 1960s. At the same time, the social standing of merchants and entrepreneurs was improving; very quickly, McCloskey's market enthusiasm prevailed. Moreover, when attention is paid to the timing of foreign trade opening, the related institutional development, and the appreciation of bourgeois virtues, it is possible to understand why sustained (and rapid) economic growth occurred in Japan first, followed by Korea and then China.

The two sources appeared in that order along with economic growth. We would not claim that these two sources of growth entirely explain the late economic growth of the three countries, despite their high levels of numerical human capital. However, they plausibly explain why Western Europe and the Western offshoots were able to convert their numerical human capital into the sustained economic growth quite early, much earlier than East Asia.

VII. Impact: Towards a model of Impoverished Numerates?

In this final section, we consider whether Early East Asian numeracy had long-term effects on growth performance today. The East Asian countries had, during the late 19th and early 20th centuries, a relatively low income, whereas we found above that they had relatively high numeracy. This is reminiscent of the situation in the Scandinavian countries, which had been termed “Impoverished Sophisticates” (Sandberg 1979). Hence, were the East Asians likewise “Impoverished Numerates”? For a definition of this concept, we examine the residual between early numeracy and early income for a large cross-section of countries. Baten and Juif (2014) recently found that the correlation between early numeracy and today’s growth-relevant human capital was remarkably close. We compare this early numeracy level with the earliest date for which a substantial number of country-specific income estimates are available, which is 1913. A substantial time lag between the explanatory variable numeracy and the dependent variable income is quite sensible here to avoid contemporaneous correlation and to reduce potential endogeneity, even if relative human capital levels were quite persistent in most countries. However, Baten and Juif (2014) also noted several exceptions during the 19th century, in which countries changed their ranking according to their human capital level. The function of this regression is not to document the correlation between early numeracy and later income but to identify the outlying cases: which countries were relatively impoverished despite a relatively high numeracy level? Among those countries, which were outliers with a numeracy level comparable to that of the “Rich West”?

We identify “Impoverished Numerates” as those cases that deviate to the lower right. The outliers are reported in Table 4. The largest negative residuals were for China and South Korea, for which the "Maddison Project database” estimates in 1913 were 550 and 820. At the same time, China and South Korea had numeracy levels of 86 and 91, respectively, around 1820. Hence, the residual is particularly large. Next follows Brazil, which was also poorer than expected. We find Japan in fourth place and Hong Kong in seventh, which were both already substantially richer than China and South Korea in the year 1910. In the case of Hong Kong, its high placement is partly due to its nature as a harbor city with trading functions.

Among the top 10 “Impoverished Numerates”, we can distinguish countries that were more or equally numerate compared with the rich West and those that were less numerate. As a threshold, we take the value of U.S. numeracy in 1820 (85%). Brazil, India, and Tunisia were below this level, whereas the other seven “Impoverished Numerates” had reached or surpassed the U.S. level in 1820. We create dummy variables for the two groups, and we use them in our regressions to assess the subsequent growth experiences of these countries during the 20th century: (1) the top 10 “Impoverished Numerates” and (2) a subgroup of (1) with higher numeracy than the U.S. We use the U.S. because its numeracy was relatively close to the average numeracy of Europe and the European offshoots (Baten and Juif 2014).

Apart from the East Asia countries, Portugal, Bulgaria, and Finland fall in this second category of seven countries. We can only speculate why these three countries are in the group. Portugal had been a great maritime empire, and the population in its harbor cities had developed substantial human capital; however, during the 19th century, Portugal had a disappointing growth record (after losing most of its maritime empire). Finland and Bulgaria were constrained in GDP growth by the problematic economic policies of the Russian and Ottoman Empires, respectively, and by war. Clearly, further research is needed to study these cases more intensively.

We perform a regression in which the GDP growth rate between two later years is the dependent variable: one regression is for the growth success between 1960 and 1980, and the other is that between 1980 and 2010. We are curious whether being among the top 7 "Impoverished Numerates" was associated with higher economic growth in a later period (Table 5, Columns 7 to 8 for the second definition). In fact, this group of countries was growing much stronger in the late 20th century than were the countries that did not fall in this group. To assess the robustness of our results, we also included a number of standard control variables that are often included in growth regressions, such as tropical share (to proxy for disease effects), ethnic fractionalization (which Mauro (1995) showed to be related to corruption), and the quality of political institutions. As a robustness test, we also use the growth rates during the entire 20th century (1913–2010, Columns 5 and 6). Finally, we assess this for the second of the two concepts mentioned above (Columns 7 and 8).

