Contributions to the discussion on the determinants of long-term human capital development in today's developing regions

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Abbreviations

ABCC	Index measuring the extent of age-heaping
ABCC2	Reformulated ABCC index for the age group 17 to 22
AJR	Acemoglu, Johnson, and Robinson
FE	Fixed Effects
GDP	Gross Domestic Product
GDPc	Gross Domestic Product per capita
GE	Gender Equality
GE_{num}	Gender Equality in numeracy
IPUMS	Integrated Public Use Microdata Series
IV	Instrumental Variable
log	Logarithm
LOWESS	Locally Weighted Scatterplot Smoothing
LSDV	Least Squares Dummy Variable
Max	Maximum
Min	Minimum
Obs.	Number of observations
OLS	Ordinary Least Squares
PPP	Purchasing Power Parity
RE	Random Effects
Std.dev.	Standard deviation
UK	United Kingdom
UN	United Nations
UNDYB	United Nations Demographic Yearbook
UNESCO	United Nations Educational, Scientific, and Cultural Organization
U.S.	United States
vs.	versus
WI	Whipple Index
WI2	Reformulated Whipple index for the age group 17 to 22

"By investing in themselves, people can enlarge the range of choice available to them. It is one way free men can enhance their welfare."

Theodore W. Schultz, Investment in Human Capital, 1961

1. Introduction

Explaining the causes of unequal global distribution of wealth today is a major task economists and economic historians are still struggling with. Although a lot of empirical evidence has been added in recent decades, the lively and controversial debate on which factor matters more for a positive economic development is still going on. The fact that history plays an essential role is hardly challenged anymore; however, as Nunn (2009:88) states, "less well understood are the exact channels of causality through which history matters." Broadly speaking, one can distinguish two main strands of explaining the long term economic growth performance of countries. The one strand considers factors that were determined already long time ago as profound sources of today's wealth, for example geographical environment, climate, factor endowment etc. In contrast, the proponents of the other strand do not take the development as determined from early-on and explain successful economic development by focusing on short term effects. According to the *Californian School,* for instance, up until the late 19th century, it was not at all taken for granted that the industrial revolution took place in Western Europe. The preconditions in China at that time were similar (Pomeranz 2000).[1] Recently, three channels assumed to play an important role in long-term economic growth performance

[1] For a comprehensive overview of this discussion, see for example Morris (2010).

have been exceedingly discussed in the literature: The role of geography, institutions, and human capital.

1.1. Geography, Institutions, and Human Capital

Diamond (1997), for example, presented a theory implying that modern-day income distribution had been determined as early as the Neolithic revolution. He suggests that initial biological and geographical conditions, such as the number of cultivable plants and domesticable animal species, as well as the size and shape of continents, determined the time and place when hunter-gatherer communities decided to transform towards agriculture. Hibbs and Olsson (2005) and Putterman (2008) test Diamond's (1997) hypothesis empirically and find strong supportive evidence that initial biogeographic preconditions explain differences in modern-day PPP-adjusted per-capital income.

Another geography-related factor is emphasized by Sachs (2003) who argues that economic development is hampered by the disease environment, as for instance the degree of exposure to malaria. Malaria can slow economic development by multiple channels including effects on fertility, population growth, saving and investment, labor productivity, absenteeism, premature mortality, and medical costs (Sachs and Malaney 2002).

Another piece of empirical evidence indicates that geography exerts an influence on economic growth via the "curse of natural resources". Most prominent in this regard is a study of Sachs and Warner (2001), who argue that countries with rich natural resources tend to grow more slowly than resource poor countries. These authors argue that resource-abundant economies tend to experience high domestic prices and, perhaps as a consequence, missout on export-led growth.

In respect to the long-term development of former colonies, Engerman and Sokoloff (1994) argue that the roots of today's income disparities between these countries are the result of initial factor endowments of the respective colonies. This is true particularly for the suitability of the cultivation of sugar and other cash crops, which often interacted with the use of slave labor, encouraged the evolution of societies where small elites – often of European descent – held a disproportionate share of wealth, human capital, and politic power. The authors also argue that countries with these extractive structures tend to maintain these structures until today, leading to persistence in economic inequality.

A second body of literature has emerged, focusing on historically developed institutions as the driving force of economic growth and development. Institutions, "the rules of the game", these authors argue, are embedded in a society's collective memory and exert executive constraints on its economic activity. The discussion was especially spurred by Acemoglu, Johnson, and Robinson (2001). They argue that differences in European colonization policies in different colonies resulted in institutional differences in these (former) colonies. In particular, these authors argue that the choice of colonization strategy was partly determined by the fact of whether Europeans were able to settle in certain places or not. In places where Europeans faced hostile disease environment, they avoided to settle permanently, and they were more likely to set up extractive institutions in these cases. In comparison, in places with a more moderate climate, better institutions were implemented as settlers were building 'New Europes' and not extractive regimes.

In a related study, Acemoglu et al. (2005) argue that those political institutions established prior to 1500 which allowed checking monarch rulers in Europe enabled some European nations to benefit more from the growth of Atlantic trade. This growth strengthened merchant groups by constraining the power of monarchs and helped merchants obtaining changes in institutions to protect property rights. These changes were crucial to subsequent economic growth and might influence global income distribution until today.

Also human capital has been stressed as an important driving force of economic development by a large body of studies. In their influential study, Mankiw, Romer and Weil (1992) find that an augmented Solow model which takes into account not only physical but also human capital, is able to explain very well international differences in living standards. Hanushek and Woessmann (2008), for example, review a large body of evidence on the role of human capital and find strong evidence that the cognitive skills of individuals and society are powerfully related to individual earning ability, to the distribution of income, and to economic growth. Especially arithmetic is an important cognitive skill, as handling numbers correctly is the basis for all economic activities and thus an important asset for successful economic development. To measure this skill Hanushek and Kimko (2000) constructed a new index for the quality of the labour force based upon comparative test results of mathematics and scientific skills for 38 countries in the period from 1960 to 1990. They found indeed a positive and strong relationship between the quality of the labour force and economic growth.

Looking at the influence of human capital on really long-term growth, Baten and van Zanden (2008) provide evidence that advanced literacy skills, proxied by per capita book production, have an impact on early-modern growth disparities. In this spirit, Becker and Woessmann (2008) test the hypothesis that Martin Luther's urge to provide education to females resulted in superior human capital levels of the female population in Protestant regions. For the case of early 19th century Prussia, they find that Protestantism indeed goes along with smaller gender gap in basic education. More generally, Protestantism seems to have had a beneficial influence on education and human capital accumulation, as Protestant regions tended to have more schools and higher school enrolment already before the industrialization (Becker and Woessmann 2010).

Each of these different approaches emphasizes a different channel of influence. However, there is a lively debate about which force has the strongest magnitude and which of these aforementioned forces is valid at all. To test these different views and to overcome the endogeneity problem here within, researchers turned their attention especially to the economic growth performance of former colonies: for colonized countries, the colonization took place as an exogenous shock; hence, this episode can be regarded as a natural experiment (see e.g. Robinson et al. 2005).

For example, Easterly and Levine (2003) investigate whether geographic endowments like temperate locations, ecological conditions shaping diseases, or an environmentally good agriculture influences economic development directly or via its effect on institutions. These authors find no evidence that tropics, germs, and crops as promoted by Diamond (1997) affect country incomes directly. Their results indicate however, that incomes are affected solely through institutions. Rodrik et al. (2004) compare the effects of institution, geography, and trade and find that "the quality of institutions trumps everything else". Similarly, Acemoglu et al. (2002) argue against the importance of geographic factors. They base this conclusion on their finding that former European colonies - which were relatively rich in 1500 - are relatively poor today whereas their geographic conditions have not changed dramatically in the 500 years since then. According to the authors, this reversal reflects changes in the institutions resulting from European colonialism. The European intervention appears to have created an "institutional reversal" among these societies, meaning that Europeans were more likely to introduce institutions encouraging investment in regions that were previously poor.

Conversely, Hibbs and Olsson (2005) find evidence, indicating that aforementioned effects of geography and biogeography on contemporary levels of economic development are remarkably strong, and therefore disagree with several studies where the effect runs solely through institutions. Glaeser et al. (2004) also disagree with arguments favoring the importance of institutions transferred by European settlers and argue instead that it was human capital that was transferred by these settlers. They conclude that human capital is a more basic source of growth than institutions. They make a case for human capital by arguing that poor countries sometimes escape poverty by good policies, sometimes pursued by dictators, and that these developments may subsequently improve political institutions.

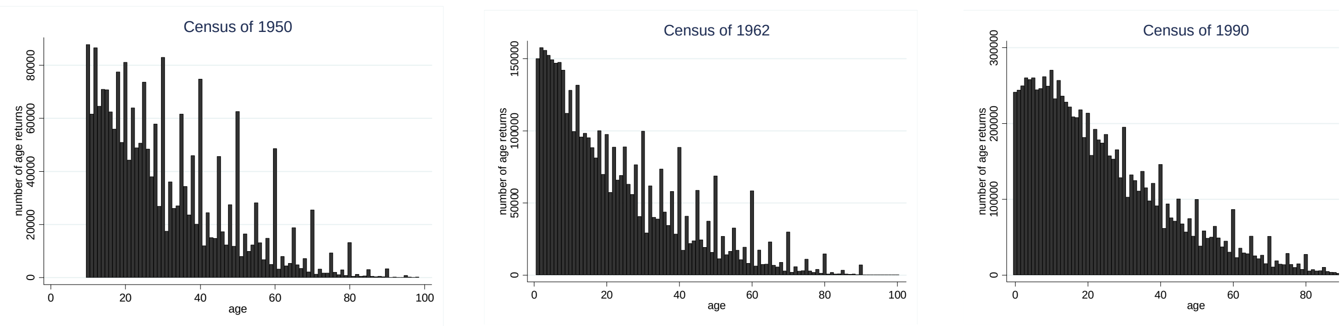
1.2. Age-Heaping as a measure of basic human capital

The importance of human capital, i.e. "quality components as skill, knowledge, and similar attributes that affect particular human capabilities to do productive work" (Schultz 1961:8), for economic growth is theoretically rarely challenged anymore (see for example Lucas, 1988; Romer, 1989; Becker et al., 1990). However, measuring the production factor 'human capital' is a major task for social scientists working with empirical data; they must not only find an appropriate method of measurement, but also data appropriate for capturing human capital. This is even more challenging for economic historians, as data on conventional educational indicators – such as literacy rates, school enrolment ratios, etc. – are scarce for the most part of human history, with some geographic regions lacking data completely until the 20th century. This task is even more challenging for work on today's developing regions that are in the focus of this thesis.

One important aim of this thesis is to present new data for assessing human capital for the countries under study. To do so, an innovative proxy of basic numerical skills is applied throughout the thesis: the age-heaping methodology. As this methodology, including sources, advantages and limitations, is discussed in detail in all the following chapters, the introduction only pertains to the general idea of this concept.

Age-heaping refers to the phenomenon that people who are not able to recall or calculate their own age accurately tend to round their age to ages ending in zero or five (thus these ages are called 'multiples of five'). This is a common feature within low educated societies (see for example Mokyr 1983, A'Hearn et al. 2009). In today's industrialized countries age-heaping vanished mainly already during the 19th century. In developing regions, however, age-heaping is still a distinctive feature and a well-known phenomenon among demographers. For illustration, Figure 1.1 displays three different histograms of age distributions as reported in three different censuses undertaken in Ecuador in 1950, 1974, and 1990. Obviously, these distributions do not represent the real age distributions of the Ecuadorian population since this disproportionate number of age statements cannot be explained by realistic reproductive behavior. In all of the three censuses a clear age-heaping behavior is evident: most prominent are the aforementioned ages of multiples of five: 25, 30, 35, etc. In comparing the three distributions, it is evident that inaccurate age statements, and thus age-heaping, become less pronounced during the course of time and eventually almost vanish. Several studies have shown that this is caused by improvements in education (e.g. Crayen and Baten 2010a, Manzel et al. (2012), Prayon (2012)).

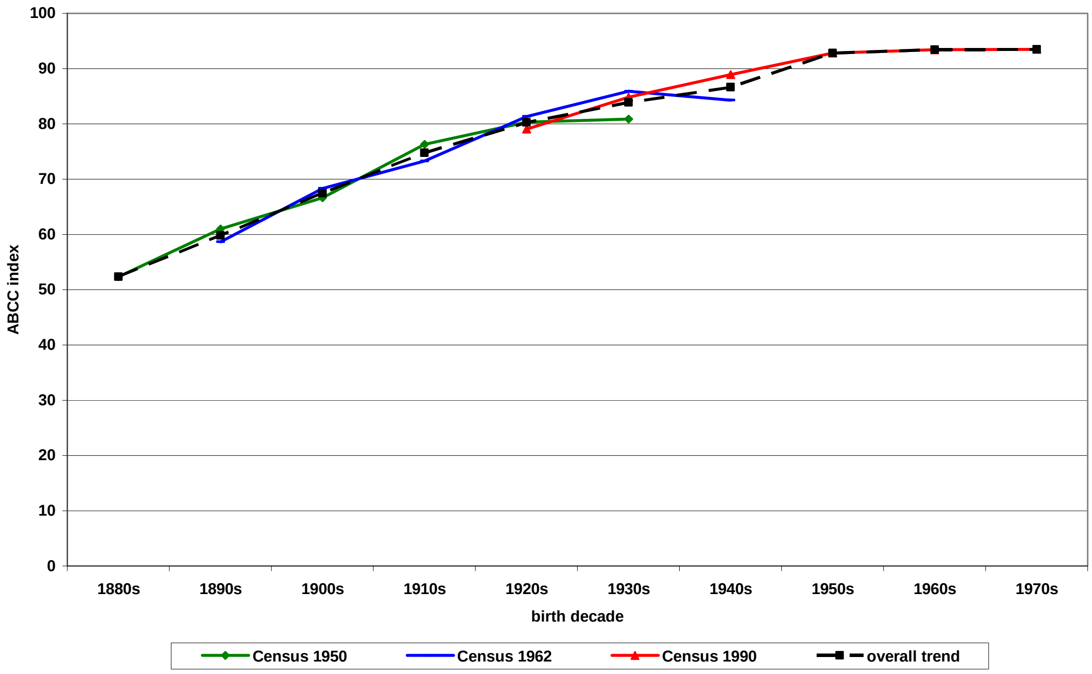
Figure 1.1: Age distribution in Ecuador according to the censuses of 1950, 1974, and 1990



Source: United Nations Demographic Yearbooks.

To quantify the extent of age-heaping, demographers use the Whipple index. However, throughout this thesis the ABCC index is used. This index was introduced by A'Hearn, Baten, and Crayen (2009) and is a linear transformation of the Whipple index. This way the index is easier to interpret since it ranges between 0 and 100 index points and can be interpreted as the estimated share of a population that is able to report an accurate age. Figure 1.2 displays the development of the ABCC index in Ecuador based on the age distributions shown in Figure 1.1.

Figure 1.2: Development of basic numerical skill in Ecuador according to the censuses of 1959, 1962, and 1990, ABCC-index (0 indicating all ages ending on multiples of five, 100 no age-heaping is visible in the age distribution data)



Source: United Nations Demographic Yearbooks.

The absence of basic numerical skills means more than just inaccurate age statements: if this basic knowledge is lacking, it is unlikely that more sophisticated skills are available, pointing towards a general lack of education. Basic reading and mathematical skills are a precondition for the acquisition of more advanced skills. In the economic context, arithmetic skills are of special interest as handling numbers properly is essential for any kind of economic activity.

1.3. Outline

This thesis aims at contributing new empirical evidence to the ongoing discussion of the different, aforementioned strands; however, the focus is mainly on the role of human capital with a special emphasis on its long term development and its persistence. Under study is the state of human capital in the countries in today's developing regions during the period from 1880 to 1960, a time when many of these countries were still colonies of the European powers. By applying age-heaping, this thesis presents new human capital estimates for world regions and a time period for which other human capital indicators are scarce or absent. In using this new dataset, it is possible to assess specific aspects of human capital, helping to better understand its role in the long-run economic development of the countries under observation.

Chapter 2 addresses directly the aforementioned discussion of possible channels that influence long-term economic growth. To do so, this chapter presents new estimates of human capital in 18th and 19th century Africa, Asia, and the Americas and reassesses the colonial legacy debate by examining the influence of institutions, human capital, and geography on the long-term economic performance of the countries under study. By using the age-heaping methodology, it is possible to trace the basic numeracy trends of 68 former colonies. The competing views are systematically tested by combining this new empirical evidence with the data introduced by Acemoglu, Johnson, and Robinson (2001) to assess the quality of institutions. In contrast to their view, Glaeser et al. (2004) argued that it might have been differences in the accumulation of human capital – mainly caused by the import of human capital from Europe – that decided whether these countries are rich or poor today. Our newly introduced human capital data supports Glaeser's (2004) argument; however, we argue that another growth factor is the idiosyncratic educational differences between the indigenous populations of the countries under study.

In Chapter 3, we turn our attention to the educational situation on the African continent. Today, Africa reveals underdevelopment in terms of human capital compared to other world regions. At the same time, a high variation between the countries is identifiable. In recent years, a number of studies on colonial education spurred discussion on the historical roots of education and schooling in Africa (e.g. Bolt and Bezemer 2009, Huillery 2009, Gallego and Woodberry 2010, Gallego 2010, Frankema 2012). For instance, different schooling policies of the colonial powers meant the development of different educational systems in Africa: the British government focused on basic education of the broad population, while France was more interested in educating the elite. The questions under investigation in this chapter are whether the differences in educational achievement observed today in Africa could be traced back into the colonial period. How does human capital develop over the past century? Which determinants in the past shaped the educational landscape in Africa? Do these factors still matter for explaining the differences in African literacy and schooling levels today? To address these questions, the age-heaping method is employed. Thereby an important human capital indicator can be added to the fragmentary data base for Africa. The new estimates cover the main part of the period from 1880 to 1960 for 34 African countries.

Chapter 4 then highlights an important aspect of human capital accumulation, namely gender inequality in education. For economic development, gender inequality is a large burden as the economic potential of women is left largely untapped and cannot be used in the growth process. Gender inequality in education is particularly harmful for development because it restricts the opportunities of women in the labour market. When examining the difference in the growth performance between South and East Asia in the second half of the 20th century, Klasen (2002) finds that a large part of this difference can be explained by differences in gender inequality in education. To better understand the reasons for these differences, this chapter traces the human capital development disaggregated by gender of 14 Asian countries for the period 1900-1960, using the age-heaping method, and aims to answer questions like: Did gender inequality in education already exist during the first half of the 20th century? How did the gender gap develop over time? Which factors played a role in determining the different levels of educational attainment of men and women? Did factors that are intrinsic within a society, such as social and cultural norms, matter more than factors influenced more directly by the political decision makers? In examining this development, a special emphasis lies on the gender gap in numeracy and its determinants. In particular, the validity of a 'U-hypothesis of gender equality' is tested, implying that gender equality in numeracy declines at initial stages of development and increases again with higher numeracy levels.

Chapter 5 contributes to the age-heaping methodology itself. A reformulated Whipple index, respectively ABCC index, is presented allowing for assessing the special heaping behaviour of young adolescents at the age from 17 to 22. Young adolescents tend to round their age to even numbers, which are 16, 18, 20, and 22, whereas the traditional Whipple and ABCC indices capture the heaping behaviour of adults of the age 23 and older, which is based on multiples of five. This chapter presents graphical and analytical analyses which indicate a high reliability of this new index. Thus, this new index allows extending existing age-heaping series by an additional age group, namely the 17- to 22-year-olds. Furthermore, in this chapter it is shown that when data sources provide only information on young adults and not on older age groups, it is possible to estimate the average heaping behaviour of the older population on the basis of the heaping level of adolescents. The thesis concludes with Chapter 6, which summarizes the main findings of the different studies presented in this thesis.

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2. Human Capital, Settlers, Institutions, and Economic Growth in Africa, Asia, and the Americas, 1750-2000

Abstract

This study presents new estimates of human capital in 18th and 19th century Africa, Asia, and the Americas and reassesses the colonial legacy debate by examining the influence of institutions, human capital, and geography on long-term economic growth. By using the 'age-heaping' method, we are able to trace the basic numeracy trends of 68 former colonies. We argue that the former colonies displayed a large variation of educational levels from the beginning. Moreover, we show that those differences in early human capital endowment have a strong impact on income differences today via the path-dependency of human capital. The results indicate that the idiosyncratic educational path dependency and the 'contact-learning effect' (human capital development of the indigenous population that came in contact with immigrants) were complementary to the well-known colonial institutional effect and direct migration transfer effects in stimulating growth.

This chapter is based on a paper with the same title, co-authored with Jörg Baten. The concept for the paper was developed jointly; the analyses and writing were equally shared.