We conclude from this section that the high level of early numeracy relative to income in 1913 did lead to elevated GDP growth rates during the late 20th and early 21st centuries.

VIII. Conclusion

This paper employs a unique data set to estimate the numeracy levels in Korea in the late 16th and 17th centuries, using age-heaping as a proxy. We find that Koreans during this period exhibited age-heaping, but the extent of inaccurate age reporting was relatively small.

We compare these numeracy levels to those in other countries in East Asia, namely Japan and China, and find that all three countries were relatively numerate by global standards. In addition, East Asians achieved their high levels of numeracy very early. Discussing the most likely reasons for this, we described (1) the labor market institutions that selected the upper class of civil servants, (2) the factor of inheritance of Medieval East Asian superiority, and (3) the necessity of collecting exact numerical dates in empires that were built on rice agriculture.

Although one of the primary reason that these human-capital-creating institutions were developed in East Asia was most likely the motivation to control and discipline the subjects of an agrarian empire, the establishment of these institutional features created—as a side effect—a large stock of human capital in early modern China and East Asia. Due to this human capital stock and the required institutional and rhetorical-cultural changes, it might have been easier for East Asia to rapidly catch up in terms of economic growth during the 20th century.

We develop and test a new idea that “Impoverished Numerates”, i.e., countries that were poor despite high early numerical human capital formation, had substantially higher growth rates during later periods, here, the late 20th and early 21st centuries. Apart from the East Asia countries, Portugal, Bulgaria, and Finland also fall into this category. Identifying these "Impoverished Numerates" in the global record can contribute to our understanding of modern growth experiences using a long-term perspective. **References**

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Table 1: Numbers of cases of age statements used in this study

Country	Source	Reporting year	Birth decades	N
Korea	*Hojok*, Daegong, population (except monks)	1606	1550s-1570s	1133
Korea	List of Monks	1678	around the 1630s	70
Japan	Population register, Bungo Province	1622	around the 1590s	551
China	Board of punishment	1735–95	1660s-1700s	163
			1710s-1740s	383
			1750s-1770s	56

Table 2: ABCC value of various groups in Korea

Subsample	ABCC Index	N of Obs.
All Household Members (birth decade 1550s)	90.1	387
All Household Members (birth decade 1560s)	89.3	445
All Household Members (birth decade 1570s)	89.7	301
Household heads	94.1	174
Monks	94.6	70

Note: Following the literature, we first calculated ABCC values by age group (23-32, 33-42, etc.) and then determined birth decades by selecting those in which the majority of individuals were born. We also performed an adjustment for the 23-32 age group, as suggested by Crayen and Baten (2010b).

Table 3: Japanese population distribution by the last digit of a person's age

Last Digit of Age	Total 21 or older (Number Persons)	Ratio of Population (in %)
0	118	21.4
1	67	12.2
2	45	8.2
3	61	11.1
4	18	3.3
5	76	13.8
6	37	6.7
7	20	3.6
8	82	14.9
9	27	4.9

Source: Hayami(2001, p. 25) (based on the population register, Hayami gun, Bungo Province, 1622.)

Table 4: Who were the Impoverishes Numerates in 1913? Selected countries of large negative residual

co	Residual	Impov. Num.	Imp.Num. & Num.	ABCC 1820	GDP/c 1913
China	-1.41	1	1	86	550
Korea	-1.11	1	1	91	820
Brazil	-0.83	1	0	72	811
Japan	-0.73	1	1	100	1350
India	-0.60	1	0	47	700
Portugal	-0.58	1	1	85	1250
Hong Kong	-0.56	1	1	85	1300
Bulgaria	-0.46	1	1	89	1500
Finland	-0.34	1	1	100	2000
Tunisia	-0.31	1	0	44	900
Peru	-0.29	0	0	51	1000
Romania	-0.29	0	0	86	1700
Thailand	-0.25	0	0	37	850
Colombia	-0.24	0	0	60	1200
Indonesia	-0.21	0	0	37	850
Hungary	-0.15	0	0	89	2050
Poland	-0.14	0	0	77	1700
Norway	-0.13	0	0	98	2400
Morocco	-0.12	0	0	17	700
Spain	-0.11	0	0	85	2000