2.1. Introduction

We study the impact of human capital development in 18th and 19th century Africa, Asia, and the Americas on long-term economic growth using the 'age-heaping' method. We combine a new data set on human capital with evidence about settler mortality and the human capital of migrants to assess the potential determinants of today's income divergence, including the role of institutions, migrant human capital, contact learning effects between immigrants and natives, and indigenous human capital investment.

Nobody would disagree that good institutions are a key ingredient of economic growth. In the empirical growth literature on the long-term impact of institutions, the indicators for the quality of institutions have mostly been based on the 'constraints on the executive' concept. According to this idea, a country's growth capability is determined by the effectiveness of law enforcement, the sanctity of contracts, and the ability of other influences to protect the security of property rights (Barro 1997:27). Modern markets can develop and foster continued economic growth, only when the constraints on the government are strong enough.[2] In the discussion about the factors that explain the different levels of income across countries today, the 'institutions view' has been supported by several empirical studies (Acemoglu, Johnson, and Robinson, 2001, 2002 (AJR); Easterly and Levine, 2003; and Rodrik, Subramanian, and Trebbi, 2004).

Instrumental variables have been used to circumvent the endogeneity issue, namely settler mortality during the 19th century and population density around 1500 in countries that became European colonies (Acemoglu et al. 2001, 2002). The idea was that European settlement decisions were influenced by the disease environments and population densities in the target countries. Where the climate and the disease

[2] It might be, however, that the recent economic crisis leads to a more careful evaluation of this effect even in the growth economics literature. Currently, most economists and the public demand more regulation of financial markets by the government, and this is conceptually somewhat different from the implications of the view that constraints on government influence are necessary for growth.

environment were more benign, as in countries that became the USA, Canada, and Argentina, Europeans were more willing to immigrate, thus they brought their 'good' European institutions with them. In contrast, areas where the first settlers faced high mortality rates, as was the case in West Africa, Europeans tended to implement more exploitative institutions with catastrophic effects on growth that have persisted until today. The settlers also avoided heavily populated countries, such as India, Egypt, and Mexico but migrated to countries with low population density.

Albouy (2008) and many others formulated doubts about AJR's measurement accuracy, although AJR responded with many arguments.[3] Glaeser, La Porta, Lopez-de-Silanes, and Shleifer (2004) suggested another causal channel to explain the growth process, namely migrant human capital, which implies criticism of the settler instrument: If potential instrumental variables are related to another line of causation, they fail to be good instruments. Settlers might have brought their institutions with them, but primarily, they brought themselves and their embodied human capital, as Glaeser et al. stressed. They argued that it might have been differences in the accumulation of human capital and the growth in income that decided whether countries are rich or poor today. Through this argument they followed therein Lipset's hypothesis (Lipset, 1960) that growth and an educated population cause institutional improvement, rather than the other way round. This view is supported by their empirical analyses, where they find human capital (measured by years of schooling) but not executive constraints as a predictor of economic development today.

Unfortunately, Glaeser et al. could not directly test their human capital view with early educational data, as evidence on this core variable of economic growth for the 19th and early 20th century was quite limited at the time of their analysis. For colonial

[3] Several studies also emphasized the regional/ethnic dimension of institutions (e.g. Michalopoulos and Papaioannou 2011 for Africa, Banerjee and Iyer (2005) for India).

countries, Glaeser et al. only had 14 observations with overlapping data for human capital around 1900 and data on settler mortality. Currently, new data on long-run human capital formation has been estimated, based partly on proxy indicators. In particular, the 'age-heaping' strategy has developed into a widely used tool to measure basic human capital in the past (following Mokyr, 1983; see the recent studies by de Moor and van Zanden, 2008; Baten et al. 2008; A'Hearn et al., 2009; Manzel and Baten, 2009; Humphries and Leunig, 2009; Baten and Mumme, 2010; Crayen and Baten, 2010a; Crayen and Baten, 2010b; Manzel et al., 2012; van Lottum and van Zanden 2011; de Moor and Zuijderduijn 2013; see also the applications in Mironov, 2006; O'Grada, 2006; and Cinnirella, 2008). In the present study, we extend the data set collected by Crayen and Baten (2010a) substantially for Africa and Asia. We combine this new evidence with the AJR data on settler mortality and test systematically the competing views. This study develops a data set of 68 previously colonised countries, including data-scarce developing countries. Our results indicate that migrant human capital might have generated growth effects. Settler mortality, which impacted the quality of institutions, also played an important role, but in a slightly less systematic way than migrant human capital.

However, our analysis goes beyond the view developed in Glaeser et al. that the import of human capital from Europe was the primary cause of growth in some countries (see Figure 2.1.). We argue that another growth factor is the idiosyncratic educational differences between the indigenous populations of the countries under study. Some of the countries without substantial European immigration had higher human capital investment early in the period studied, whereas others did not. Moreover, we hypothesise that the combined effects of European immigration and indigenous human capital development might play a role: spill-over effects could play a role even where a relatively small immigrant group was present, relative to the large majority of the indigenous population. In other words, the focus should be on the human capital of the total population of a country, which we will assess below. To analyse this factor, we will replace the instrument variables settler mortality and population around 1500 with the instrument ‘Basic Numeracy’ (and other instruments), to which the contact learning and the idiosyncratic human capital differences contributed.

2.2. Human capital and long-term economic growth

The theoretical impact of human capital on the long-term growth performance is rarely challenged anymore (Lucas, 1988; Romer, 1989; Becker et al., 1990; among others). However, proving the endogenous growth theories empirically still requires overcoming challenges. Finding the right testing strategy and the right measurement of the factor ‘human capital’ are the main challenges. Gundlach (2001:5) notes that the empirical measurement of the human capital factor and the productivity of education in economic growth are not satisfying thus far. Hence, it is not surprising that the estimates of the production elasticity of human capital reported in empirical studies vary, sometimes displaying contradictory results (for the latter case see, for example, the study of Benhabib and Spiegel (1994)). This measurement problem gets more and more challenging the further we go back in history because standard measurements in modern economies, such as schooling rates and even literacy rates, are not or only sporadically available. Nevertheless, with the construction of better educational indices or the exploitation of new data sources, a growing number of studies have shown in the last years that human capital is an important factor contributing to economic growth. For example, Hanushek and Kimko (2000) constructed a new index for the quality of the labour force based upon comparative test results of mathematics and scientific skills for 38 countries in the period 1960-1990. They found a positive and strong relationship between the quality of the labour force and economic growth. Bolt and Bezemer (2009) collected information on colonial era education in Sub-Saharan Africa and constructed an educational indicator based upon the pupil-population ratio. In their study on long-term growth performance in Africa, they provided evidence that education predicts growth rates better than institutional quality.

The Unified Growth Theory (Galor and Weil, 2000; Galor and Moav, 2002; and Galor, 2005), which explains the demographic transition from the epoch of Malthusian stagnation to the era of sustained economic growth, has attracted much attention in recent years. Human capital is a driving force within this theoretical framework; the interaction of population growth and technological progress allowed an escape from the Malthusian equilibrium and led to the first Industrial Revolution. The onset of the second Industrial Revolution during the late 19th century stimulated increased demand for skilled workers. In response, parents began to invest in the quality of their offspring instead of maximising quantity. This led to falling fertility rates and enabled the economies involved in this change to go through the process of the demographic transition. Even more important, the accumulation of human capital stimulated technological progress and paved the way for a sustained growth process. In this way, the Unified Growth Theory can explain income differences across time and countries.

Mokyr and Voth (2010) highlight the importance of using definitions of human capital that are much broader than formal education alone to capture the effects of the Unified Growth Theory. Recent studies have presented different human capital indicators that perform quite well. To measure basic human capital development, they advocate studying the ability of citizens to write their signatures (signature ability) and numeracy, measured using the age-heaping method. Also, the percentage of craftsmen that have formal apprenticeships could emerge as a valuable measurement in empirical studies. Finally, Mokyr and Voth emphasise the role of non-cognitive skills, such as discipline.

From a theoretical point of view, literacy should be an important input factor for the social and economic development of a society, as only literate people are able to interact with state institutions effectively and perform more sophisticated work. This finding is true for the modern period. A number of studies sought to find this influence empirically (e.g., Barro, 1991); however, other studies failed to find a significant influence of literacy on growth. That finding might be due to the inconsistent measurement of literacy across countries, to the lack of variation across countries in the post-war period and to the presence of an upper boundary to the literacy index.[4] For periods in which information on literacy ratios are not available, historians began to build an index based on the percentage of a population with signature ability by counting people who signed their names on documents and comparing them to people who marked an "X" instead of their name (Kaestle, 1985:13). Reis (2005) presents data on signature ability in Europe around 1800 that shows a big variation between and within countries. The Netherlands and England reveal much higher values than Southern Europe. Whether the better skilled workforce in Britain accounted for the Industrial Revolution is debatable because France, for example, had a similar high skill level, but its industrialisation occurred at a later date (Mokyr and Voth, 2010).

One indicator for more advanced human capital is book production. Baten and Van Zanden (2008) introduced per capita book production in pre-industrial Europe as a proxy for advanced literacy skills. Similarly, Buringh and Van Zanden (2009:409) interpreted the production and accumulation of medieval manuscripts in a long-term study on Western Europe as a proxy for the production and accumulation of ideas. Baten and Van Zanden (2008) present strong empirical evidence for the importance of human capital for sustained economic growth before 1800. Using instrumental variable methods, they show that the countries with the strongest increase in per capita book production were also the countries with the fastest real wage growth. This finding holds when non-

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[4] The latter problems were a major reason why researchers turned to other human capital measurements such as years of schooling or educational attainment (e.g., Barro and Lee 2000).

European countries are included (Japan, Indonesia, China, India, and the US), leading the authors to the conclusion that a fundamental cause of the Great Divergence is the difference in human capital endowment.

Hanushek and Woessmann (2008) show strong empirical evidence that the cognitive skills of individuals and society have strong effects on individual earning ability and on economic growth. One important cognitive skill is arithmetic. Handling numbers correctly is the basis for all economic activity and, hence, is a valuable asset for successful economic development.

2.3. The concept of basic numeracy

Conventional human capital data, such as literacy or schooling rates, for the countries during the period of interest in this discussion are only partially available. To fill this lack of data, we apply the age-heaping strategy to obtain estimates of basic numeracy as a proxy for human capital. The age-heaping strategy is explained in greater detail here, as the application of this method in studying economic history is still relatively new. This approach employs methods that developed because of the phenomenon of age-heaping, i.e., the tendency of poorly educated people to round their age erroneously. For example, a poorly educated individual will say he is "30", if he is in fact 29 or 31, whereas an individual who is with a better endowment of human capital will give an exact age (Mokyr, 1983). Demographers treat age-heaping usually as a statistical problem, as the reported ages do not reflect the true age distribution. They use the Whipple index to measure the accuracy of age statistics, with high Whipple indices indicating unreliable data. This index measures the proportion of people who state an age ending in a 5 or 0, and this proportion is compared to a 'true' age distribution, where it is assumed that each terminal digit should appear with the same frequency (n_x is the population of age x):[5]

[5] 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.

$$(1)\ W = \left(\frac{n_{25} + n_{30} + ... + n_{75} + n_{80}}{\frac{1}{5}\sum_{i=23}^{82} n_i} \right) \times 100 \text{ if } W \geq 100\text{; else } W = 100.$$

We interpret age-heaping from a different point of view: we associate high Whipple indices with a lack of numerical skills of the population. This was first suggested by Bachi (1951) who found an inverse correlation between age-heaping and educational levels within and across countries. Mokyr (1983) pioneered its use in economic history. Crayen and Baten (2010b) found that age-heaping tends to be more pronounced in population groups with lower income and/ or lower-status occupations.

In this study we use another index, the so-called ABCC index as suggested by A'Hearn, Baten, and Crayen (2009).[6] It is a simple linear transformation of the Whipple index, ranging between 0 and 100: 0 indicates an age distribution with ages ending only on multiples of five whereas 100 implies no age-heaping at all:

$$(2)\ ABCC = \left(1 - \frac{(W - 100)}{400}\right) \times 100 \text{ if } W \geq 100\text{; else } ABCC = 100.$$[7]

The data set used for the numeracy analyses in the following sections consists mainly of census data (see Appendix II).[8] We collected information on the age distribution of the population of 68 countries that were former colonies of European powers. Based on the assumption that basic numerical skills are acquired during the first decade of life, we calculate the ABCC index for birth cohorts. Since mortality increases with higher ages,

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

[7] Whipple indexes below 100 (ABCC indexes above 100, respectively) in the 20th century rich countries are normally caused by random variation, hence those indexes are normally set to 100.

[8] Some census data provided by the UN Demographic Yearbooks were smoothed and/or rounded, for example the census data of 1961 for India, and cannot be used for the age-heaping method. The same is true for census data that show heaping patterns other than favouring ages ending on 0 or 5 or censuses where individuals were asked for their year of birth rather their age. In the latter case, a strong birth year heaping is observable, which cannot be captured by the conventional Whipple or ABCC indexes. Those types of heaping patterns would distort the ratio of the numerator and denominator in the index formulas and, therefore, overestimate the numeracy levels. We also excluded data from countries with a population size smaller than 500,000 and census data that considered only European populations in colonies rather than the whole population.

the frequencies of reported ages ending in multiples of five would augment and lead to an underestimation of the ABCC index. To overcome this problem, we spread the final digits of 0 and 5 more evenly across the age ranges and define the age-groups 23-32, 33-42, …, 73 to 82. In a second step, the age-groups are assigned to the corresponding birth decades. In the case that data overlap for one or several birth decades within a country because more than one census was available for this country, we calculated the arithmetic average of the indices. In the entire data set, the birth decades range from the 1680s to the 1970s for some countries, whereas for the majority of countries data are only available for the birth decades from the 1870s to the 1940s for most individual countries.

A major advantage of the age-heaping method is its consistent calculation. This way, age-heaping results might be more easily comparable across countries, whereas comparisons of literacy or enrolment rates might be misleading due to significant measurement differences or different school systems. Further, owing to usually high drop-out rates in developing countries and heterogeneous teacher quality, it can be argued that enrolment rates are less conclusive for our goal as enrolment ratios are an input measure of human capital: Even though a country might have high enrolment ratios, they do not permit conclusions about the quality of education. Age-heaping on the other hand is - like literacy - an output measure of human capital.

Recently, several studies confirmed a positive correlation between age-heaping and other human capital indicators. In their global study on age-heaping for the period 1880 to 1940, Crayen and Baten (2010a) identified primary school enrolment as a main determinant of age-heaping: an increase of enrolment rates led to a significant decrease of the age-heaping level. A'Hearn, Baten, and Crayen (2009) used a large U.S. census sample to perform a very detailed analysis of the correlation between regional numeracy and literacy. Based on a sample of 650,000 individuals from the 1850, 1870, and 1900

IPUMS U.S. censuses, they found for the overall sample as well as for subsamples a positive and statistically significant relationship between these two human capital indicators.[9] They also went back further in time and studied the relationship of signature ability as a proxy for literacy and age-heaping as a proxy for numeracy in early modern Europe. Here as well they found a positive correlation between the two measures. In a study on China, Baten et al. (2010) found a strong relationship between the age-heaping and literacy among Chinese immigrants in the US born in the 19th century. Additionally, Hippe (2012) examined systematically the relationship of numeracy and literacy on the regional level in seven European countries in the 19th century and in ten developing countries in the 20th century. He found for each country separately a high correlation between the two indicators.

Possible objections to the age-heaping method should be addressed here. One concerns the uncertainty of what is actually being measured; is it the age-awareness of the respondent during the interview or the diligence of the reporting personnel? The other possible objection relates to other forms of age-heaping, i.e., other patterns than the heaping on multiples of five. Concerning the first objection, Crayen and Baten (2010b) admit that the possibility of 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 analysing 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 just crosses or other symbols (Crayen and Baten (2010b:460)). They argue, however, that the empirical findings in previous age-heaping studies, namely that there is generally less numeracy among the lower social strata and similar regional differences of age-heaping and illiteracy, support their assumption that the age-awareness of the respondent is captured and the bias of meticulous or inaccurate reporting is negligible. A study by Scott and

[9] Manzel and Baten (2009) found the same strong relationship between literacy and numeracy in a study on the regions of Argentina.

Sabagh (1970) supports the assumption that it does not make a difference whether the individual or the reporting personnel reports a rounded age if the true age is unknown. They investigated the behaviour of canvassers during the Moroccan Multi-Purpose Sample Survey of 1961-1963 and found that the canvassers were indeed not free of reporting rounded ages of people that did not know their age themselves. The interesting feature in this context is that between 70 and 90 per cent (dependent on the underlying age group) of the interviewed people did not know their age and thereupon the historical calendar method was applied. Expressed in ABCC values this would imply an overall numeracy level somewhere between 10 and 30 ABCC points. And indeed, this fits well the calculated age-heaping level observed in Morocco for the census of 1960, namely an ABCC level between 20 and 40.

To overrule the second objection, which is different heaping patterns, we exclude in our study all individuals younger than 23 and older than 82 to minimise possible biases due to age effects. The very old are dropped as mortality effects might distort the age-heaping indices. Among teenagers and young adults, we often find a heaping pattern on multiples of two instead of multiples of five, indicating a more precise age-awareness than older age groups that heap on multiples of five. The reason is probably that many important events in life, marriage, military recruitment, and reaching legal age happen during the late teens and early twenties; such occasions might increase age awareness. Further, special cultural number preferences – like the dragon year or the number eight in Chinese culture – do not seem to influence the index much, as Baten et al. (2010) found in a study on China.

Crayen and Baten (2010a) also examined whether the degree of bureaucracy in a country could account for lower age-heaping values, i.e., if the government interacts with its citizens more regularly, the age-awareness of the population might be higher than in countries without well developed institutions, independently of one's individual educational attainment. To test this possible bureaucratic factor, they included two explanatory variables, one measuring the 'state antiquity' and one that accounts for the numbers of censuses performed in each country up to the period under study. For all specifications, those variables showed no significant influence on the age-heaping level of the countries, leading to the conclusion that this 'bureaucratic factor' does not play an important role. The fact that countries with an early introduction of birth registers and a high number of censuses show higher age-awareness can be explained with the fact that these countries introduced also schooling relatively early. Again, schooling outweighs the independent bureaucratic effect. Somehow related to this is the question of cultural differences in age-awareness. However, analysis showed that only the East Asian region had systematically less age-heaping than the other regions under study. This finding might be due to the importance of the Chinese astrological calendar in daily life, which relies on greater numerical ability in the population. In conclusion, the correlation between age-heaping and other human capital indicators is quite well established, and the 'bureaucratic' factor does not invalidate this relationship (Crayen and Baten 2010b:458).

Additionally, could it be a problem that we construct our trends based on different census years? Crayen and Baten (2010a) examined the possible correlation of age and age-heaping and found only a systematic influence of age on the heaping behaviour among the youngest age group: 23 to 32. People at this age tend to heap their age less than the older age groups. Based on this observation, Crayen and Baten suggested an adjustment of the numeracy index for the youngest birth cohort that we applied in this study as well.[10] Figure 2.12 displays the ABCC trends of three example countries disaggregated by census year. The youngest age group (i.e. always the last data point of each trend line) already underwent the suggested adjustment. What we can see is that the

[10] The proposed adjustment for the youngest age group (23-32) is: (W-100)*0.25+W. For more details, see the Appendix in Baten and Crayen (2010a).

overall levels of the trends do not differ strongly.[11] Even though the trends fluctuate in the case of India during the 19th century, the general trend is obvious. The deviations are most likely caused by differing underlying census data from British India (see Appendix II: ABCC sources). These trends show that, although the data come from different census years, they correspond quite well, i.e. no effects of better 'census-taking' or learning effects among adults are visible. This finding supports additionally our assumption that basic numeracy is acquired mainly during the first decade of life.

2.4. What might have influenced the numeracy development?

In this section, we discuss what might have influenced numeracy and age awareness apart from the colonial legacy and settlement variables. First, religious factors could be important. Max Weber's well-known hypothesis that Protestants, Calvinists in particular, had special attitudes found strong support recently in the works of Becker and Woessmann (2009) who stressed the human capital development effects of Protestantism. Colonies of protestant countries have recorded higher literacy levels through the present (Barro and McCleary, 2005), and colonies of the partly Calvinist Dutch (such as Sri Lanka, Indonesia or Surinam) might have had higher human capital values than the average of each country's respective region. Census and population registration traditions can also be considered to be cultural factors, although Crayen and Baten (2010a) found in systematic tests that this effect was not visible in the data (except in countries with very long census traditions).