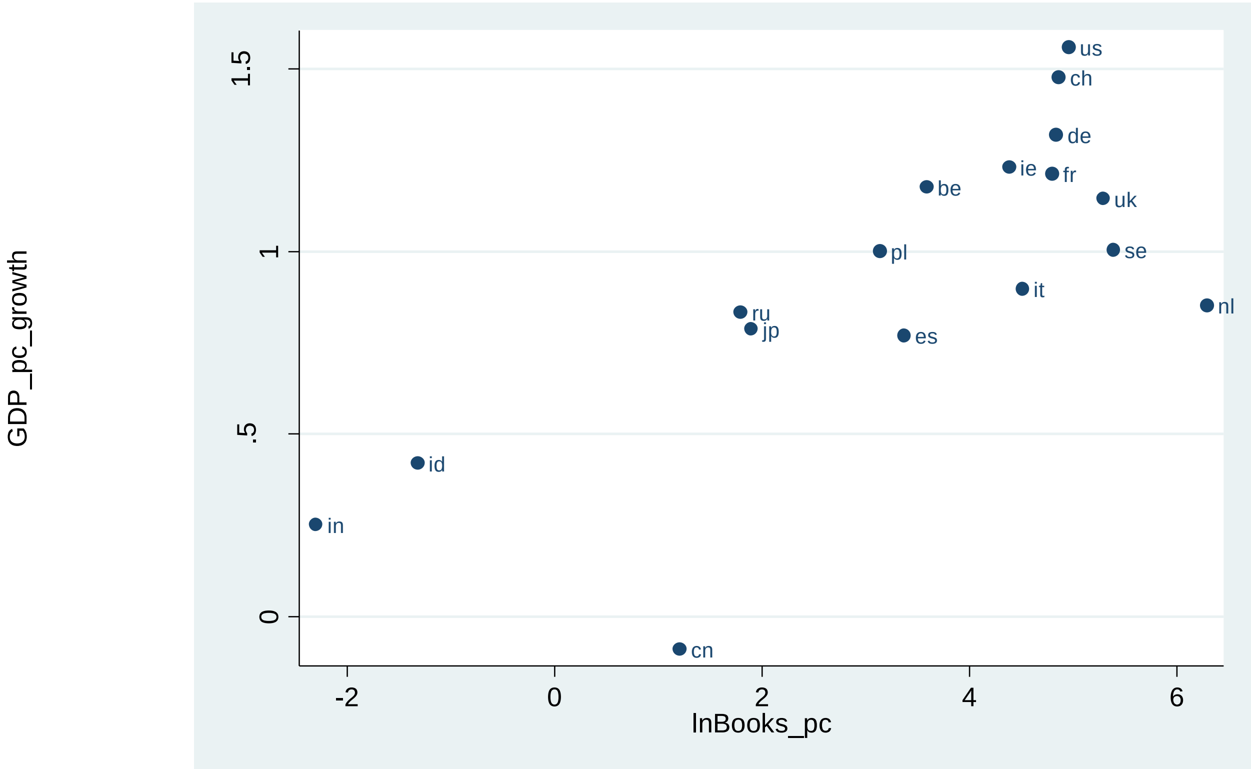
Source: The table shows the countries with largest negative residual from a regression of GDP (1913) on numeracy (1820). The top 10 in this ranking are denoted with a 1 in column 3. Column 4 identifies the 7 cases which were impoverished numerates and had higher numeracy than the U.S.

Table 5. GDP growth regressions: were the Impoverished Numerates (around 1820/1910) growing faster during the 20th century?

Period	1960-80	1960-80	1960-2010	1960-2010	1913-2010	1913-2010	1913-2010	1913-2010
Impov. Numerate	0.93***	0.39*	1.70***	0.72*	1.48***	0.68	2.00***	1.20***
	(0.000)	(0.065)	(0.000)	(0.052)	(0.001)	(0.112)	(0.000)	(0.009)
Initial GDP (log)	0.03	-0.27**	-0.18	-0.67***	-0.15	-0.97***	-0.20	-0.90***
	(0.761)	(0.013)	(0.258)	(0.000)	(0.440)	(0.000)	(0.229)	(0.001)
Share of tropics		-0.24		-0.13		-0.75		-0.59
		(0.210)		(0.787)		(0.157)		(0.274)
Ethnic fractionaliz.		-1.46***		-2.86***		-1.25**		-1.07**
		(0.000)		(0.000)		(0.021)		(0.024)
Institutions		0.03**		0.05***		0.07***		0.07***
		(0.021)		(0.006)		(0.000)		(0.000)
Constant	0.47	3.56***	2.95**	8.17***	4.77***	11.30***	5.21***	10.68***
	(0.513)	(0.000)	(0.021)	(0.000)	(0.002)	(0.000)	(0.000)	(0.000)
Observations	146	122	103	88	64	57	64	57
R-squared	0.08	0.36	0.14	0.42	0.23	0.42	0.30	0.46

*Notes: Robust p-value in parentheses: *** p<0.01, ** p<0.05, * p<0.1. In column 1-6, all top ten "Impoverished numerates" were identified with the indicator variable. In column 7 and 8, only the seven cases which had a higher numeracy than the U.S. were included.* Sources: ‘Tropic share’ refers to the share of a country's population living in a tropical zone (1995). Source: Center for international development, Geography datasets (download at http://www.cid.harvard.edu/ciddata/geographydata.htm, General Measures of Geography). *Institutional quality (Polity II) Gurr, T. R. (1990). Polity II: Political Structures and Regime Change, 1800–1986. Boulder, CO: Center for Comparative Politics. [http://www.icpsr.umich.edu/icpsrweb/ICPSR/studies/9263]; Ethnic fractionalization Alesina, A., Devleeschauwer, A., Easterly, W., Kurlat, S., and Wacziarg, R. (2003). Fractionalization. Journal of Economic Growth, 8(2): 155–194.*

Figure 1: Book production per capita between 1750 and 1800 and GDP per capita growth 1820-1913 (books on log scale).



Source: Baten and van Zanden (2012)

Figure 2: New evidence on numeracy in Korea and Japan

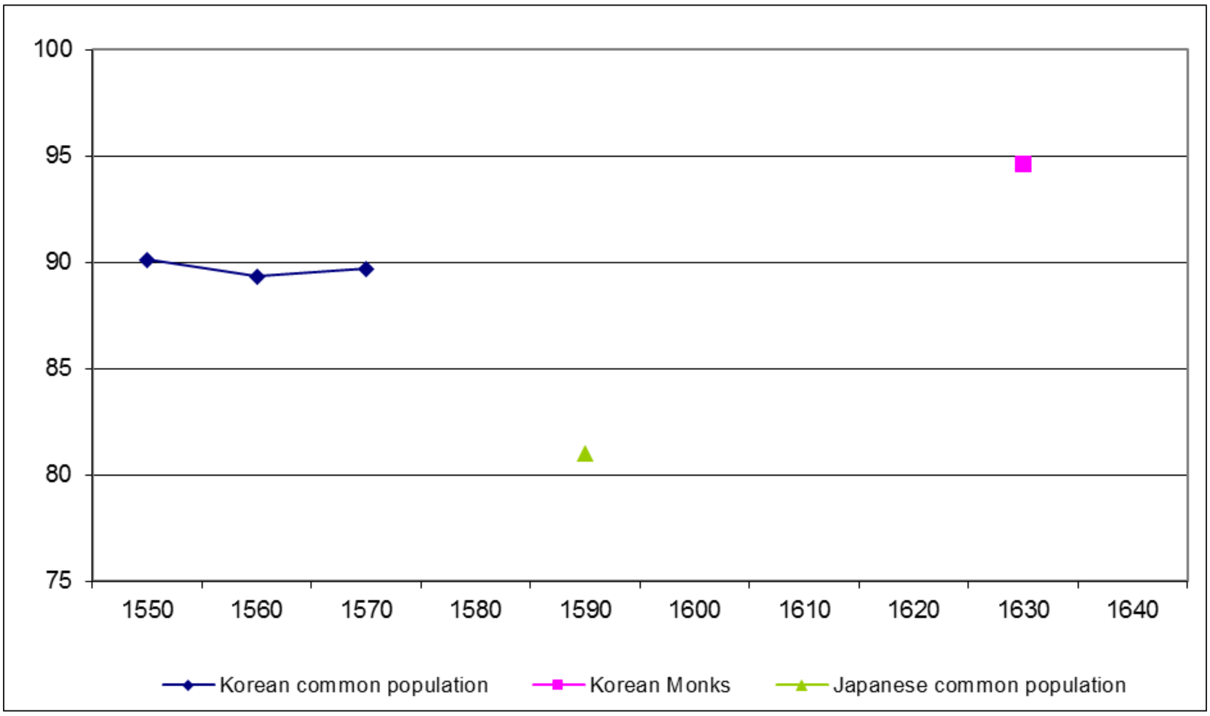
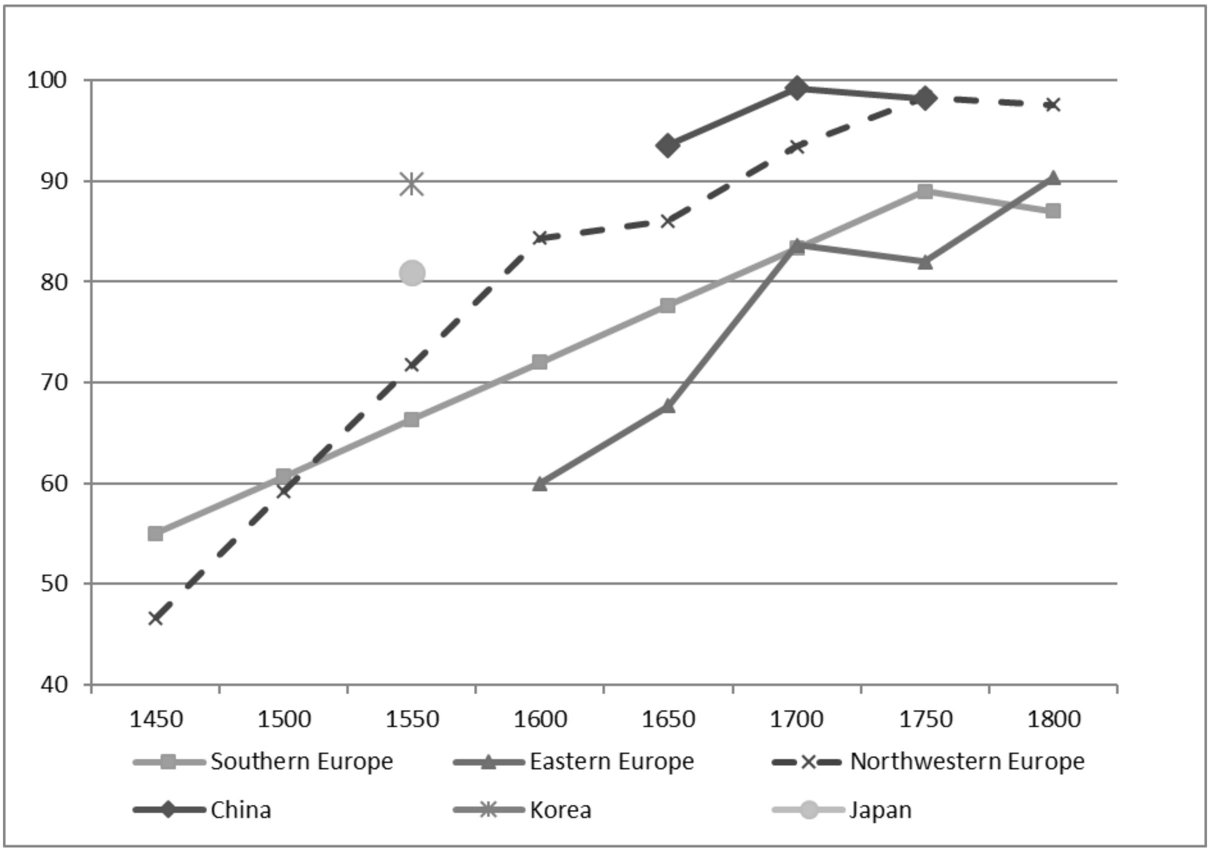
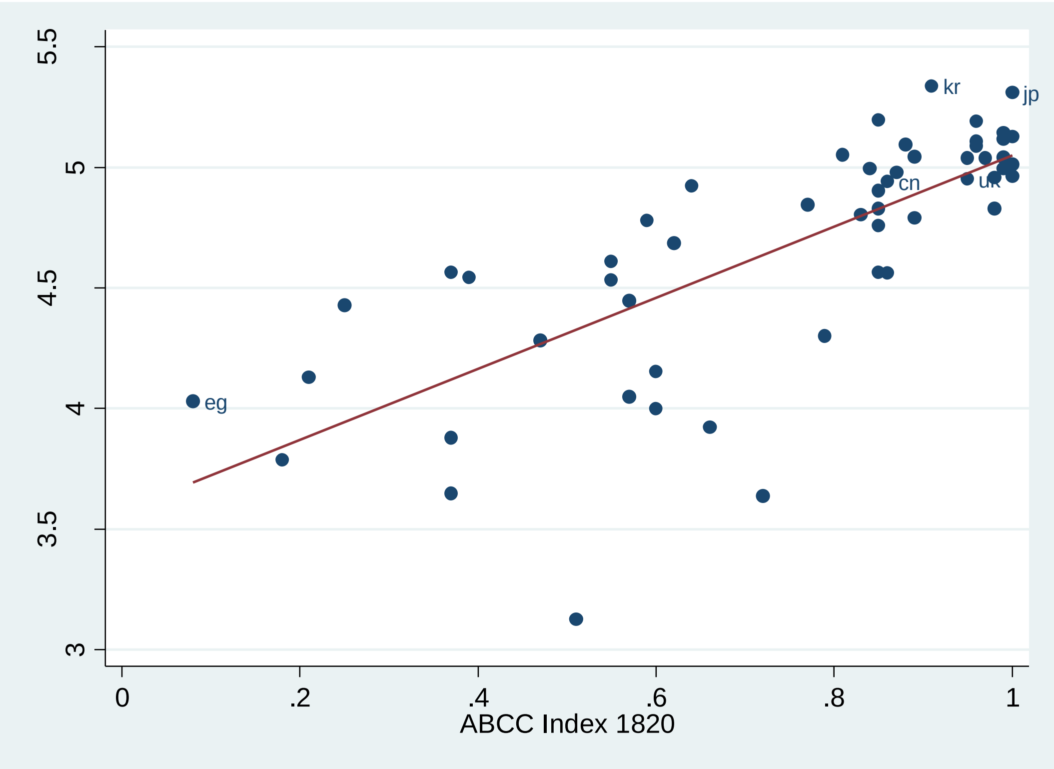