Second, population density might also matter. AJR interpreted a high population density in 1500 as a signal of wealth. Hence, European colonisers might have decided to set up exploitative institutions in countries with a high population density. In the Glaeser et al. context of immigrating human capital, one could adopt a different view. Because

[11] Generally, our interest is on the overall trends and we do not interpret small changes of the index.

indigenous populations were large, the European immigrants were by far outnumbered by the indigenous people. If the human capital of the latter population was low then the average level of human capital in the entire population was also quite modest. Moreover, in such a situation, a high level of inequality might be the result, as Engerman and Sokoloff (1997) stressed for Latin America. Finally, high population density early-on might also imply adverse nutrition and health effects (Koepke and Baten, 2005 and 2008; Steckel, 2008; and Komlos and Baten, 2004). If the quality of nutrition deteriorates due to high population density, a larger fraction of the population might suffer from infant protein malnutrition syndrome, which tends to retard cognitive development of children and therefore might lead to retarded human capital formation (see the extended review in Baten, Crayen and Voth, 2013).

Third, the combined effects of European immigration and indigenous human capital development might play a role; spill-over effects could promote higher education even where immigrants were a substantial minority (between 5 and 50 percent) and the indigenous population formed a majority.

Another interesting aspect in the AJR versus Glaeser et al. debate is the issue of timing. Institutions have a long-run nature by definition. AJR would have preferred to obtain 18th century data on settler mortality as the institutional decisions, exploitative or growth-promoting, were already made in this early period. In contrast, if growth is caused via importing people with high human capital, there might also be short-run effects if the immigrants elevate the human capital level of the whole population in the target country. This might have played a role in some countries, such as Argentina and Uruguay, which were subject to migrant waves late in the 19th century when Europe had already introduced mass-schooling, and the recent migrant waves were more educated than the older migrant waves.

Finally, in the European and 'Neo-European' countries, more advanced levels of education, through the development of mass schooling in the late 19th century, were initiated by democracy movements, national competition and regional participation in schooling decisions (Lindert, 2004).

2.5. Trends in sample countries

Now we analyse the numeracy trends in a large number of countries. Our special interest will be (1) whether there was similarity of variation within groups of colonies that had similar levels of settler mortality, (2) whether countries with high population density in 1500 had high levels of human capital in the early modern period, (3) whether immigration effects exist and (4) if contact learning effects are visible. Figures 2.2-2.10 display the numeracy trends of former colonies, where numeracy levels could be calculated. All numeracy values are organised by birth cohorts, as the very basic levels of numeracy measured here are normally obtained during the first decade of life. Figure 2.2 reports those cases in the Americas for which we could obtain long-run trends, i.e., birth decades before the 1860s are documented. Numeracy levels were high in Canada and to a lesser extent in the U.S. during the 18th century, whereas they were low in Venezuela and Mexico and, around 1800, even lower in Ecuador. Among many countries of low numeracy values, progress was limited until the late 19th century. The wide range of numeracy values that can be observed for the 1870s (between about 40 and 100 percent) was already visible in the 1810s. One of the countries with an early improvement was the immigration intensive case of Argentina, whereas most of the other, less-educated countries improved only after the 1870s. What does this tell us for our main research question, i.e., whether imported institutions or immigrating people with their human capital was more important? As mentioned in section 2.4, institutions are defined by long-run stability, and AJR argue that institutions were already imported during the late 18th

century. In contrast, if development was caused by an influx of human capital intensive immigrants, countries might show evidence of changes occurring over the short run. This finding is visible in the Argentinean case, in which European mass immigration occurred during the late 19th century. It also applies to Uruguay and Brazil, although European immigration to Brazil was more modest, relative to the large resident population, and occurred slightly later.

Can we distinguish cases with high population densities early on from countries with low population density in Figure 2.2? Clearly, Mexico and Peru were countries with high population densities early on. While our data for Peru starts late, we find that human capital development in Mexico stagnated between the late 18th and the late 19th centuries. Is this evidence for weak institutions or low human capital importation? Unfortunately, it can be caused by both, so we cannot use this evidence to confirm or reject our contrasting hypotheses. During both the late 18th and the late 19th centuries, European immigration to Mexico was quite limited, which meant that shocks to both institutional and human capital development did not occur.

In Figures 2.3 and 2.4, we show the Latin American cases for which data start during the 1870s (and partly the 1860s). Countries with strong immigration had high levels initially, such as Chile and Guyana. Lagging in development were countries such as Bolivia, Haiti, and the Dominican Republic.

In North Africa, we have a long series for Egypt, which became a British colony in 1882 when British troops occupied the country (Figure 2.5). Egyptian numeracy stagnated at a very low level from the late 18th century to the very late 19th century. In fact, Egypt had the lowest numeracy among the countries observed in our sample. As Egypt is an example with very high population density early on, the situation is somewhat similar to the Mexican case, which was stagnant with low human capital development until quite late. Jointly with Morocco, it had a strong upward trend after the 1880s. The

French colonies of Algeria and Tunisia showed a relatively high basic numeracy early on. Perhaps the French educational system played a role in these countries, but in many other French colonies in West Africa, it did not have such a strong effect. We interpret the Algerian and Tunisian cases as experiencing contact-learning effects, i.e., spill-over effects from French immigrants because the French became a substantial minority in those countries.

In West Africa, the range seems to have been between 40 and 70 percent in the 1890s, i.e., not a much lower minimum than the Americas but note the higher Latin American maxima (Figures 2.6). Low values were given in Nigeria with its very problematic institutional quality (which lasted until the 21st century). The colonies of Togo and Ghana were doing somewhat better early on in West Africa. Liberia was the second-best country in this region, perhaps due to the immigration of former African-American slaves. In summary, within the West African 'exploitation colonies', a large variation of early human capital formation is identifiable.

In the rest of Sub-Saharan Africa, Mauritius and Reunion stand out with a very high early numeracy, perhaps promoting the relatively high income per capita until the present (by African standards, see Figure 2.7). They are followed by South Africa and Tanzania. Relatively low initial basic numeracy was observed in Cameroon, Uganda, and Kenya (Figure 2.8).

Finally, in Figure 2.9, we present some data for Asia. The time-series on the territory of today's India, Pakistan, and Burma stretches back to the early 19th century. India had a low numeracy level in the 1830s, whereas Burma had higher numeracy levels. This difference might be the result of the Buddhist temple schools in Myanmar. Sri Lanka and Malaysia also had remarkably high numeracy levels around the mid-century, but the values in Australia, New Zealand, and Hong Kong were even higher, which had solved their basic numeracy problem by the 1860s. On the other hand, the regions that became

Bangladesh and Pakistan had very low numeracy, with levels similar to Egypt around 1900. Indonesia was situated between the numeracy levels in India and Sri Lanka.

One important conclusion from this descriptive analysis is that population density around 1500 does not correlate with high initial human capital. Egypt is a clear counterexample as are India and Mexico. Second, the short-term effects of large-scale immigration were clearly visible in cases such as Argentina. Third, colonies with a substantial minority of settlers, such as Algeria and Tunisia, displayed contact learning effects.

2.6. Migrant human capital and 'contact learning effects'

Glaeser et al. (2004) argue that it was mostly the human capital of migrants that made a difference in rates of human capital development and economic growth. The most obvious cases are the U.S., Canada, Australia, and New Zealand, where North-western and Central European migrants account for a large share of the population, who already had a high level of human capital as early as 1700 and consistently by 1800. Similarly, the Latin American 'Southern Cone' (Argentina, Chile, and Uruguay) populations consist mostly of Europeans, though human capital levels in the migrants' countries of origin (primarily Southern Europe) were slightly less impressive around 1700 and 1800.

What is important in the other countries analysed, those with a substantial minority of Europeans, is the human capital advantage over 'indigenous' populations. For example, what about South Africa, where European immigrants represented a minority of approximately 20 percent? Could the human capital difference be large enough so that the 20 percent had a substantial impact on the overall population? This question has been studied for the case of Brazil, where late 19th century immigration also only accounted for a modest share of the overall population (Stolz et al., 2013). The native population of Brazil in this period consisted of a high percentage of American Indians and Africans who had been forced to migrate and descendants of earlier migrants mostly from Portugal. Many native Brazilians had ancestors from different ethnic groups. In general, the educational level of native Brazilians was lower than that of the European immigrants but not much lower. Overall, Stolz et al. (2013) estimate a difference of less than ten ABCC points between the immigrants and the native Brazilians and conclude that direct human capital transfer from the late 19th century immigrants cannot have caused a large share of the increase of educational levels that occurred at the same time.

However, there might have been some indirect effects from skill-intensive immigration, and this is an externality that we call the contact learning effect. If natives perceive skilled immigrants as superior in social status or as a challenge in the labour markets, they might increase their children's education. The immigrants can also play an active role by initiating schooling or providing teachers, as was the case in Brazil. The South African example is more ambivalent because the 20th century Apartheid laws limited schooling of the black and coloured majority. Nevertheless, the educational level was high in South Africa compared with other developing countries. In the case of colonies where European settlers accounted for a substantial minority (from 5 to 50 percent), we sometimes observe this contact learning effect quite clearly. French Algeria and Tunisia are examples. Even if the French minority was not large enough to cause a strong migrating human capital effect, they had an impact via the contact learning effect. However, the 'contact learning effect' does not only depend on European immigration. An interesting example is the case of Liberia; former African-American slaves formed an upper-class in this West African country and the non-immigrant population acquired skills quite early. As a result, Liberia was a high performer with respect to basic numeracy within Africa.

Unfortunately, we cannot perform the same calculations for all 68 colonies in our study as Stolz et al. did for the Brazilian case. However, we can perform a thought experiment with the assumption that the European immigrants had the same ABCC value as the population of the corresponding colonial power around 1900, e.g. we assigned the value of France to the immigrants in Tunisia, Algeria, Madagascar and so forth. As we know their population percentage and the ABCC level in 1900 in the colonies, we can estimate the ABCC of the non-European population (Table 2.3). In a next step, we can estimate how much the ABCC level of the whole population increases due to the presence of European immigrants. For example, in Algeria, the whole population had a human capital endowment of 84 ABCC points. The European settler ratio within the population was 13 percent. This finding leads to an estimated ABCC value of 82 for the Non-European population in Algeria. Thus, the 13 percent Europeans raised the ABCC level of the whole population only by around 2 points at that time. Table 2.3 displays those level effects of immigrating human capital. Within the group of countries with a substantial European minority (between 5 and 50 percent), we observe that Europeans account for a 'mark-up' of 0.07 to 12.4 ABCC points. However, the values of these migration effects show clearly that the direct effect of the European presence is not strong enough to explain the large variation of the ABCC around 1900. Moreover, the effect is negligible for countries without a substantial share of Europeans (countries with less than 5 percent European residents). The idiosyncratic human capital endowment of the indigenous population and the 'contact learning effect' must have been stronger than the migration effect.

One might argue that the timing of colonisation might play a role here, i.e., countries that were colonised in the 16th and 17th centuries (e.g., Ghana, Brazil, or the US) might have accumulated those migration effects and/or 'contact learning effects' over time, whereas countries that came under European rule much later (e.g., most parts of Africa) did not. The Neo-European countries are not of interest in this context, as the indigenous populations were more or less replaced by Europeans. In countries with a substantial European minority, the settlers could play a role. Examining the countries with a substantial European minority in 1900, we find a positive relationship between the length of colonisation and the ratio of Europeans, i.e., the earlier a country was colonised the more inhabitants of European descent lived there around 1900.[12] However, we do not find the same positive correlation between the length of colonisation and the ABCC values. This is especially visible in the case of the late colonies of Namibia and Algeria. Even though those countries came under European rule as recently as the 19th century and do only show a modest share of European settlers, their ABCC values are above the average of the other countries in this group. All these observations are strong evidence that the overall educational levels around 1900 are the result of the combination of the idiosyncratic human capital endowment and positive spill-over effects from the European migrants.

2.7. Comparing settler mortality and early human capital formation

Settler mortality and early human capital formation should be negatively correlated, following from the discussion above. Which of the two variables can serve as better potential instruments of later institutional quality and education? We focus on those countries in which settler mortality and early human capital formation deviated (Figure 2.10). In general, both indicators correspond, with low settler mortality in the high-education cases of the US, Canada, New Zealand, Hong Kong, and South Africa. Interestingly, Malaysia, Guyana, and Mauritius also fit this pattern. On the other hand, countries such as Nigeria, Mali, and the Gambia had low numeracy and high settler mortality and, therefore, serve as classical West African cases. There were five interesting deviations, with only modest settler mortality but high population density and very low early human capital values in 1900: Bangladesh, India, Pakistan, Egypt, and Morocco.

[12] We used the new data set with dates of colonization compiled by Olsson (2009).

Settler mortality in those countries is estimated to be lower than in most Latin American countries, including Argentina and Uruguay. To a lesser extent, Indonesia also belongs to this group, although settler mortality was somewhat higher. All of those are still poor countries today, and their institutional and human capital level during the second half of the 20th century was modest. This finding would suggest that the early human capital formation had a stronger influence than the settler-mortality-related factors, i.e., the institution building and the direct human capital impact of migrants.

We tested the various instruments in an instrumental regression framework, following AJR and Glaeser et al. A replication of their results is reported in Table 2.1. Glaeser et al. used regression analysis to show that the ultimate causality chain ran from settler mortality and early population density via modern human capital to modern income. In contrast, we argue that the human capital of the indigenous people and the spill-over effects from migrants should also be acknowledged in the model. Hence, we will test whether those instruments can be replaced by early human capital formation or, more precisely, basic numeracy. This proves to be the case (Table 2.2). Early human capital might be interpreted as the outcome of idiosyncratic developments and contact learning effects in countries with substantial immigrant minorities. From the comprehensive data of the late 19th century, we find a causal chain from early human capital via recent (1960-1990) human capital to income differences today. For the early 19th century, our data set is too small for a reliable interpretation but the causal chain remains significant.

We were also curious about whether the instrumental variables that had an effect via human capital level of the recent past (1960-1990) would also have a significant effect on GDP per capita today in a cross-section of countries. This does not mean that we have a different theoretical model in mind; we still think that those variables create an impact via the path of human capital and institutions. However, we can learn from this exercise how much difference a unit of learning investment around 1900 made, and how much a percent of settler mortality matters. Moreover, we can examine the interactions with initial GDP levels and climatic effects. We find that even after controlling for climate and French legal origin, both settler mortality and early numeracy had an impact on income differences in the present (Table 2.4, columns 1-3, 5-6). In a direct comparison between the two variables in two regressions, settler mortality demonstrates a higher explanatory share of R^2 (not shown). The coefficient of both variables increases when the share of the population living in temperate zones is not controlled for (column 2). The climatic factor is associated with a more or less difficult disease environment for the whole population (and not only for settlers) and clearly interacts with the two variables studied here but has no independent effect once initial GDP is included (column 3).

However, one could argue that human capital measures the early deviation between incomes, hence we need to control for initial GDP as well. Unfortunately, GDP estimates around 1900 are only available for 23 colonised countries (Maddison, 2010). Controlling for GDP, the effect of early human capital investments and the settler mortality effect remains significant (columns 3 and 4).

Finally, we would like to disentangle the direct and indirect impacts of European migrants on the human capital levels in the colonies. Examining the relationship of settler ratios and the ABCC values around 1900 in the countries analysed (Figure 2.11), we observe the following pattern: countries with a substantial population ratio of Europeans (greater than or equal to 5 percent) all have ABCC values over 65. Furthermore, all of the Neo-European countries (countries with a share of Europeans over 50 percent) reveal numeracy levels of almost 100 ABCC points. This finding meets the expectation that a high share of Europeans increases the overall ABCC level of the population in the settlement countries. However, countries without a noteworthy European community show the full range of ABCC values, from an extremely low 19 points in Bangladesh to above 95 ABCC points in Guyana, Cambodia, Mauritius, and Hong Kong. Among this group of countries, we find our second expectation confirmed, namely that the colonies had a great variety of different human capital endowments around 1900. This large variation supports the argument that, in contrast to the view of Glaeser et al., it was not only the ‘imported’ human capital of the settlers that mattered for economic performance but also the idiosyncratic human capital endowment of the local population.

To test whether the presence of Europeans had a systematic influence, we included additional interaction terms for the ABCC with the settler ratios, one for the Neo-European countries and another for the countries without a substantial European population ratio (under 5 percent), leaving the group of countries with settler ratios between 5 and 50 percent in the reference category (see Table 2.3 for country classification). Those are the cases of ‘substantial European minorities’, where we would expect contact learning to be most important. Column 5 in table 2.4 displays the baseline model with additional interaction terms. The main results are a positive coefficient of the interaction term between the ABCC and the Neo-European countries and a strongly negative coefficient of the interaction term between the ABCC and ‘No-Settler countries’ (all compared to countries with a substantial settler minority). However, the coefficients are significant only for the latter case. If we compare these results with the more parsimonious model in column 6, we observe that the coefficient for the Neo-European interaction term does not change much when the climate variable is included as compared to the interaction term with the No-Settler countries. We can interpret this interaction effect such that countries without a substantial settler minority faced greater difficulties transforming their idiosyncratic human capital into welfare in the long run. The mechanism behind this phenomenon might be the contact-learning effect.

What did we learn from this exercise? To summarize, because our ABCC coefficient remains stable and significant in all specifications, we conclude that the idiosyncratic human capital endowment of the whole population matters strongly and impacts the long-term economic performance via human capital and institutions.[13] Countries without contact learning effects faced greater difficulties to transform their idiosyncratic human capital into welfare growth.

2.8. Conclusion

We have studied the human capital development in 19th century Africa, Asia, and the Americas. Our main methodological tool was the age-heaping method that estimates the share of persons who were able to report their age exactly in years. We combined this new data set with the evidence about settler mortality and long-term economic growth to test systematically the views of the colonial legacy literature. Our results indicate that the evidence supports both the Glaeser et al. (2004) views on human capital growth effects as well as the Acemoglu et al. (2001, 2002) view that settler mortality impacted on the quality of institutions. We went a step further arguing that the human capital of the indigenous population and potential spill-over effects were also very important. In our regressions, another growth factor was idiosyncratic educational differences between the indigenous populations of the countries under study. Some of those countries without substantial European immigration had higher human capital investment early on, whereas others did not. Moreover, we found that the combined effects of European immigration and indigenous human capital development might play a role through spill-over effects even where a relatively small immigrant group was present.

We also suggested a slightly different view of the instrumental variable ‘population density around 1500’. The original interpretation was that population density is an indicator of wealth. Because they were rich, they became victims of European exploitative institutions. However, if the migration of Europeans and their importation of

[13] The relationship also holds when GDP(log) data of 1900 are included in models 5 and 6.

human capital is the decisive factor in the development of human capital, the overall human capital in densely populated countries such as Mexico, Egypt or India might have remained low because the number of European immigrants was by far outnumbered by the indigenous population. We found in fact that countries such as Egypt and Mexico stagnated in basic numeracy during most of the 18th and late 19th centuries. Apart from institutional and migration factors, this finding might also have been caused by nutritional and health problems in such densely populated countries and by the high inequality between some elite groups and the majority of the population.

2.9. References

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2.10. Tables

Table 2.1: Settler mortality and population density around 1500 as instruments: IV regression of today's GDP per capita on human capital and institutional quality, instrumented with settler mortality and population density around 1500

	(1)	(2)
Years of schooling (1960-2000)	0.7894***	0.4836**
	(0.2753)	(0.1875)
Executive constraints (1960-2000)	-0.3432	-0.2965
	(0.2577)	(0.241)
Share of population living	-1.6969	-0.0863
in temperate zone (1995)	(1.2053)	(0.7714)
Observations	47	55
R-squared	0.31	0.5

Source: Glaeser et al. (2004). Second-stage regressions. Dependent variable is log GDP per capita in 2000. Both are instrumented with the share of population living in moderate zone, and French legal origin. Moreover, (1) is instrumented with settler mortality and (2) with population density in 1500.
Standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table 2.2: Numeracy as instrument: IV regression of today's GDP per capita (log) on human capital and institutional quality, instrumented with early human capital

Panel A: 1860-1900

	(1)	(2)	(3)	(4)	(5)
Birth decade	1900	1890	1880	1870	1860
Years of schooling	0.632**	0.509***	0.326***	0.205***	0.315***
(1960-2000)	(0.255)	(0.178)	(0.0780)	(0.0600)	(0.0592)
Executive constraints	-0.754	-0.390	-0.0901	0.172	-0.237
(1960-2000)	(0.628)	(0.405)	(0.158)	(0.129)	(0.202)
Constant	8.907***	7.931***	7.629***	6.984***	8.558***
	(1.562)	(0.927)	(0.493)	(0.437)	(0.835)
Observations	43	38	27	23	11
R-squared		0.192	0.428	0.718	0.748

Panel B: 1820-1850

	(6)	(7)	(8)	(9)
Birth decade	1850	1840	1830	1820
Years of schooling	0.337***	0.345***	0.357***	0.333***
(1960-2000)	(0.0238)	(0.0258)	(0.0259)	(0.0163)
Executive constraints	-0.138***	-0.144***	-0.167*	-0.0749
(1960-2000)	(0.0516)	(0.0554)	(0.0856)	(0.0494)
Constant	7.892***	7.851***	7.879***	7.515***
	(0.259)	(0.276)	(0.475)	(0.390)
Observations	8	10	9	8
R-squared	0.955	0.894	0.891	0.901

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. All columns are instrumented with the ABCC numeracy index of the respective birth decade, the share of population living in moderate zone, and French legal origin. See Appendix I for variable sources.

Table 2.3: Country classification by European settler ratio

Countries with a substantial settler community	Settler Ratio	ABCC Non-Europeans	Migration Effect	Countries without a substantial settler community	Settler Ratio	ABCC Non-Europeans	Migration Effect
Algeria	0.13	82	2.40	Bangladesh	0	19	0.00
Bolivia	0.3	54	12.36	Botswana	0.03	89	0.26
Brazil	0.4	79	6.67	Burkina Faso	0	48	0.00
Chile	0.5	78	8.68	Burma	0	85	0.00
Colombia	0.2	71	4.87	Burundi	0.01	79	0.21
Costa Rica	0.2	86	1.82	Cambodia	0	95	0.00
Dominican Republic	0.25	63	8.12	Cameroon	0	58	0.00
Ecuador	0.3	58	11.07	Egypt	0.01	22	0.76
El Salvador	0.2	62	6.69	Gambia	0	49	0.00
Guatemala	0.2	64	6.14	Ghana	0	68	0.00
Honduras	0.2	91	0.72	Guyana	0.02	95	0.06
Mauritius	0.05	97	0.07	Haiti	0	66	0.00
Mexico	0.15	65	4.54	Hong Kong	0.04	98	0.00
Namibia	0.1	80	2.02	India	0	27	0.00
Nicaragua	0.2	59	7.12	Indonesia	0	48	0.00
Panama	0.2	87	1.68	Kenya	0.01	80	0.18
Paraguay	0.25	95	0.12	Liberia	0	75	0.00
Peru	0.3	76	5.61	Madagascar	0	78	0.00
South Africa	0.22	82	3.55	Malawi	0.03	88	0.29
Trinidad and Tobago	0.4	92	2.42	Malaysia	0	87	0.00
Venezuela	0.2	70	5.01	Morocco	0.01	26	0.74
				Mozambique	0.03	72	0.72
				Philippines	0	75	0.00
				Sri Lanka	0	71	0.00
				Tanzania	0	74	0.00
				Togo	0	75	0.00
				Tunisia	0.03	90	0.29
				Uganda	0	67	0.00
				Zambia	0.03	84	0.41

Source: Settler ratio: see Appendix I. Migration effect: authors own calculations: Migration effect $= \mathrm{ABCC}_{\mathrm{all}} - \mathrm{ABCC}_{\mathrm{non-europ}}$
with $\mathrm{ABCC}_{\mathrm{non-europ}} = (\mathrm{ABCC} - \text{settler ratio} \times \mathrm{ABCC}_{\mathrm{europ}})/(1 - \text{settler ratio})$
and with $\mathrm{ABCC}_{\mathrm{europ}}$ = ABCC of colonial power in 1900, namely UK = 98, France = 100, Spain = 95, Belgium = 100, Netherlands = 100, Portugal = 96, Germany = 100, and USA = 98
(Source: Crayen and Baten 2010a).

Table 2.4: Cross-sectional regressions of today's GDP per capita (log)

	(1) baseline model	(2) parsimonious model	(3) GDP 1900 included	(4) GDP1900 included	(5) interaction term incl.	(6) interaction term incl.
European settler mortality (log)	-0.612***	-0.674***	-0.509***		-0.528***	-0.559***
	(0.116)	(0.0895)	(0.0675)		(0.120)	(0.101)
ABCC 1900 (/100)	0.851**	1.102***	0.963***	1.123**	0.946**	0.957**
	(0.359)	(0.383)	(0.298)	(0.507)	(0.404)	(0.413)
French legal origin	0.288		0.376***		0.0696	
	(0.226)		(0.115)		(0.262)	
Temperate zone°	0.706***		-0.0152		0.669**	
	(0.230)		(0.194)		(0.288)	
ABCC 1900 (/100)*NeoEurope					-0.0793	0.377
					(0.377)	(0.233)
ABCC 1900 (/100)*NoSettlers					-0.624*	-0.660**
					(0.349)	(0.304)
GDP/capita 1900 (log)			0.336*	0.687***		
			(0.183)	(0.187)		
Constant	10.15***	10.55***	7.615***	3.169**	10.04***	10.30***
	(0.509)	(0.540)	(1.334)	(1.142)	(0.517)	(0.522)
Observations	47	47	22	23	47	47
R-squared	0.731	0.681	0.883	0.685	0.761	0.744

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. OLS-method. See Appendix I for variable sources. For expository purposes we divided the ABCC values by 100.

° Share of population living in temperate zone.

2.11. Figures

Figure 2.1: Main views on institutional and human capital determinants of income

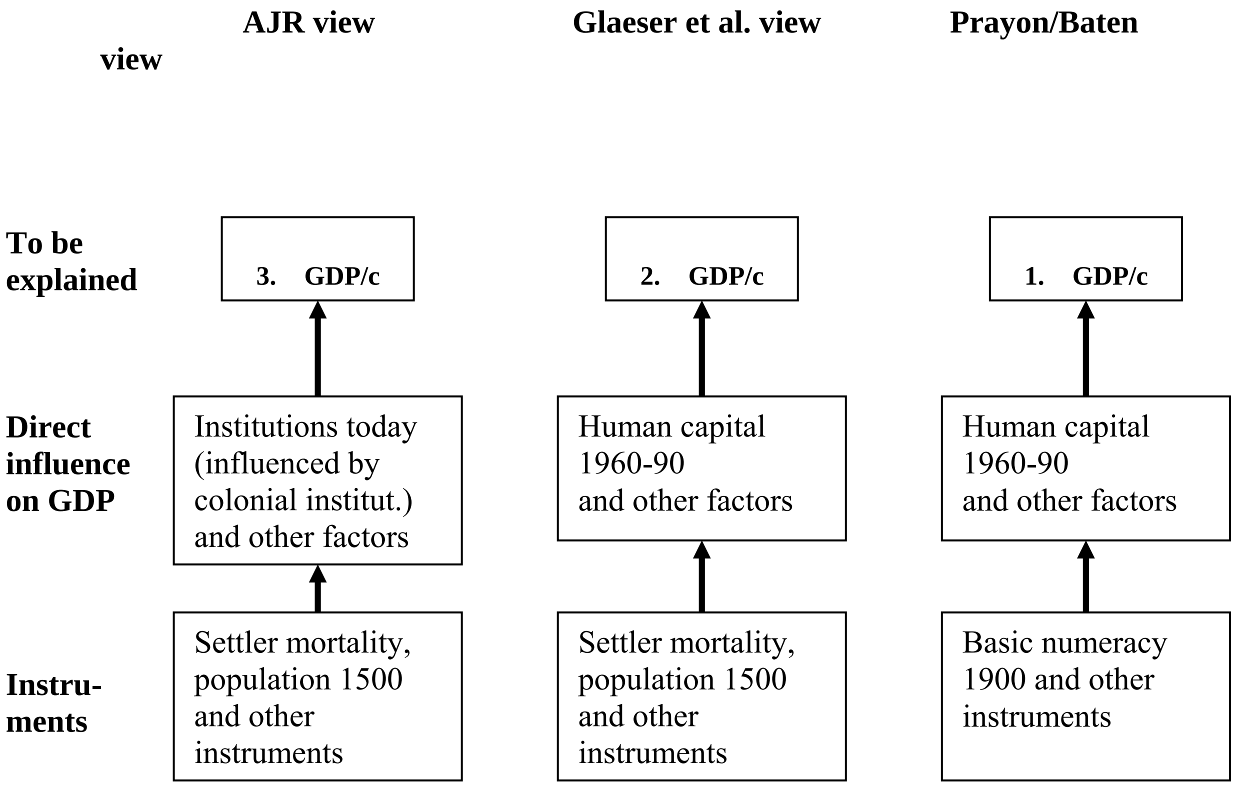


Figure 2.2: Long-run numeracy trends (ABCC-index) for former colonies in the Americas