Figure 3: East Asian and European numeracy comparison



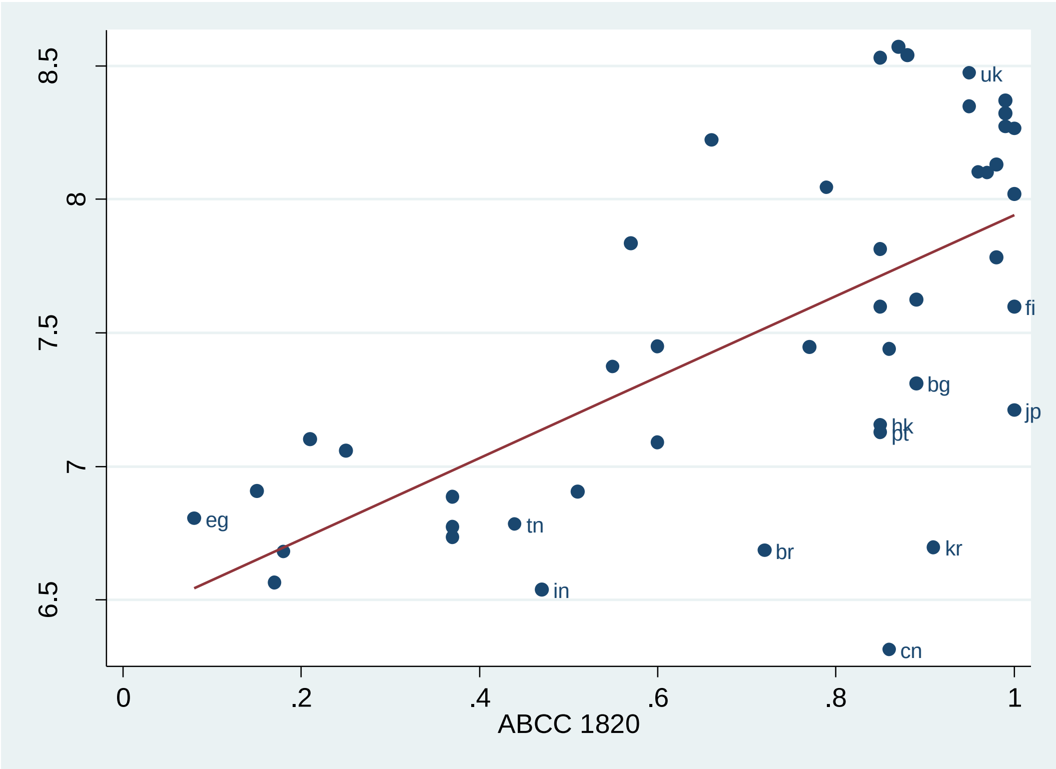
Notes: Values refer to half centuries of birth around the years noted. The evidence is based on A'Hearn, Baten and Crayen (2009), Table 4. We included all the countries for which longer series or at least early values were available: "Northwestern Europe" is the UK, the Netherlands and Protestant Germany, and "Southern Europe" is northern Italy. "Eastern Europe" is the average of Russia, Bohemia and Austria (from approximately 1600). "Average" is the average of those three regions. When values between the benchmark dates were missing, they were interpolated. Weak estimates (in italics in Table 4 of A'Hearn et al.) were omitted. For the UK and the Netherlands before 1600, the benchmark year is 1600 in the UK, and the changes are calculated based on Protestant Germany.