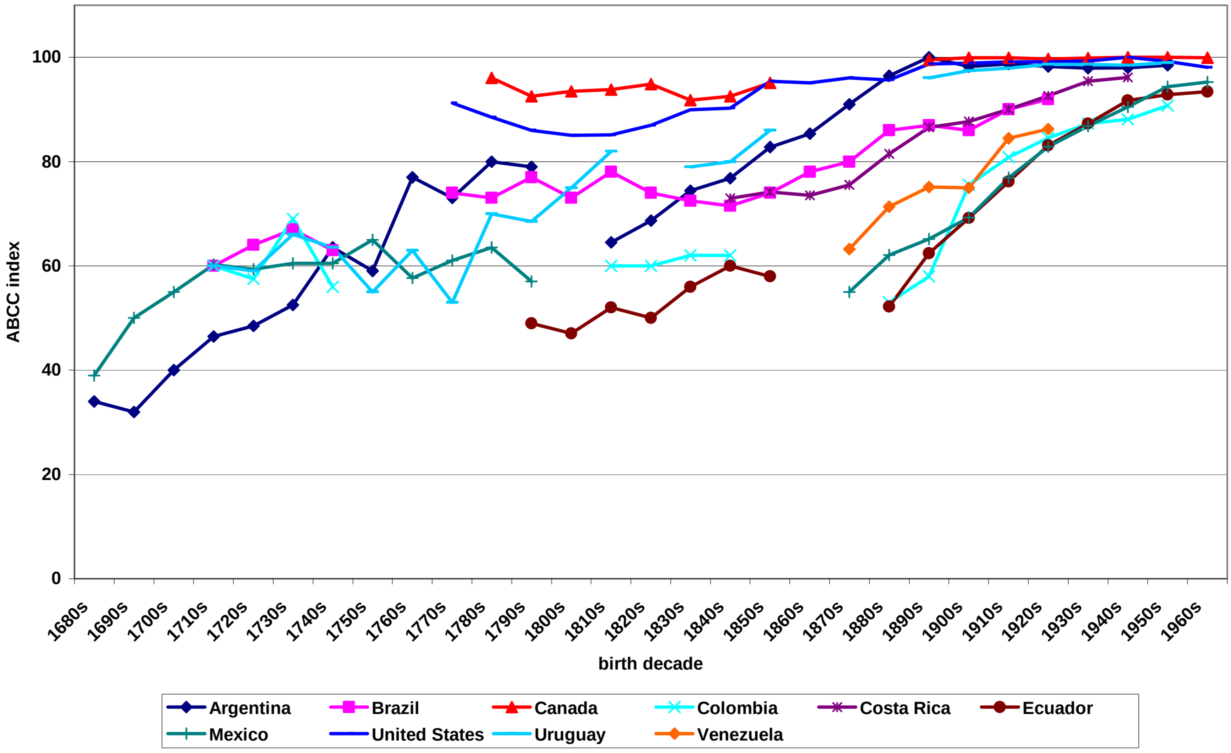


Figure 2.3: Numeracy trends (ABCC-index) for former colonies in the Americas II

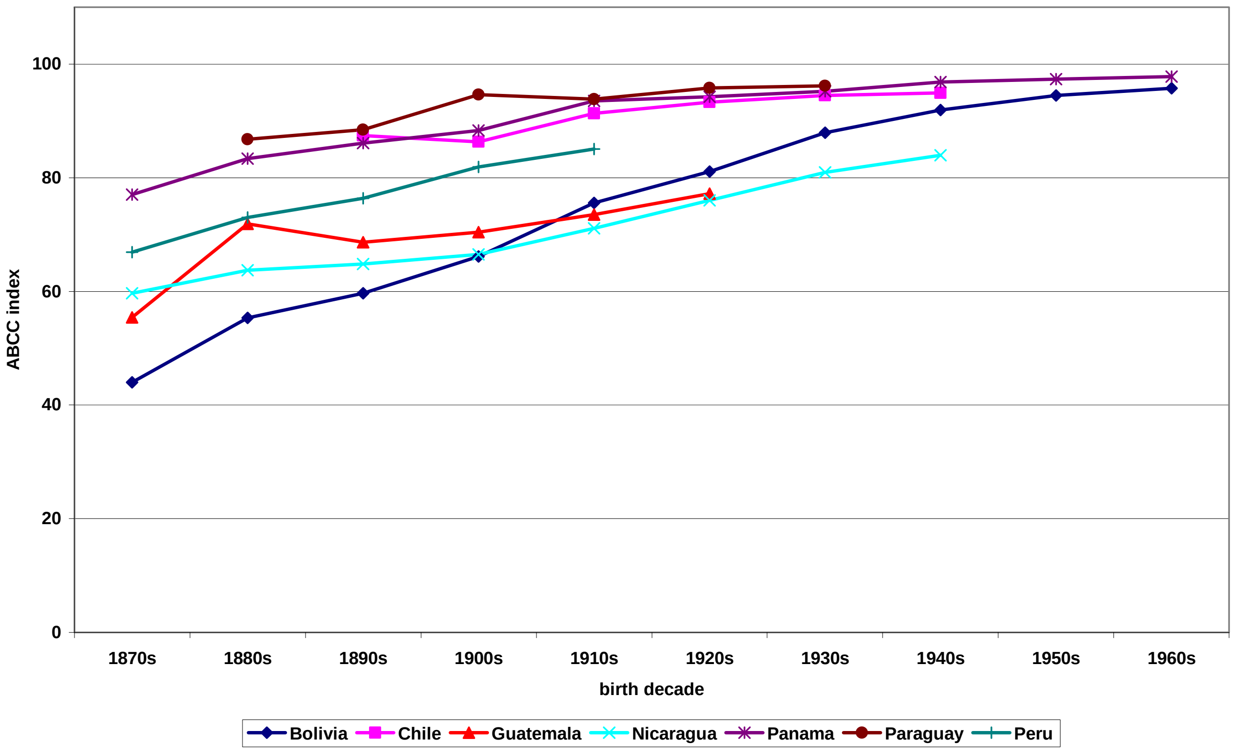


Figure 2.4: Numeracy trends (ABCC-index) for former colonies in the Americas III

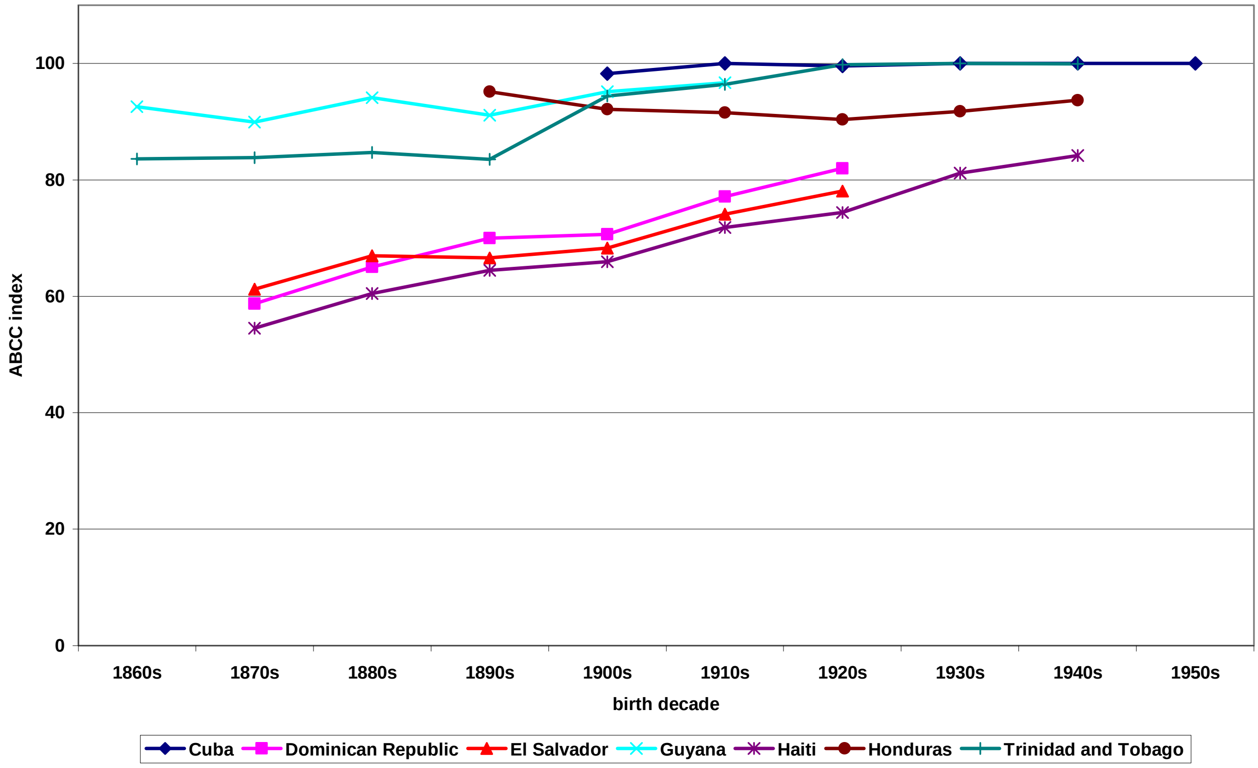


Figure 2.5: Numeracy trends (ABCC-index) for former colonies in North Africa

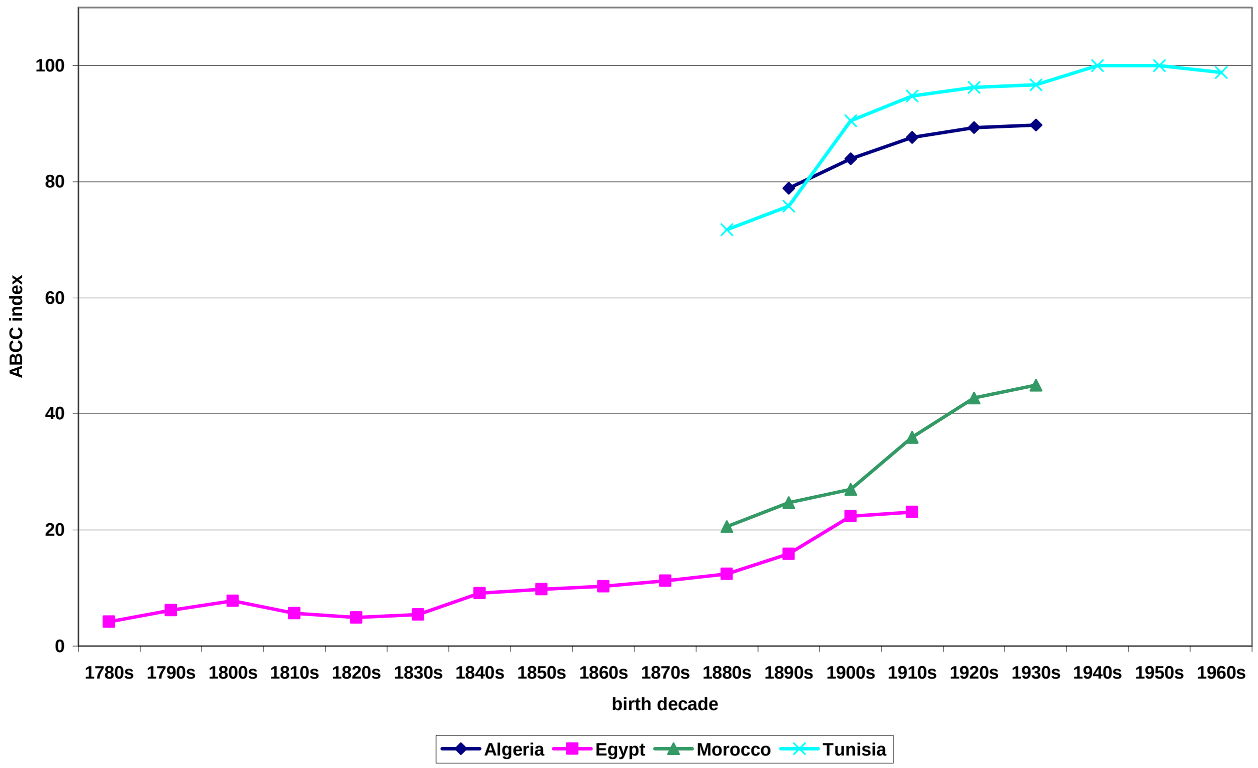


Figure 2.6: Numeracy trends (ABCC-index) for former colonies in West Africa

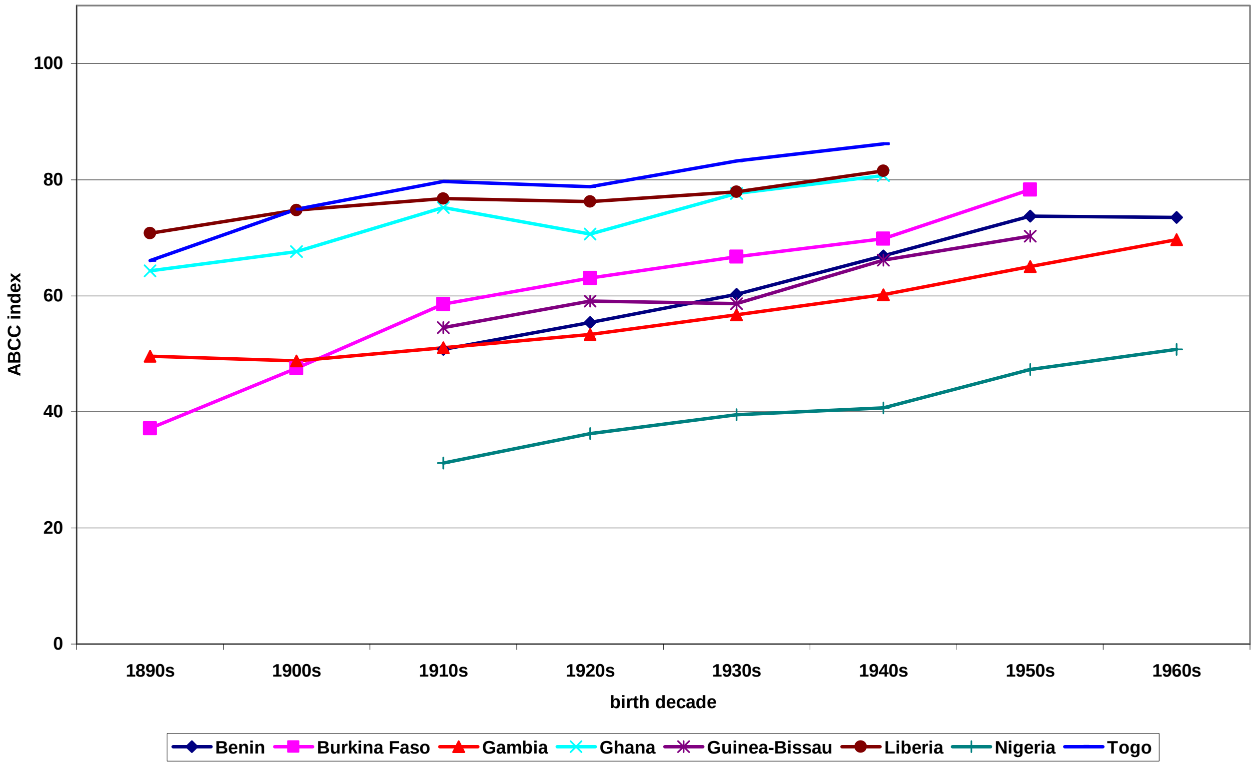


Figure 2.7: Numeracy trends (ABCC-index) for former colonies in Southern Africa

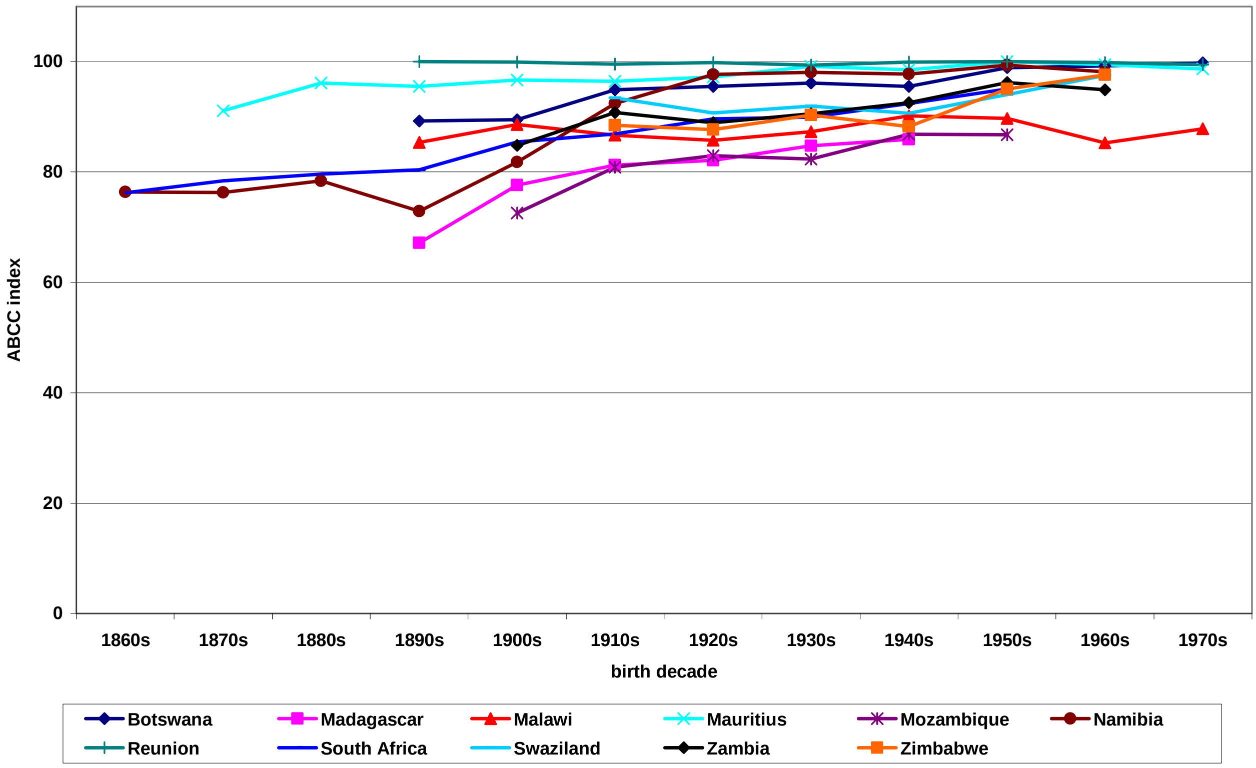


Figure 2.8: Numeracy trends (ABCC-index) for former colonies in Eastern and Central Africa

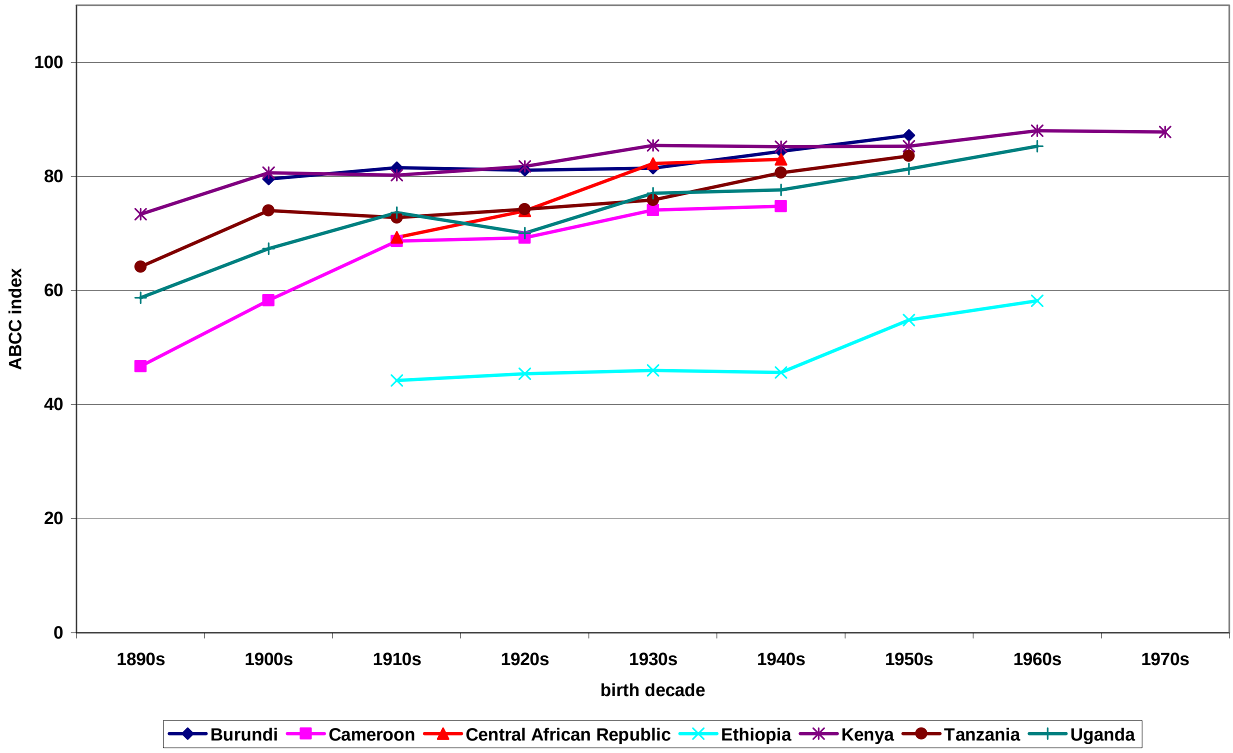


Figure 2.9: Numeracy trends (ABCC-index) for former colonies in Asia and Oceania

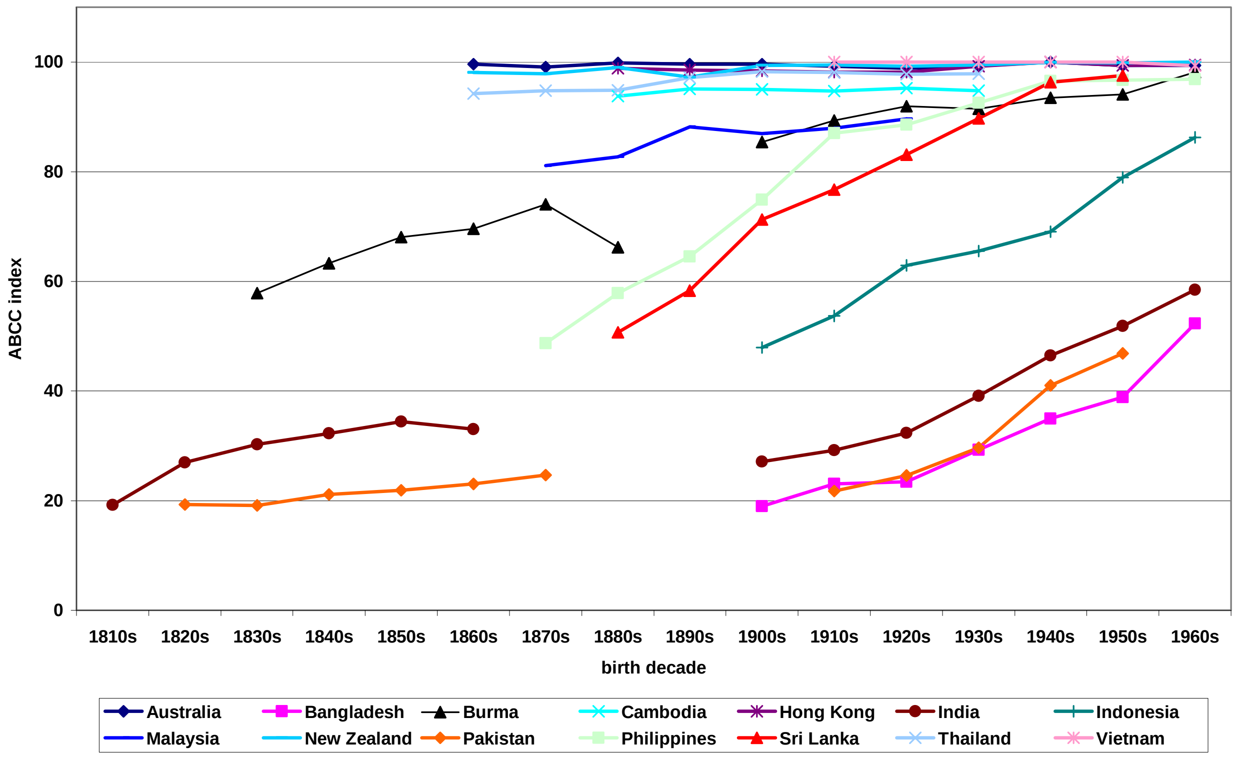
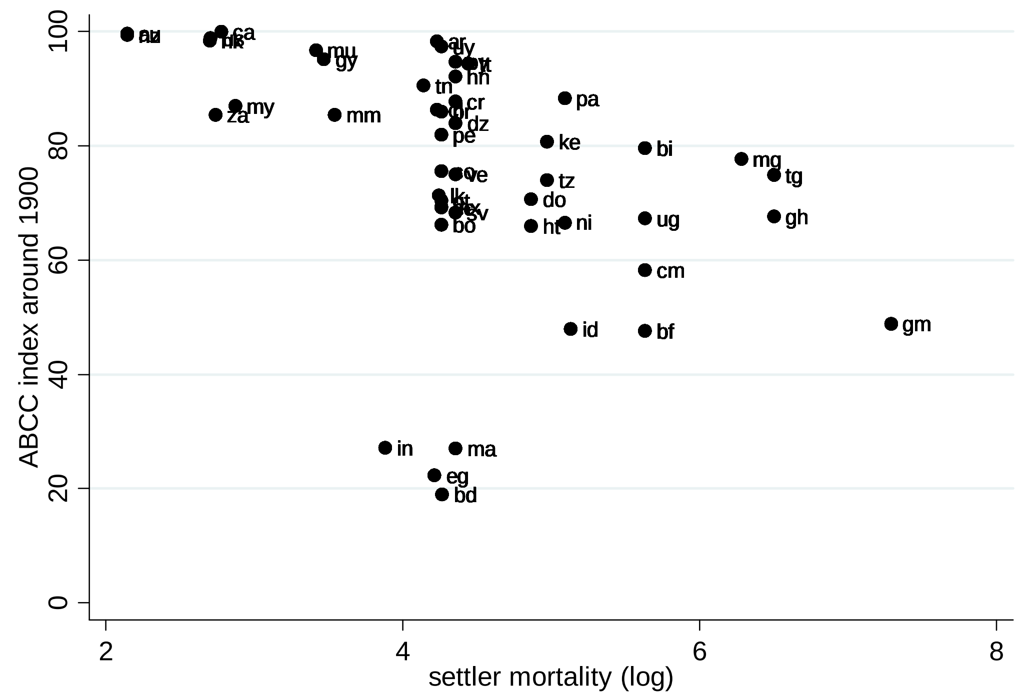
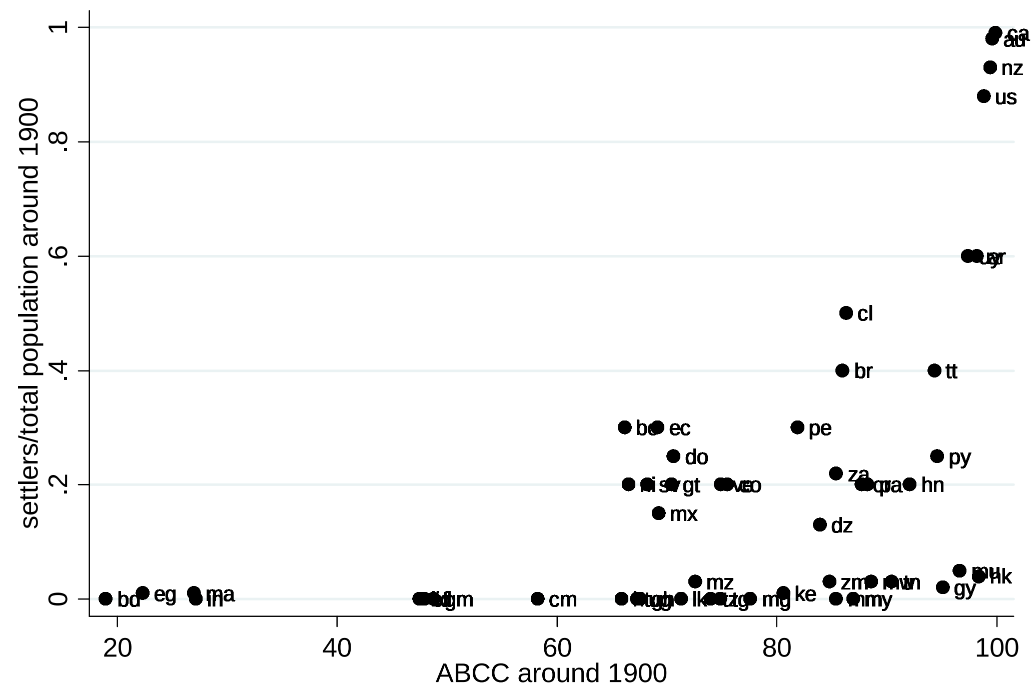


Figure 2.10: Numeracy (ABCC-index) vs. settler mortality (log) in 1900



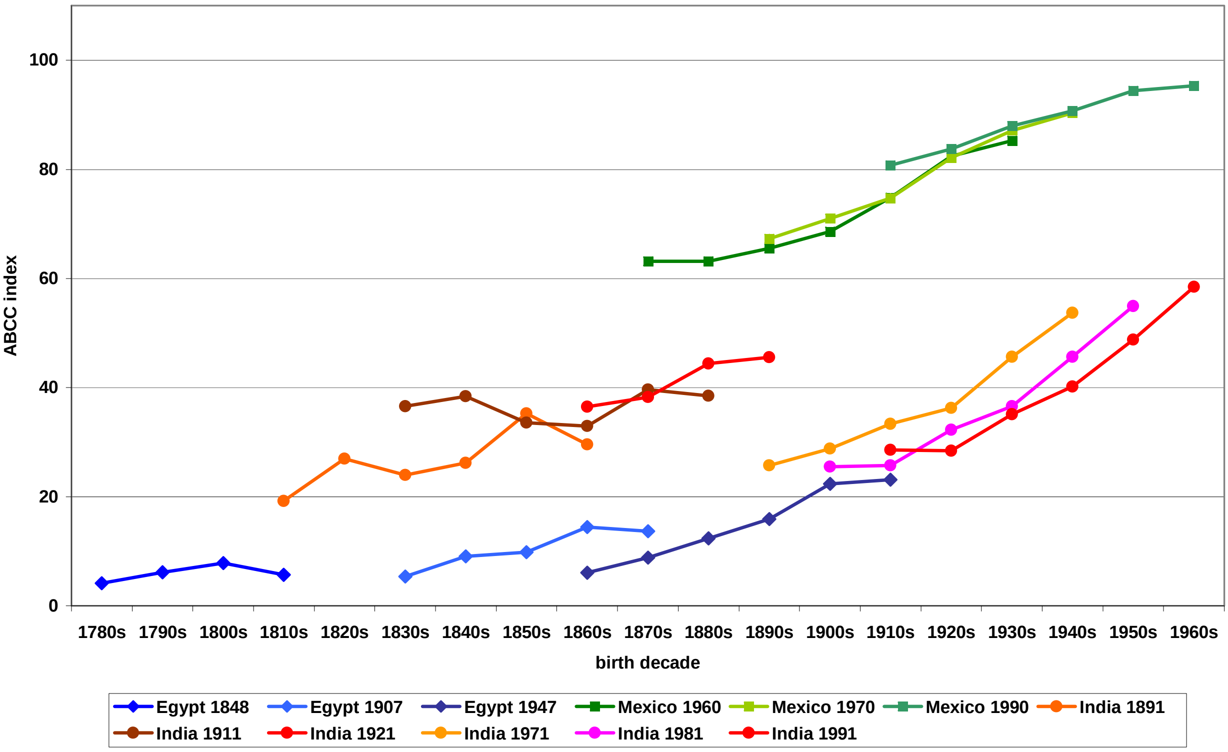
Note: See Appendix for variable definitions, sources and country codes.

Figure 2.11: ABCC values and European settler ratios around 1900



Note: See Appendix for variable definitions, sources and country codes.

Figure 2.12: Example for numeracy trends based on overlapping census data



2.12. Appendix I: Variable Definitions

ABCC
Proxy for basic numerical skills. Linear transformation of the Whipple index. The ABCC index ranges between 0 and 100 (100 = no age heaping, 0 = only ages ending on multiples of 5 are reported). See section 3 for more details.
Sources: See Appendix II.

Executive constraints
A measure of extent of institutional constraints on the decision main powers of chief executives. The variable ranges from 1 (unlimited authority) to 7 (executive parity or subordination). This variable is calculated as the average from 1960 to 2000, whereas the values -66,-77,-88 for periods of interruption or transition were treated as missing values.
Source: Jaggers and Marshall (2000).
Data available online at: http://www.systemicpeace.org/polity/polity4.htm
This paper uses the data from the Polity IV Dataset version p4v2007.

French legal origin
Dummy variable that identifies the French legal origin of the company law or commercial code of each country.
Source: La Porta et al. (1999).

GDP per capita (log)
Gross domestic product per capita.
Source: Heston et al. (2002).
Data available online at: http://pwt.econ.upenn.edu/php_site/pwt_index.php
This paper uses the data from the PWT 6.1 version (reference year 1996).
Missing values for the year 2000 for the Central African Republic, Guyana, Haiti, and Vietnam are interpolated based upon the versions PWT 6.1 and PWT 6.2 (reference year 2000).

GDP per capita 1900 (log)
Mean of decade 1900.
Source: Maddison (2010).
Data for Algeria, Egypt, Ghana, Morocco, South Africa, Tunisia, Vietnam, Thailand, Hong Kong, Nepal, Singapore, and Jamaica come from 1913. Data for Malaysia come from 1911.

Population density in 1500
Total population divided by total arable land in 1500 A.D.
Source: McEvedy and Jones (1978) as cited by Acemoglu, Johnson, and Robinson (2002).

Settler mortality (log)
Log of the mortality rate faced by European settlers at the time of colonisation.
Source: Acemoglu, Johnson, and Robinson (2001).

Settler ratio
Share of population that was European or of European descent in 1900.
Source: Acemoglu, Johnson, and Robinson (2001).
Supplemented with data for Burundi, Namibia, Liberia, Cambodia, and the Philippines from Würzburger and Roesner (1932). Data for Botswana (British Bechuanaland) come from the Census of the Colony of the Good Hope 1904 (1905). Cape Town: Cape Times Ltd.

Share of population living in temperate zone
Percentage of a country's population in Koeppen-Geiger temperate zone in 1995.
Source: Gallup, Mellinger, and Sachs (1999).
Data available online at: http://www.cid.harvard.edu/ciddata/ciddata.html
Additional interpolation: Mauritius coded as Madagascar, Hong Kong coded as Taiwan.

Years of Schooling
Years of schooling of the total population aged over 25. This variable is constructed as the average from 1960 through 2000.
Source: Barro and Lee (2000).
Data available online at: http://www.cid.harvard.edu/ciddata/ciddata.html

2.13. Appendix II: ABCC sources and Country codes

Africa:
Algeria: 1966 (United Nations Demographic Yearbook, hereafter UNDYB); **Benin**: 1979 (UNDYB), 1992 (UNDYB); **Botswana**: 1971 (UNDYB), 1981 (UNDYB), 1991 (UNDYB), 2001 (UNDYB); **Burkina Faso**: 1975 (UNDYB), 1985 (UNDYB); **Burundi**: 1979 (UNDYB); **Cameroon**: 1976 (UNDYB); **Central African Republic**: 1975 (UNDYB); **Egypt**: 1848 (Census of Cairo), 1907 (Census of Egypt), 1947 (UNDYB); **Ethiopia**: 1994 (UNDYB); **Gambia**: 1973 (UNDYB), 1983 (UNDYB), 1993 (UNDYB); **Ghana**: 1970 (UNDYB); **Guinea-Bissau**: 1979 (UNDYB); **Kenya**: 1969 (UNDYB), 1989 (UNDYB), 1999 (UNDYB); **Liberia**: 1962 (UNDYB), 1974 (UNDYB); **Madagascar**: 1975 (UNDYB); **Malawi**: 1977 (UNDYB), 1987 (UNDYB), 1998 (UNDYB); **Mauritius**: 1952 (UNDYB), 1962 (UNDYB), 1972 (UNDYB), 1990 (UNDYB), 2000 (UNDYB); **Morocco**: 1960 (UNDYB); **Mozambique**: 1980 (UNDYB); **Namibia**: 1946 (UNDYB), 1991 (UNDYB); **Nigeria**: 1991 (UNDYB); **Reunion**: 1967 (UNDYB), 1982 (UNDYB), 1990 (UNDYB), 1999 (UNDYB); **South Africa**: 1946 (UNDYB), 1970 (UNDYB), 1980 (UNDYB), 1985 (UNDYB); **Swaziland**: 1997 (UNDYB); **Tanzania**: 1967 (UNDYB), 1978 (UNDYB); **Togo**: 1958 (UNDYB), 1970 (UNDYB); **Tunisia**: 1966 (UNDYB), 1984 (UNDYB), 1994 (UNDYB); **Uganda**: 1969 (UNDYB), 1991 (UNDYB); **Zambia**: 1980 (UNDYB), 1990 (UNDYB); **Zimbabwe**: 1982 (UNDYB), 1992 (UNDYB), 1997 (UNDYB).

Asia/ Oceania:
Australia: 1947 (UNDYB), 1986 (UNDYB), 1991 (UNDYB); **Bangladesh**: 1891 (Census of India, 1891 (Bengal)), 1911 (Census of India, 1911 (Bengal)), 1974 (UNDYB), 1991 (Population Census); **Burma**: 1911 (Census of India, 1911 (Burma)), 1983 (Burma, 1983 Population Census), 1991 (UNDYB); **Cambodia**: 1962 (UNDYB); **Hong Kong**: 1961 (UNDYB), 1976 (UNDYB), 1986 (UNDYB), 1991 (UNDYB); **India**: 1891 (Census of India, 1891 (Bombay, Madras, North-Western Provinces)), 1911 (Census of India, 1911 (Bombay, Madras, United Provinces)), 1921 (Census of India, 1921 (Assam, Bombay, Cochin, Hyderabad, Madras, North-Western Provinces, Oudh)), 1971 (UNDYB), 1981 (UNDYB), 1991 (UNDYB); **Indonesia**: 1971 (UNDYB), 1980 (UNDYB), 1990 (UNDYB); **Malaysia**: 1957 (UNDYB); **New Zealand**: 1945 (UNDYB), 1961 (UNDYB), 1986 (UNDYB), 1991 (UNDYB); **Pakistan**: 1891 (Census of India, 1891 (Punjab)), 1911 (Census of India, 1911), 1921 (Census of India, 1921), 1981 (UNDYB); **Philippines**: 1948 (UNDYB), 1960 (UNDYB), 1990 (UNDYB); **Sri Lanka**: 1963 (UNDYB), 1971 (UNDYB), 1981 (UNDYB); **Thailand**: 1947 (UNDYB) 1960 (UNDYB); **Vietnam**: 1989 (UNDYB).

The Americas:
Argentina: *see Manzel, Baten, Stolz 2012 online appendix p.4/5,* 1980 (UNDYB)*;* **Bolivia**: 1950 (UNDYB), 1976 (UNDYB), 1992 (UNDYB); **Brazil**: *see Manzel, Baten, Stolz 2012 online appendix p.4/5;* **Canada**: 1852 (1852 Historical Census of Canada), 1881 (1881 Historical Census of Canada), 1976 (UNDYB), 1981 (UNDYB), 1991 (UNDYB); **Chile**: 1970 (UNDYB); **Colombia**: *see Manzel, Baten, Stolz 2012 online appendix p.4/5,* 1985 (UNDYB)*;* **Costa Rica**: 1927 (Census of Costa Rica 1927); 1950 (UNDYB), 1963 (UNDYB), 1973 (UNDYB); **Cuba**: 1981 (UNDYB); **Dominican Republic**: 1950 (UNDYB); **Ecuador**: *see Manzel, Baten, Stolz 2012 online appendix*

p.4/5, complemented with new evidence by Christian Schneider (2011), Das Humankapital in den Regionen Ecuadors, Unpubl. Diploma Thesis Univ. Tuebingen, 1962 (UNDYB), 1974 (UNDYB), 1990 (UNDYB)*;* **El Salvador**: 1950 (UNDYB); **Guatemala**: 1950 (UNDYB); **Guyana**: 1946 (UNDYB); **Haiti**: 1950 (UNDYB), 1971 (UNDYB); **Honduras**: 1974 (UNDYB); **Mexico**: *see Manzel, Baten, Stolz 2012 online appendix p.4/5,* 1960 (UNDYB), 1970 (UNDYB), 1990 (UNDYB)*;* **Peru**: 1940 (Census of Peru 1940)*;* **Nicaragua**: 1950 (UNDYB), 1963 (UNDYB), 1971 (UNDYB); **Panama**: 1950 (UNDYB), 1960 (UNDYB), 1980 (UNDYB), 1990 (UNDYB); **Paraguay**: 1962 (UNDYB); **Trinidad and Tobago**: 1946 (UNDYB), 1970 (UNDYB); **United States**: 1850 (IPUMS), 1860 (IPUMS), 1870 (IPUMS), 1880 (IPUMS), 1900 (IPUMS), 1910 (IPUMS), 1950 (UNDYB), 1970 (UNDYB), 1980 (UNDYB), 1990 (UNDYB); **Uruguay**: *see Manzel, Baten, Stolz 2012 online appendix p.4/5,* 1975 (UNDYB), 1985 (UNDYB)*;* **Venezuela**: 1950 (UNDYB), 1981 (UNDYB).

Country codes:

dz	Algeria	et	Ethiopia	ng	Nigeria
ar	Argentina	gm	Gambia	pk	Pakistan
au	Australia	gh	Ghana	pa	Panama
bd	Bangladesh	gt	Guatemala	py	Paraguay
bj	Benin	gw	Guinea-Bissau	pe	Peru
bo	Bolivia	gy	Guyana	ph	Philippines
bw	Botswana	ht	Haiti	re	Reunion
br	Brazil	hn	Honduras	za	South Africa
bf	Burkina Faso	hk	Hong Kong	lk	Sri Lanka
mm	Burma	in	India	sz	Swaziland
bi	Burundi	id	Indonesia	tz	Tanzania
kh	Cambodia	ke	Kenya	th	Thailand
cm	Cameroon	lr	Liberia	tg	Togo
ca	Canada	mg	Madagascar	tt	Trinidad and Tobago
cf	Central African Republic	mw	Malawi	tn	Tunisia
cl	Chile	my	Malaysia	ug	Uganda
co	Colombia	mr	Mauritania	us	United States
cr	Costa Rica	mx	Mexico	uy	Uruguay
cu	Cuba	ma	Morocco	ve	Venezuela
do	Dominican Republic	mz	Mozambique	vn	Vietnam
ec	Ecuador	na	Namibia	zm	Zambia
eg	Egypt	nz	New Zealand	zw	Zimbabwe
sv	El Salvador	ni	Nicaragua		

3. Development and Persistence of Human Capital in Africa since the late 19th Century

Abstract

This study presents new data for the assessment of human capital in Africa for the period 1880 to 1960. The age-heaping method is employed to obtain estimates on basic numeracy for 34 African countries. The data reveal large differences between countries and regions, supporting the assumption that the high educational inequality between countries observed today was already notable during the colonial period. Regression results suggest that primary school enrolment ratios and the presence of European settlers in the colonies played the most important roles in determining basic numerical skills.

The main finding is that countries with underdeveloped human capital early on face a similar situation today and only a few countries escaped the trap created by early educational underdevelopment through consequent investments in schooling. Even after controlling for factors like school enrolment and public expenditure on education, the numeracy level 100 years ago still has a significant influence on literacy rates today in Africa.

3.1. Introduction

Most African countries still belong to the group of the least developed countries in the world today (see e.g. United Nations Development Programme 2009). One important driving force of economic and social development is human capital (see e.g. Mankiw et al. 1992). Therefore, education is a crucial matter. Unfortunately, the United Nations has a dim forecast for the ability of many African countries to meet the Second Millennium Development Goal ("ensure that, by 2015, children everywhere, boys and girls alike, will be able to complete a full course of primary schooling")[14], especially so for sub-Saharan Africa. According to available data, half the countries in sub-Saharan Africa have more than 30 percent of their primary-school students drop out before reaching the final grade. A glance at the state of Africa's human capital today not only reveals underdevelopment in comparison to other world regions but also large differences between countries. Countries like South Africa, Zimbabwe and Namibia have literacy rates over 80 percent, whereas others, such as Burkina Faso and Mali, do not exceed a literacy rate of 20 percent. School enrolment rates display a similar discrepancy.

A number of studies on colonial education spurred discussion on the historical roots of education and schooling in Africa (e.g. Bolt and Bezemer 2009, Huillery 2009, Gallego and Woodberry 2010, Gallego 2010, Frankema 2012). Prior to the arrival of the Europeans, education was more informal and mainly provided by families, the village community or trading networks (Frankema 2012). Western-style, formal education was introduced in Africa under colonial rule. Christian missionaries played a crucial role in this change: According to Woodberry (2004), over 90 percent of Western education in sub-Saharan Africa during the colonial period was provided by missionaries. Additionally, the different schooling policies of the colonial powers meant the

[14] The Millennium Development Goals Report 2010, *United Nations*, p.16.

development of different educational systems in Africa: The British government focused on basic education of the broad population, while France was typically more interested in educating the elite. This pattern is reflected in primary school enrolment rates during the period 1870 to 1940, with British colonies showing higher enrolment rates than French colonies (Benavot and Riddle 1988). France introduced French as the language of instruction in its colonies, while the British recommended that local languages be used in primary school instruction (White 1996).

Some studies examine colonial education on a disaggregated level, revealing a picture more precise than the one obtained by looking only on a national level. Frankema (2012), for example, shows that school enrolment rates varied at least as much within British Africa as between British and non-British colonies. Further, Gallego and Woodberry (2010) demonstrate the importance of the competition between Catholic and Protestant missionary work. In areas where missionary work was regulated in favour of Catholic missionaries, Protestant missionaries appear to have been more productive in recruiting pupils. In areas without state protection, Catholic missionaries were at least as active and innovative as their Protestant counterparts. The authors conclude that - when controlling for Protestant missionary activity - coloniser's identity loses its explanatory power in predicting education during colonial times.

The aim of this study is to present new data on the condition of human capital in Africa between 1880 and 1960 and add this evidence to the ongoing discussion concerning the colonial origins of education in Africa. Using the age-heaping method (as applied by A'Hearn et al. 2009, Crayen and Baten 2010a, 2010b), data on basic numeracy for 34 African countries are calculated. The advantage of these data is that basic numeracy captures an output measure of human capital, similar to writing and reading skills: Either people are able to calculate their age, or they are not. Enrolment rates and pupil/ teacher ratios, on the other hand, are input factors (or quantity factors) of human capital and do not give us information on the output (or quality) of education.[15] Numerical skills are an important facet of human capital, as economic activities in particular require the proper handling and manipulation of numbers. The calculated numeracy levels reveal a high variation between countries and between regions for the period under observation. An important aim of this paper is to explore determinants of these differences in basic numeracy.

Additionally, this study addresses the question of whether the educational differences observed in Africa today were visible 100 years ago and examines how the educational situation changed over the course of the 20th century. A high persistence of human capital measured with schooling data and based on former colonies is described by Gallego (2010). Bolt and Bezemer (2009) also report a high correlation between African educational standards in colonial times and Africa's educational achievements in 1995. The results of the study at hand indicate that numeracy levels from around the year 1900 are reflected in literacy levels today. That is to say, the countries with the lowest numeracy levels in 1900 are virtually the same countries showing the lowest literacy rates in the present (with a few exceptions).

The paper is organized as follows. Section 2 describes the age-heaping method which is used to obtain new human capital estimates for colonial Africa. Section 3 presents the new data. Section 4 discusses the possible determinants of numeracy levels in Africa during the period 1880 to 1960 that could help explain the high variation between countries. An empirical analysis of those determinants is provided in section 5. Section 6 discusses the high path dependency of human capital in Africa. Section 7 concludes.

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[15] In contrast, literacy rates reflect at least partially the outcome of schooling policies of a country.

3.2. Age-heaping: A proxy for basic numerical skills

Measuring the production factor 'human capital' is a major task for social scientists working with empirical data; they must not only find an appropriate method of measurement but also data appropriate for capturing human capital. This is even more challenging for economic historians, as data on education are scarce for the most part of human history, with some geographic regions lacking data all the way up until the 20th century. This is especially the case for Africa, where the earliest literacy data for a broad population base are virtually non-existent before 1960. The earliest data on human capital that extensively cover Africa are enrolment rates collected by Benavot and Riddle (1988) for the period 1880 to 1940. Bolt and Bezemer (2009) collected data on the ratio of total numbers of pupils to total population during colonial times. Similarly, for French West Africa, Huillery (2009) compiled a data set on the number of teachers per 100,000 habitants. Frankema (2012) presents new gross primary school enrolment rates in British Africa for the period 1830 to 1950.

To add to the current stock of human capital data for the first half of the 20th century in Africa, the so-called age-heaping strategy is used in this paper. This approach is based on the phenomenon that people in less educated societies tend to round their age if unable to recall or calculate their exact age when asked. For example, they may state their age as 40 even though they are in fact 39 or 42.[16] The age-heaping method is usually applied to less developed countries in the past. This is due to the fact that after the mid-19th century, today's industrialized countries ceased to show meaningful age-heaping. In these scenarios, indices of more advanced human capital, e.g. years of schooling, have to be applied to capture differences between the countries. However, the tendency of rounding ages can still be found in present-day developing countries despite a quite developed administration with obligatory schooling, birth certificates, passports etc.

[16] See Figure A.1 in the Appendix for an example of extreme age heaping.

Age-heaping is a well-known phenomenon among demographers who treat it as a statistical problem, as it distorts age distributions. Most demographers, including those at UN statistical departments, calculate Whipple indices to measure the accuracy of age statistics, with high Whipple indices indicating unreliable data.[17] The Whipple Index is constructed as follows (n_x is the population of age x):

$$(1) \quad WI = \left(\frac{n_{25} + n_{30} + ... + n_{65} + n_{70}}{1/5 \times (n_{23} + n_{24} + n_{25} + ... + n_{72})} \right) \times 100 \text{ if } WI \geq 100; \text{ else } WI = 100.$$

Thus, the index measures the proportion of people who state an age ending in a 5 or 0, assuming that each terminal digit should appear with the same frequency in the 'true' age distribution.[18] The study at hand uses the so-called ABCC index as suggested by A'Hearn, Baten, and Crayen (2009). It is a simple linear transformation of the Whipple Index with a range from 0 to 100, where 0 indicates that only ages ending in 0 and 5 (significant age-heaping) are reported and 100 indicates no age-heaping at all. Thus, the interpretation of the ABCC Index is more intuitive than that of the Whipple Index: The higher the ABCC value, the better the basic numerical skills:

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

Here, we interpret the phenomenon of age-heaping from a different point of view. We do not associate high Whipple Indices with a data problem but rather with a lack of numerical skills of the population. As less educated people often choose ages with digits ending in multiples of five, the share of persons able to report their exact age is an indicator for numerical skills, and therefore age-heaping can be used as a human capital indicator.

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[17] See, for example, United Nations Demographic Yearbook 1993, p.19.

[18] 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. Whipple Indices below 100 (ABCC indices above 100, respectively) in the 20th century rich countries are normally caused by random variation, hence those values are normally set to 100.

The age-heaping method is usually only applicable to the age group 23 to 72. Children usually do not state their age by themselves. Among young adolescents a heaping pattern on even numbers as well as on special ages is visible. This is due to the fact that young people are more aware of their age due to their 'fresh' memory of important events in their life. Among old people a certain tendency for exaggeration and/or general obliviousness makes the age-heaping method unreliable. Additionally, a possible survivor bias has to be taken into consideration as the more educated usually fall into the wealthier social strata and have a longer life expectancy. Crayen and Baten (2010a) examined a possible correlation between age and age-heaping and found only a systematic influence of age on the heaping behaviour among the youngest age group (age 23 to 32). People at this age tend to heap less relative to people in older age groups who, on average, round as strongly as expected for their birth cohort. Based on this observation, Crayen and Baten suggest an adjustment of the numeracy index for the youngest birth cohort which is applied in this study.[19]

The usefulness of age-heaping as a human capital indicator was first suggested by Bachi (1951), who found an inverse correlation between age-heaping and educational levels within and across countries. Mokyr (1983) pioneered the use of age-heaping in the field of economic history. Crayen and Baten (2010b) found that age-heaping tends to be more pronounced in population groups with lower incomes and/or lower-status occupations.