Figure 4: Numeracy (ABCC) in 1820 and math- and science-oriented skills during the late 20th century.



Source: Baten and Juif (2014)

Figure 5: GDP/c in 1913 and numeracy in 1820: identifying "Imoverished Numerates"



Source: Calculated with data from Growth and Development Centre (2013), Baten and Juif (2014)

Appendix A (Internet-appendix, not to be included in the print version): Age-heaping

The use of age-heaping measurements in the context of modern economic history has recently experienced spectacular growth.[8] Age-heaping measurements have been employed to understand numeracy in France and the US from the 17th to the 19th centuries and in China from the 18th to the 20th centuries (Crayen and Baten 2010a; Baten et al. 2010). Beyond individual countries, scholarly interest has extended to Latin America, Europe, and even worldwide (A'Hearn, Baten, and Crayen 2009; Crayen and Baten 2010b; Manzel, Baten, and Stolz 2012).

Measuring the 'human capital' production factor has never been simple, as advanced forms of skill are difficult to compare. Therefore, economists have resorted to the use of proxy indicators, such as years of schooling or, in long-run studies, the share of individuals signing a marriage register. We will explain the advantages and caveats in somewhat greater detail, as the application of this method in economic history is still relatively new.

This approach employs a set of methods that developed around the phenomenon of "age-heaping," i.e., the tendency of poorly educated people to erroneously round their ages. For example, less educated people are more likely than people with a greater human capital endowment to state their age as "30," even if they are in fact 29 or 31 years old (Mokyr 2006).[9] The ratio between the preferred ages and the others can be calculated using several indices, one of which is the Whipple index.[10] Thus, the index measures the proportion of individuals reporting an age ending in a five or zero, assuming that each terminal digit should appear with the same frequency in the "true" age distribution.[11]

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[8] Mokyr (2006) pioneered their use, and Duncan-Jones (1990) applied them to study ancient economies.

[9] Among demographers, this specific type of age misreporting constitutes "one of the most frustrating problems" (Ewbank 1981, 88). It is treated as a source of distortion in age-specific vital rates that needs to be removed, or at least minimized, to study family or household variables.

[10] 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 reliably ranks samples with different degrees of heaping.

[11] A value of 500 means an age distribution with ages only ending in multiples of five, whereas 100 indicates no heaping patterns on multiples of five, that is, exactly 20

$$(1)\quad Wh = \left(\frac{(Age25 + Age30 + Age35 + ... + Age60)}{1/5 * (Age23 + Age24 + Age25 + ... + Age62)} \right) \times 100$$

For an easier interpretation, A'Hearn et al. (2009) suggested another index called the ABCC index.[12] It is a simple linear transformation of the Whipple index and yields an estimate of the share of individuals who report their ages correctly:

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

A'Hearn et al. (2009) found that the relationship between illiteracy and age-heaping for Less Developed Countries after 1950 is very close. They calculated age heaping and illiteracy for no fewer than 270,000 individuals who were organized into 416 regions, ranging from Latin America to Oceania. The correlation coefficient with illiteracy was as high as 0.7. The correlation with the PISA results for numerical skills was as high as 0.85; hence, the age-heaping measures are more strongly correlated with numerical skills.

A'Hearn et al. (2009) used a large U.S. census sample to perform a detailed analysis of the relationship between age-heaping and illiteracy. They subdivided the sample by race, gender, high and low educational status, and other criteria. In each case, they obtained a statistically significant relationship. It is also remarkable that the coefficients are relatively stable across samples, i.e., a unit change in age-heaping is associated with similar changes in literacy across the various tests. Those results are not only valid for the U.S.; there was substantial age-heaping in all countries that have been explored thus far, and the correlation was found to be both statistically and economically significant.[13]

To assess the robustness of these results from the U.S. census and the similar conclusions that could be drawn from the less developed countries of the late 20th century, as mentioned in the introduction to this study, A'Hearn et al. (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 illiteracy, 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 produced the reduced statistical significance (Baten and Szołtysek 2012).[14]

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percent of the population reported an age ending in a multiple of five.

[12] The name results from the initials of the authors' last names plus that of Gregory Clark, who suggested this in a comment on their paper.