Several studies confirm a positive correlation between age-heaping as a proxy for basic numerical skills and other human capital indicators. In their global study on age-heaping for the period 1880 to 1940, Crayen and Baten (2010a) identified primary school enrolment as a main determinant of age-heaping: an increase of enrolment rates lead to a significant decrease in age-heaping. Manzel et al. (2012) found the same close correlation

[19] Crayen and Baten (2010a, Appendix, Footnote 21) suggest the following adjustment for the youngest age group (23-32): $WI_{23\text{-}32}$: (WI-100)*0.25+WI.

between schooling and basic numeracy in Latin America for the period 1870 to 1930. A'Hearn, Baten, and Crayen (2009) examined the U.S. Census of 1850, 1870, and 1900 and found for the overall sample and sub-samples a positive and statistically significant relationship between literacy and basic numeracy. They also studied the relationship of signature ability as a proxy for literacy and age-heaping as a proxy for numeracy in early modern Europe. Here as well they found a positive correlation between the two measures. In a study on China, Baten et al. (2010) found a strong relationship between age-heaping and literacy among Chinese immigrants in the U.S. born in the 19th century. Friesen et al. (2012) found a high correlation between literacy and basic numeracy for the first half of the 20th century in Asia. Additionally, Hippe (2012) examined the relationship of basic numeracy and literacy on the regional level in seven European countries in the 19th century and in ten developing countries in the 20th century. For every country studied, he found a high correlation between the two indicators. Thus, even though the systematic study of age-heaping as a proxy for human capital has occurred primarily in the past few years, the correlation between basic numeracy and other human capital indicators can be regarded as well-established.

Indeed, the age-heaping method displays advantages that other human capital indicators (like literacy, enrolment ratios or years of schooling) lack. Due to the consistent calculation of the Whipple Index, age-heaping results might be more easily comparable across countries, whereas comparisons of literacy and enrolment rates might be misleading due to significant measurement differences or different school systems. Further, owing to typically high drop-out rates in developing countries and heterogeneous teacher quality, it can be argued that enrolment rates are less conclusive as enrolment ratios are an input measure of human capital. Although a country might have comparatively high enrolment rates, this fact does not permit conclusions about the quality of education. Age-heaping on the other hand is - like literacy - an output measure of human capital, i.e. either people state their age exactly and reveal so a certain ability for basic arithmetic, or they do not.

Another advantage of the age-heaping method is its applicability to a wide range of data sources, for instance census records, passenger lists, and other kinds of individual age recording. For many countries, individual age records are easier to obtain and/or more readily available for historical time periods than detailed information on education. In addition, the age-heaping method can capture information about specific social groups (i.e. women, ethnic groups, marginal groups) that might be neglected by other indices. To conclude, the age-heaping method is useful and highly valuable for the study of the long-term development of human capital, as it is possible to trace the basic numerical skills of populations for time periods and geographical locations where no other human capital indicators currently exist.

Like other proxies, the age-heaping measure has its limitations. It only captures age-heaping on multiples of five, although people in their late teens and early-20s tend to round on multiples of two. In addition, some cultures have specific number preferences, for example the number eight or the dragon year in China. However, Baten et al. (2010) find that these preferences do not distort the index much. Similarly, if individuals were asked for their date of birth instead for the age at their last birthday, a birth year-heaping pattern was seen in certain cases. In cases of cultural number preference and birth-year heaping the age-heaping method does not return unbiased estimates, so the age-heaping pattern of each underlying population should be checked carefully before applying this method. Further, meaningful results are hard to obtain when this method is applied to populations with almost full numeracy because its upper boundary hampers variation.

For the explanatory power of the age-heaping method it is important to know if age information was derived from statements made by the individual himself, a second party (e.g., a husband gives the age of his wife), or estimates made by the enumerator.

The known facts about the census data used in this study and the way they were collected supports the assumption of reliable data quality. First, most of the censuses were conducted between the 1960s and 1990s, when most countries had adopted international census standards as promoted by the United Nations. The personnel was trained and briefed before conducting the census, helping to ensure a certain level of quality and consistency in the data collection process. Second, in countries with prevailing illiteracy, censuses are usually conducted with the help of canvassers instead of relying on self-enumeration, lowering the probability that the interviewed individual made up some answers.

However, the use canvassers introduces another possible bias: ”If that [age] is not known, then an estimate of the age is made by the trained canvasser following determined guidelines, for example, that are based on a calendar of local historical events” (Domschke and Goyer 1986:20). It is remarkable that strong age-heaping exists even when the historical calendar method is used in developing countries since one would assume a lesser degree of age-heaping. It seems, therefore, that it does not make a difference whether the individual or the canvasser reports a rounded age in the event that true age is unknown.[20] A study by Scott and Sabagh (1970) supports this view. They investigated the behaviour of canvassers during the Moroccan Multi-Purpose Sample Survey of 1961-1963 and found that the canvassers often reported rounded ages for people who did not know their own age. The interesting feature in this case is that between 70 and 90 percent (dependent on the underlying age group) of the people interviewed did not know their age, and therefore the historical calendar method was applied. Expressed in ABCC values this would imply an overall numeracy level somewhere between 10 and 30 ABCC points. And indeed, this fits with the calculated

[20] This applies also to another problem: “It was not practical to ask the date and year of birth in a country where the Mohammedan, Coptic and Roman calendars are in use.” Source: The 1953 pilot population census for the first population census in Sudan 1955 (p.30).

age-heaping level observed in Morocco for the 1960 census, namely an ABCC level between 20 and 40 (see section 3.3).

3.3. The development of African numeracy

Most of the underlying data for the following numeracy trends come from national censuses conducted between the 1940s and 2001, as reported by the United Nations Demographic Yearbooks.[21] Age distribution data for almost all African countries are included in the base data set. However, not all data are suitable for calculating age-heaping levels due to smoothing of the data by the statistical offices (e.g., in the case of the 1993 Sudanese census) or preferences for certain ages – mostly birth-year heaping – that cannot be captured with the conventional ABCC index (heaping on multiples of five). Also, only census data covering the whole population (and not only the 'non-indigenous population' as e.g. in Madagascar 1951) are considered.[22] Finally, age distribution data from 72 different censuses are included in the following analyses (see list of censuses in the Appendix).

In the first step, ABCC indices for age groups ranging from 23 to 32, 33 to 42, …, 63-72 are calculated according to formula (2). In the second step, these indices are assigned to the corresponding birth decades. This procedure is based on the assumption that basic numeracy is acquired during the first decade of life (see Appendix of Crayen and Baten 2010a). In the case that data overlap for one or several birth decades within a country because more than one census was available for this country, the arithmetic average of the indices was calculated.[23] Figures 3.1 through 3.4 show the numeracy trends

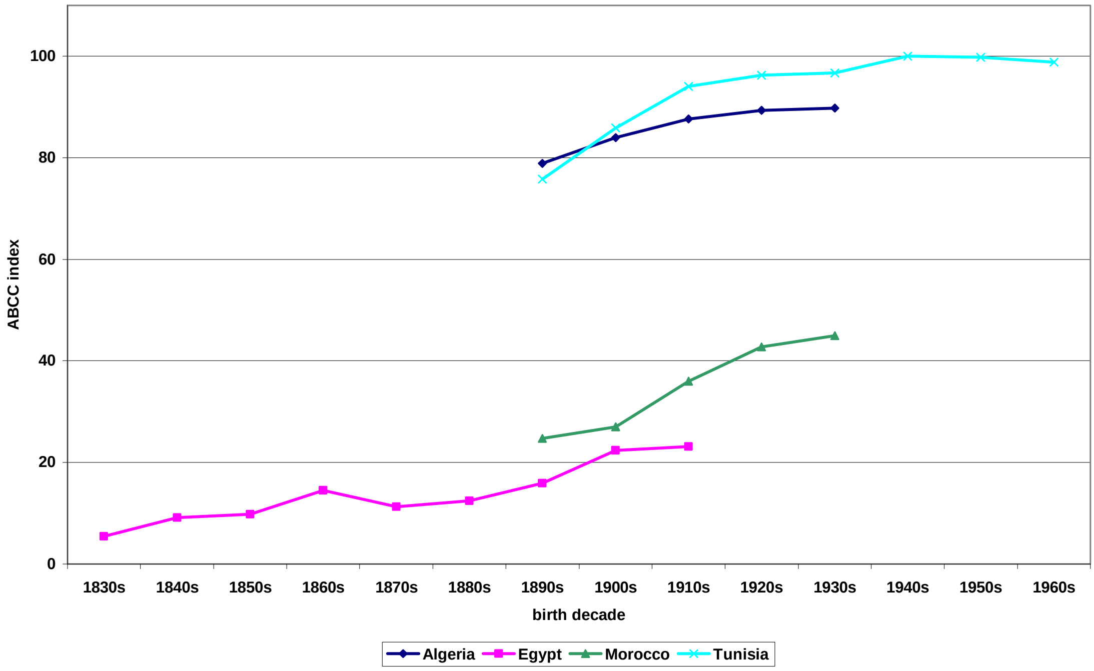
[21] See Appendix for the list of censuses.

[22] According to the United Nations Demographic Yearbook, few census data have not been adjusted for underenumeration (for example Cameroon 1976). Because the UN assumes the underenumeration usually not higher than 4 percent, this is not considered as problematic for the representativeness. Hence, those data were included in this study.

[23] Prayon and Baten (2012) and Friesen et al. (2012) show several examples of overlapping census data. These trends show that, although the data come from different census years, they correspond quite well, i.e. no effects of better 'census-taking' or learning effects among adults are visible. This finding is an important difference to literacy. Doing the same procedure with literacy rates, we often find quite strong differences

for Africa, divided into broad regions. Table A.1 in the Appendix presents the corresponding ABCC values and Table A.2 summarizes the single age returns underlying these values.

Figure 3.1: ABCC index development in the North African region



The North African region shows the largest variation of age-heaping, with Egypt and Morocco on the lower bound and Algeria and Tunisia on the upper bound (Figure 3.1). Egypt displays the worst numeracy trend observed so far, both for Africa and worldwide. Numerical skills do not improve much over almost a century. At the beginning of the 20th century, only 20 percent of the Egyptian population could state their age exactly. Even though the trend in Morocco is much shorter, numeracy level was almost as low as that in Egypt at the turn of the 20th century, leading to the assumption that Morocco had a similarly low level during the 19th century. The other two countries of

between different census years for the same birth cohorts. Hence, for literacy learning effects later in life are much more common than for basic numeracy. This finding confirms the assumption that the latter is acquired mainly during the first decade of life.

this region stand in extreme contrast to Morocco and Egypt. The French settler colonies Algeria and Tunisia show numeracy levels over 80 ABCC points around 1900 and the levels show continual improvement throughout the early decades of the 20th century.

The graph of numeracy trends in West Africa shows a large variation in basic human capital among the countries (Figure 3.2). The ABCC indices range from 40 points in Nigeria to almost 100 points in Cape Verde. The numeracy levels of all countries show improvement during the period under observation. Burkina Faso shows the strongest increase in numeracy, gaining over 30 ABCC points in half a century.

Figure 3.2: ABCC index development in the Western African region

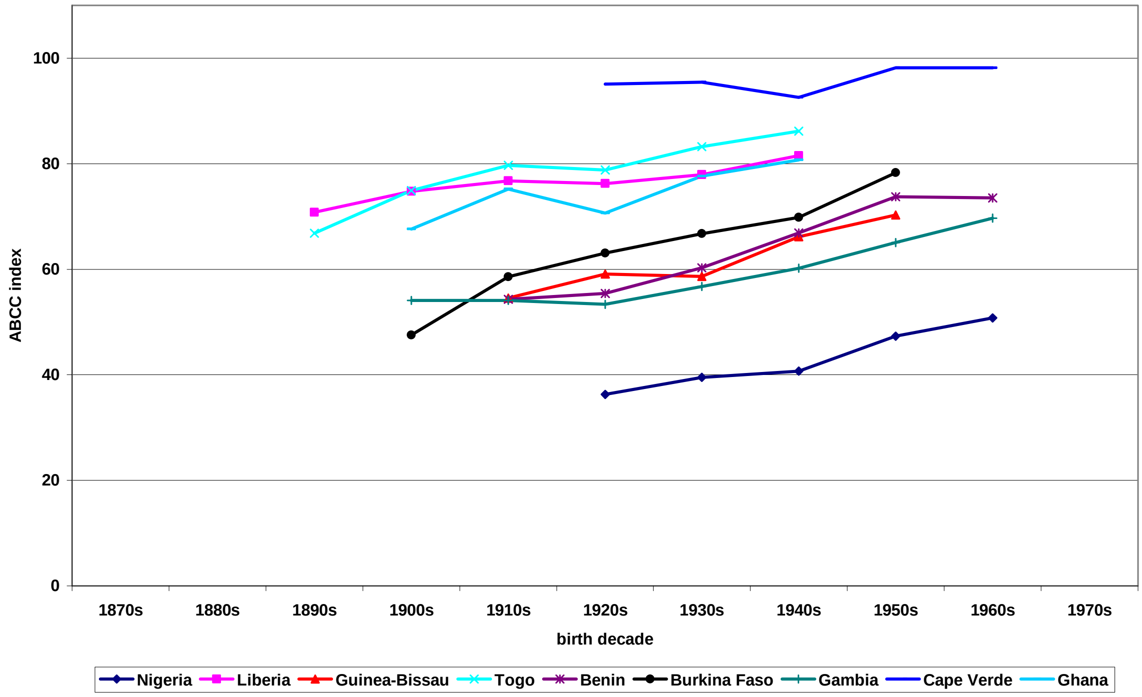
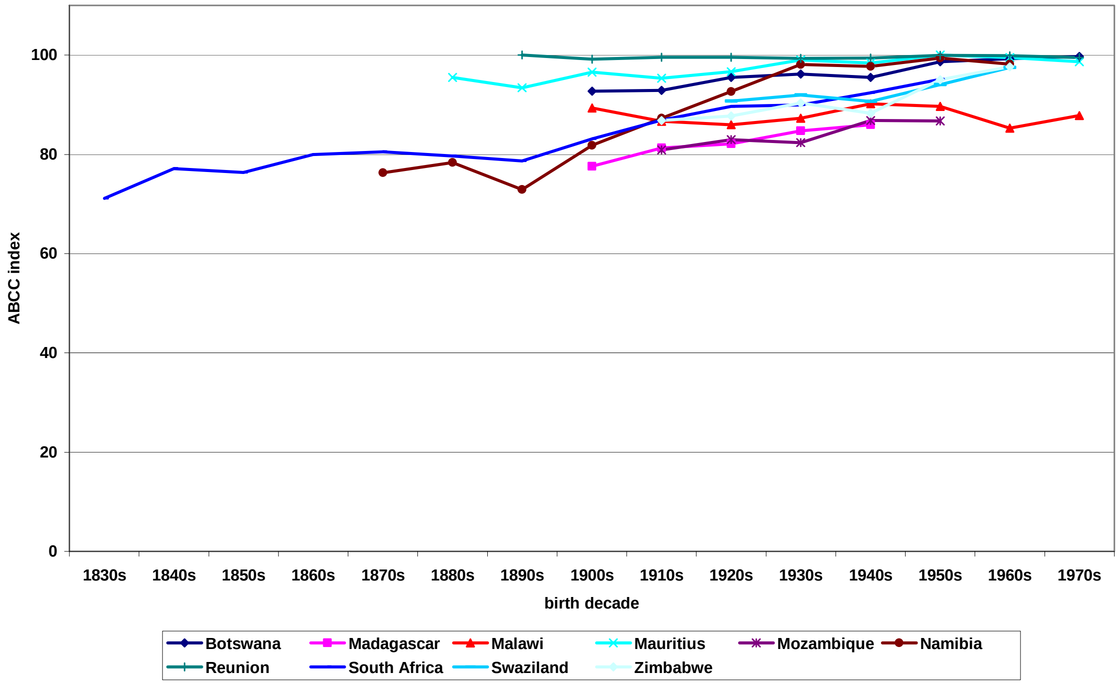


Figure 3.3 illustrates the high numeracy levels of the countries of Southern Africa around 1900. All countries range broadly between 80 and 100 ABCC points. The trend in South Africa is the longest of all African trends and spans one hundred years. As early as the 1830s the South African people had a numeracy level of 70 ABCC points. The island-countries of Mauritius and Reunion have the highest numeracy scores among this group;

Madagascar and Mozambique have the lowest. Malawi shows no improvement in numeracy level is quite interesting: it does not improve its numeracy level during the period under observation, stagnating at around 85 ABCC points. The country which experienced the greatest increase in numeracy levels is Namibia.[24]

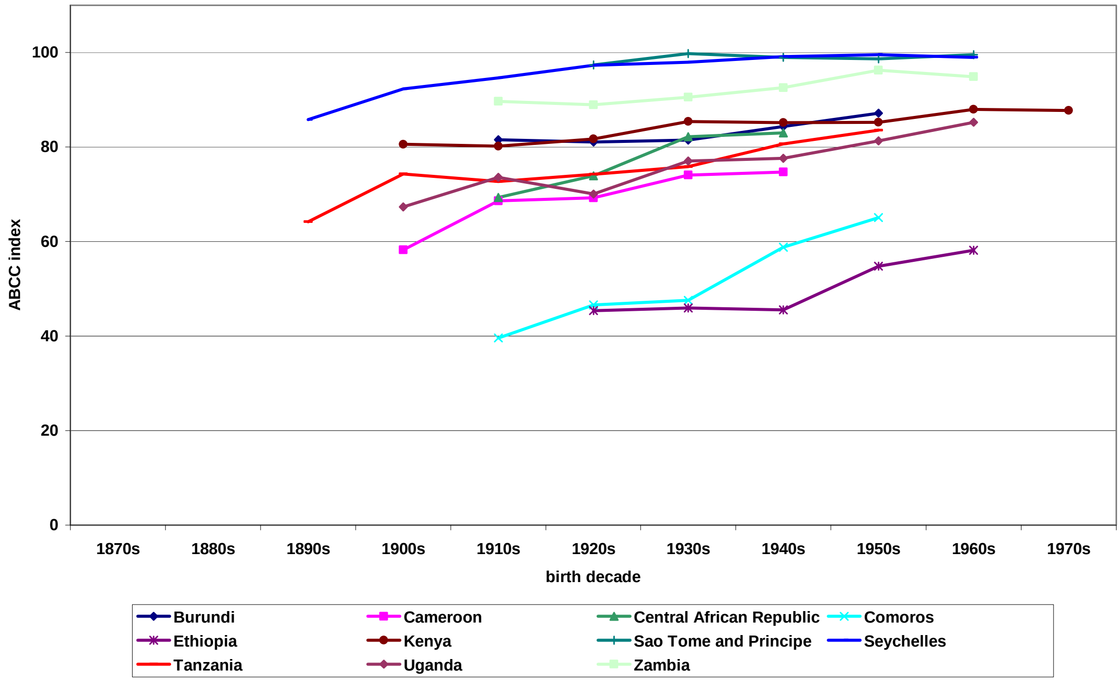
Figure 3.3: ABCC index development in the Southern African region



Similar to the Western region, East and Central Africa show a big variation of numeracy levels among countries (Figure 3.4). The Comoros and Ethiopia stand out from the others with significantly poorer performance. In the Comoros, numeracy increases quite rapidly from the 1930s onwards, and numeracy levels start rising in Ethiopia a decade later. On the opposite side of the spectrum, Kenya, for example, starts high with 80 ABCC points in the 1900s but improves its numeracy level by only five points over the next seven decades. On the islands of the Seychelles and Sao Tome and Principe, the population reaches full numeracy (i.e., people know their exact age) in the 1930s/1940s.

[24] Note that the data for Namibia in 1910 and 1920 reflect are linear interpolation between the earlier census and the subsequent census.

Figure 3.4: ABCC index development in the Eastern and Central African region



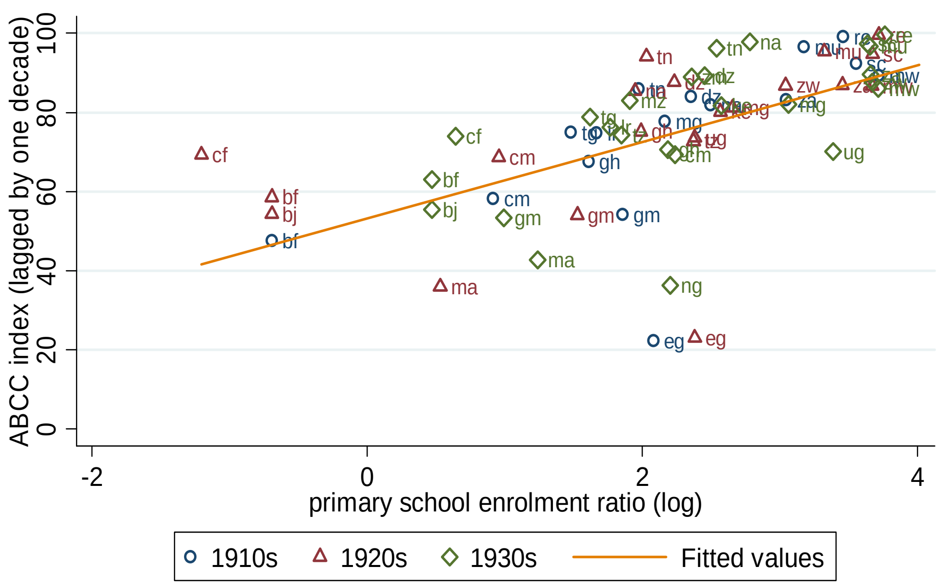
Looking at all available numeracy data for Africa, only Tunisia, the Seychelles, Sao Tome and Principe, Reunion, Mauritius, Zimbabwe and Botswana had mostly solved their basic numeracy problems by the mid-20th century. The overall bad performance of Africa is especially striking when compared to today's so-called industrialized regions (Western Europe, Northern America, Japan, New Zealand and Australia), all of which reached 100 ABCC points by the mid-19th century (see Fig.A.2, here the trends of the United Kingdom and France are shown). The only region that performs even worse than most African countries is parts of the Indian subcontinent (Bangladesh, India, and Pakistan, see Prayon and Baten 2012).