[13] On Argentina's regions, see, for example, Manzel et al. (forthcoming).

[14] The experience of historical demographers shows that data from premodern periods were often very rough, imprecise, or fragmentary. Even 18th-century statistical materials still contain a host of uncertainties and traps, as they were

The broadest geographical sample studied thus far was created by Crayen and Baten (2010b), who were able to include 70 countries for which both age-heaping and schooling data (and other explanatory variables) were available. In a series of cross-sections between the 1880s and 1940s, they found that primary schooling and age-heaping were closely correlated, with R-squared values between 0.55 and 0.76 (including other control variables, see below). Again, the coefficients were shown to be relatively stable over time. This large sample also allowed for 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, independent of personal education, Crayen and Baten used the number of censuses performed for each individual country up to the period of study as an explanatory variable for their age-heaping measure. Except for countries with a very long history of census taking, all of the variations in this variable were statistically insignificant, which would suggest that an independent bureaucracy effect was rather weak. In other words, it is likely the case that societies with a high number of censuses and an early introduction of birth registers had a high degree of age awareness. Those societies also introduced schooling early, and this variable clearly exhibited greater explanatory power than the independent bureaucracy effect. Crayen and Baten also tested whether the general standard of living influenced age-heaping tendencies (using height and GDP per capita as welfare indicators) and found a varying influence: in some decades, there was a statistically significant correlation, while in others, there was none.

In conclusion, the correlation between age-heaping and other human capital indicators is well established, and the 'bureaucratic' factor does not invalidate this relationship. A caveat relates to other forms of heaping (apart from the heaping on multiples of five), such as heaping on multiples of two, which is quite widespread among children and teenagers and to a lesser extent among young adults in their twenties (Baten and Szołtysek 2012). This demonstrates that most individuals knew their ages as teenagers, but only in well-educated societies are they able to remember or calculate their exact age later in life. At higher ages, this heaping pattern was mostly negligible, but it was, interestingly, somewhat stronger among populations who were numerate enough not to round to multiples of five. We will exclude those below age 23 and above 72, as a number of possible distortions affect those specific age groups, leading to age reporting behavior different from that of the intermediate adult group. Many young males and females married in their early twenties or late teens, when they also had to register as voters, military conscripts, etc. On such occasions, they were, in some instances, subject to minimum age requirements, a condition that gave rise to increased age awareness. Moreover, individuals in this age group were growing physically, which makes it easier to determine their ages with a relatively high level of accuracy. All of these factors tend to deflate age-heaping levels for children and young adults, compared to the age reporting of the same

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frequently collected haphazardly and analyzed without skill; as a result, they often only encompass a part of the phenomenon, which is incomplete (Szołtysek 2011). This refers in particular to the quality of data on age.

individuals at higher ages. The aged should also be excluded because the age-heaping pattern of very old individuals is subject to upward and downward bias for the reasons mentioned above.

There remains some uncertainty over whether age-heaping in the sources contains information about the numeracy of the responding individual or about the diligence of the reporting personnel who wrote down the statements. The age data for the relevant age groups 23–72 were normally derived from statements directly from the person. However, it is possible that a second party, especially the husband, may have made or influenced the age statement or even that the enumerator estimated the age without asking the individual. If the latter occurred, we would not be able to measure the numeracy of the person interviewed. In contrast, if the enumerator asked and obtained no response, a round age estimated by him would still measure basic numeracy correctly. A large body of literature has investigated the issue of people reporting on others' age. Recently, Friesen, Prayon, and Baten (2012) systematically compared the evidence of a gender gap in numeracy and literacy for the early 20th centuries, and found a strong correlation. They argued that there is no reason why the misreporting of literacy and age should have yielded exactly the same gap between genders. A more likely explanation is that the well-known correlation between numeracy and literacy also applies to gender differences. For our study, the question of whether the women themselves responded is slightly less important, as we only seek to estimate male numeracy.

Of course, a potential bias always exists if more than one person is involved in the creation of a historical source. For example, if literacy is measured by analyzing the share of signatures in marriage contracts, there might have been priests who were more or less interested in obtaining real signatures, as opposed to crosses or other symbols. We find it reassuring that previous studies have generally found much more age-heaping (and less numeracy) among the lower social strata and among the half of the sample population who had lower anthropometric values (Baten and Mumme 2010). Moreover, the regional differences in age-heaping are similar to the regional differences in illiteracy. It can be concluded that the method of age-heaping is a useful and innovative tool for assessing human capital.