3.4. Determinants of numeracy levels in Africa

What might have influenced numeracy levels in Africa? Former studies on age-heaping found that schooling is the main determinant of basic numeracy because a formal schooling system is likely to improve children's structural thinking skills in general and arithmetic skills in particular (A'Hearn et al. 2009, Crayen and Baten 2010, Manzel et al.

2011). This relationship can also be confirmed for the African sample presented in this paper using the Benavot and Riddle (1988) data set on primary enrolment ratios. Primary school enrolment rates varied widely in colonial Africa. Whereas many countries in Southern Africa had ratios of 30 percent and higher by the beginning of the 20th century, enrolment rates in countries in North and West Africa did not even exceed 10 percent. The Seychelles, la Reunion and Malawi had the highest enrolment rates in the early 20th century. The lowest primary school enrolment ratios were observable in Angola, French West Africa and French Equatorial Africa, all with less than three percent. The positive relationship between schooling and basic numeracy is shown in Figure 3.5. Regressing ABCC values on enrolment rates (in logs) yields a highly significant relationship for the birth decades 1910s, 1920s and 1930s with an explanatory power of around 36 percent.[25]

Figure 3.5: Relationship between primary enrolment rates and ABCC 1910-1940



Country codes: bf=Burkina Faso, bi=Burundi, bj=Benin, bw=Botswana, cf=Central African Republic, cm=Cameroon, cv=Cape Verde, dz=Algeria, eg=Egypt, et=Ethiopia, gh=Ghana, gm=Gambia, gw=Guinea-Bissau, ke=Kenya, km=Comoros, lr=Liberia, ma=Morocco, mg=Madagascar, mu=Mauritius, mw=Malawi, mz=Mozambique, na=Namibia, ng=Nigeria, re=Reunion, sc=Seychelles, st=Sao Tome and Principe, sz=Swaziland, tg=Togo, tn=Tunisia, tz=Tanzania, ug=Uganda, za=South Africa, zm=Zambia, zw=Zimbabwe.
Note: For variable definitions and sources see Appendix.

[25] Basic numeracy is assumed to be acquired during the first life decade whereas primary schooling usually takes place around the age of 10. As the data set is organized by birth decades, the ABCC values are lagged by one decade in this and the following analyses.

A prevailing opinion on colonial schooling policies is that France was more interested in educating the elite whereas Britain focused on mass education (White 1996). Therefore, the colonizer's identity could be of interest. The enrolment ratios of Benavot and Riddle (1988) confirm this hypothesis: Primary enrolment rates in French colonies are on average 10 percent lower than in British colonies. Using the ABCC values we find that French colonies have an ABCC level seven points lower on average than the rest of the African countries. Countries colonized by the British show on average an ABCC that is five points higher than countries colonized by the other European powers. Hence, the numeracy indicator shows the same pattern with respect to the colonizer's identity as the enrolment ratio. However, this is not surprising given the assumption that numeracy is influenced by school enrolment which was determined by the schooling policies of the colonial powers. Therefore, it is very likely that the observed relationship between colonizer's identity and numeracy is the result of enrolment ratios.

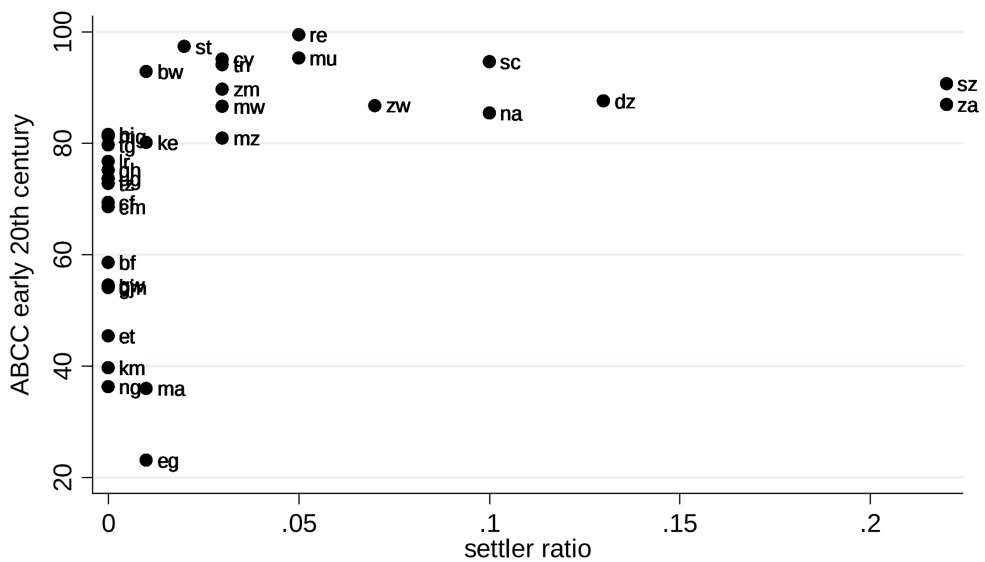
Another important determinant could be the presence of European settlers in an African country. As mentioned above, Western Europe had solved its basic numeracy problem in the 19^{th} century, and therefore it is highly likely the incoming European settler population had higher numeracy rates than the indigenous African population. Unfortunately, only for a slight few countries do age-heaping data exist that make it possible to distinguish numeracy levels between the indigenous and European populations. Algeria is one of those countries; its 1948 census data shows a European population with 100 ABCC points and an indigenous Muslim population with 80 ABCC points. As such, if the population of European settlers was significant enough in relation to the indigenous population, there could have feasibly been a direct, positive effect on numeracy levels. However, the ratio of Europeans to indigenous peoples in most African countries was too low to have any real impact on overall numeracy. The only countries with a substantial European population were South Africa (to include Lesotho and

Swaziland) with around 22 percent and Algeria with around 13 percent (Acemoglu et al. 2001).

It is more likely that the presence of European settlers alone influenced numeracy levels indirectly through investment in educational institutions. This argument follows Acemoglu et al.'s (2001) hypothesis that Europeans brought 'good' European institutions to their colonies; however, Glaeser et al.'s (2003) argument that settlers brought not only their institutions but also their embodied human capital to the colonies should be also considered.

The relationship of numeracy to settler-indigenous ratios around 1900 is mixed (Figure 3.6). Countries with a settler population of over one percent had ABCC values between 80 and 100. In contrast, extreme variation in ABCC values existed between countries with no substantial numbers of European settlers. Prayon and Baten (2012) examined this phenomenon, focusing on the role of migrant human capital. Assuming the numeracy levels of incoming European populations had already reached nearly 100 percent by 1900, the calculations of ABCC levels for indigenous populations should reflect the 'real' numeracy level if a direct channel was indeed at work here. For South Africa, these calculations attribute a maximum increase of 3.5 ABCC points to the influence of European settlers. In all other countries, calculations of the direct human capital effect of European migration show an increase of zero to two ABCC points. This small impact stands in contrast to the actual indigenous ABCC values (the ones that can be observed). As pointed out above, Algeria's Muslim population had an ABCC value of 80 in 1948; the calculated value is 85. This would mean there was an additional impact on the numeracy level via indirect channels of five ABCC points. The calculated migration effect, however, is only 2.4 ABCC points. Prayon and Baten (2012) concluded that there might have been some indirect effects stemming from skill-intensive immigration, calling this externality a 'contact learning effect'. For example, if natives perceived skilled immigrants as superior in social status or as a competitive threat in the labour market, they might have chosen to increase their children's educations. The immigrants may also have played an active role in initiating schooling or providing teachers.

Figure 3.6: Relationship between settler ratio and ABCC around 1900



Country codes: bf=Burkina Faso, bi=Burundi, bj=Benin, bw=Botswana, cf=Central African Republic, cm=Cameroon, cv=Cape Verde, dz=Algeria, eg=Egypt, et=Ethiopia, gh=Ghana, gm=Gambia, gw=Guinea-Bissau, ke=Kenya, km=Comoros, lr=Liberia, ma=Morocco, mg=Madagascar, mu=Mauritius, mw=Malawi, mz=Mozambique, na=Namibia, ng=Nigeria, re=Reunion, sc=Seychelles, st=Sao Tome and Principe, sz=Swaziland, tg=Togo, tn=Tunisia, tz=Tanzania, ug=Uganda, za=South Africa, zm=Zambia, zw=Zimbabwe.
Note: For variable definitions and sources see Appendix.

Closely related to this is the question of the state of infrastructure in the colonies: Investment in infrastructure reflects the engagement level of the colonial power. Well-developed infrastructure boosts the possibility that the colony was developed not only economically but also politically and administratively. Further, it may have been the case that the better the infrastructure, the better the integration of markets, engaging more people in trade. A job in trade required basic numeracy skills (i.e., calculations or bargaining), and these numeracy skills may have been acquired on-the-job rather than exclusively through formal schooling. In this context it is important to keep in mind that - while numeracy and literacy are well-correlated - the two measures are not interchangeable indicators. Literacy is usually acquired at schools or through other forms of institutionalized/formal learning. Basic numeracy on the other hand does not necessarily need formal education (i.e., it can be acquired through parental tutoring or on-the-job training). Therefore, the hypothesis is that trade was one way in which the numerical ability of a population was improved.

Factors in numeracy levels outlined thus far were mainly the influence of colonizers themselves. Another category of factors relate to the local conditions the colonizers faced in their colonies. Numeracy could have been influenced by mortality rates; high mortality rates may have discouraged investment in children's educations, as the expected return is reduced under conditions of low life expectancy (e.g. Gallup et al. 1999). The same outcome would have been true if the population was exposed to diseases (not necessarily fatal) that lowered the ability and capability to work and study. The assumption is therefore that the higher the mortality rates or risk of contracting a serious infection, the lower the schooling and numeracy rates. As data on mortality rates for the period of interest is only available for a few countries, data on the prevalence of malaria is used instead to assess the influence of the disease environment on numeracy.[26]

The role of geography and disease environment on macroeconomic growth is also discussed extensively in the colonial legacy literature. Acemoglu et al. (2001) and Glaeser (2003) argue that the mortality rates faced by Europeans in the colonies shaped the settlement decisions of the Europeans. They preferred to settle in regions like e.g. North America where rates of disease and infection were lower in comparison to (e.g.) West Africa's disease-friendly climate. The same argument was put forth by Gallego and Woodberry (2010) in respect to missionary activities in Africa: As mission schools were the main source of schooling during this time, it is highly likely that missionaries avoided

[26] The even today's still strong impact of malaria on the micro- and macroeconomic level in areas exposed to malaria is pointed out by Sachs and Malaney (2002): "Today malaria kills more than one million people a year, and perhaps close to three million when the role of malaria in deaths related to other diseases is included. Much of the mortality in endemic areas is concentrated among children under the age of five. The first is the effects that occur through changes in household behavior in response to the disease, which can result in broad social costs. These include such factors as schooling, demography, migration and saving."

areas with high mortality rates. In as much, the provision of schooling was lower in these areas. According to these arguments, then, the negative impact of the disease environment can run either through mortality rates among the population per se or though the settlement patterns of the Europeans.

Woodberry (2004) states that over 90 percent of Western education in sub-Saharan Africa during colonial period was provided by Christian missionaries. As such, one might assume that in areas with a high prevalence of Islam, the teaching of European-styled curricula was less likely. Bolt and Bezemer (2009) point in the same direction: Western education was usually restricted by the colonizers themselves in Islamic areas due to the prevailing resentment against it among the local population. At the same time, however, pre-colonial formal schooling and literacy tended to be higher in areas that were already Islamicised. Therefore, Bolt and Bezemer conclude that the prevalence of Islam could have been a hindrance for colonial education systems and/or a vantage ground for pre-colonial formal schooling. However, as the Islamic schools usually emphasize the memorization of the Qur'an (Boyle 2004), it is highly likely that the teaching of arithmetic skills was less of a priority in the curricula of the Islamic schools than in Western-styled schools. Therefore, it is possible that Islamic areas did not perform as well in respect to basic numeracy.

Another factor that might have influenced pre-colonial numeracy levels could have been the social and state structure in existence at that time. According to Murdock (1967), a huge variation of different pre-colonial state structures existed in pre-colonial Africa. It is very difficult to measure and especially to obtain data on state structure for the pre-colonial period, but ethnographic data could shed some light onto this issue. The expectation is that the more centralized a state, i.e. the more 'developed' a country in the Western sense, the more often people interact with administrative structures which assists in the development of numeracy skills. These arguments are closely linked to the assumptions concerning the influence of population density. One might assume that the more crowded a region, the more interaction between people and the more organizational tasks that need to be accomplished. Therefore, higher population density is linked to more urbanization. Population density has also been used as an indicator for the wealth of a society (La Porta et al. 2004, Acemoglu et al. 2002) as it is one sign of a society's potential for economic and social development, including the development of schooling systems (Bolt and Bezemer 2009). The possible influence of population density on numeracy is probably positive: it can boost numerical skills either through an increased interaction between the people or the provision of schools in more urbanized areas (economies of density).

A related topic is the fractionalization of a society. Ethnic and linguistic fractionalization is a crucial feature of Africa and associated with negative outcomes for the quality of government, as it is considered a hindrance to effective distribution of financial resources, including spending on education (Alesina et al. 2003). Easterly and Levine (1997) showed the negative impact of fractionalization on -among other things - schooling, political stability and infrastructure in Africa. Ethnic and linguistic fractionalization was even used as an instrumental variable for corruption (Mauro 1995, 1998). The assumption is that the more fractionalized a society, the lower the numeracy level. This can run either at a macroeconomic level through the provision and financing education or via discrimination between ethnic groups where parts of the population are excluded from receiving education.

3.5. Regression results

Table 3.1 shows OLS regression results with time fixed effects on basic numeracy (lagged by one decade) for the cross-section of African countries between the 1880s and 1930s. As expected we find a positive and significant influence of primary school enrolment ratio on the numeracy level. Enrolment ratio alone has an explanatory power of around 34 percent. Colonizer's identity shows ambiguous results. This is likely due to the high correlation between colonizer's identity and enrolment ratio (Table A.3). As mentioned above, countries colonized by the British had higher primary school enrolment ratios than countries colonized by other colonial powers. Comparing model 2 and model 3, the indicated inverse relationship between ABCC level and colonizer's identity in the second model runs apparently via the enrolment ratio. Hence, colonizer's identity is excluded from the remaining models.

The data indicate that the presence of European settlers had a strong positive and significant influence on the numeracy level: settler colonies score over 20 ABCC points higher in numeracy than peasant colonies. Angeles' (2007) definition of a settler colony is implemented here. Angeles distinguishes between 'New Europes' (more than 50 percent European settlers), settler colonies (between one and 30 percent) and peasant colonies (less than one percent). New Europes include Australia, Canada, New Zealand and the United States. African countries fall only in either the category of settler or peasant colonies. For this study the settler ratios as cited by Acemoglu et al. (2001) are used.

As the availability of historical data on infrastructure in colonial Africa is very limited for most countries, the numbers of open railway lines are used in these regressions as a proxy for the state of infrastructure. However, the coefficients in the different models do not point in a clear direction and offer no further insight into the causal relationship.

Table 3.1: OLS regression results (with time fixed effects), dependent variable: basic numeracy (ABCC index) 1880 - 1940 in Africa

VARIABLES	(1) ABCC	(2) ABCC	(3) ABCC	(4) ABCC	(5) ABCC	(6) ABCC	(7) ABCC	(8) ABCC
Enrolment ratio (log)	10.18***	8.588***		6.029***	-0.119	4.818***	4.742***	4.832***
	(1.438)	(2.572)		(1.489)	(1.905)	(1.339)	(1.441)	(1.568)
UK colony		-11.56**	3.159					
		(5.237)	(4.037)					
Settler colony		20.45***	27.93***		31.47***			
		(5.295)	(4.576)		(5.603)			
Railway per qkm (log)		1.643	-0.317					
		(1.426)	(1.313)					
Islam				-0.143*	-0.221***	-0.260***	-0.242***	-0.257***
				(0.0776)	(0.0538)	(0.0650)	(0.0608)	(0.0615)
Malaria				-0.209**	0.0682	-0.141**	-0.162	-0.124
				(0.0846)	(0.0665)	(0.0682)	(0.0982)	(0.139)
Population density (log)				-2.344	2.513*			
				(1.418)	(1.350)			
Ethnic fractionalization						-21.01	-21.20	-19.59
						(13.53)	(14.85)	(23.85)
Pre-colonial settlement pattern							-9.595**	
							(4.264)	
Pre-colonial state stucture								0.994
								(4.873)
Constant	36.18*	46.00***	26.77	68.16***	43.69***	82.68***	113.0***	58.60
	(20.24)	(16.79)	(19.29)	(7.858)	(6.935)	(11.58)	(29.04)	(41.48)
Observations	73	54	69	65	65	65	57	57
R-squared (adj.)	0.344	0.584	0.469	0.432	0.690	0.444	0.430	0.400

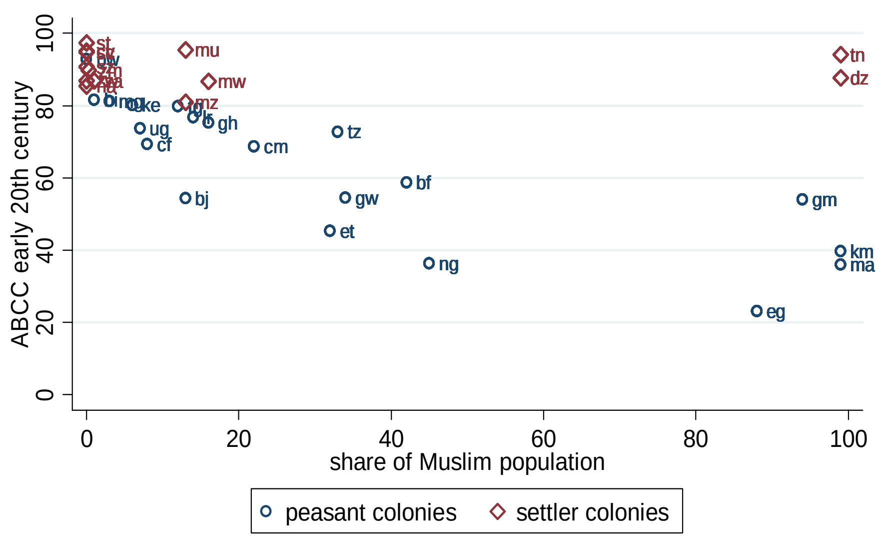
Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. The coefficients for time fixed effects are not reported in this table. See Appendix for variable definitions and sources, the summary statistic of the variables used are displayed in Table A.4. Dependent variable: ABCC index, lagged by one birth decade.

Models 4 through 8 include two variables measuring local conditions that the colonial powers faced in Africa: the percentage of the population that was Muslim and the percentage of the population living under the threat of malaria. The prevalence of Islam shows a consistently negative impact on numeracy. As the variable 'Islam' is defined in percentage points, a country with 100 percent Muslim population has (depending on the model specification) on average 14 to 25 ABCC points less than a country without a Muslim population. This is a very strong influence.

A glance at the relationship between the share of Muslims in the population and the numeracy level (Figure 3.7) basically reveals a negative relationship. However, two

North African countries - Algeria and Tunisia, both former French colonies - with populations nearly 100 percent Muslim are stand outs, showing almost full numeracy. Therefore, it cannot be said that a high prevalence of Islam in a country necessarily leads to lower numeracy levels. With the distinction between settler and non-settler colonies, the graph shows clearly that the variation among settler colonies is much smaller than among non-settler colonies and that all settler colonies have numeracy levels higher than 80 ABCC points around 1910/1920. But even if we control for settler colonies as in model 5, the coefficient of Islam remains negative and significant. However, in this case, enrolment ratio turns negative. This is probably due to multicollinearity as enrolment ratio and settler colony are highly correlated. Similarly, the prevalence of malaria turns out to have a strong negative influence on ABCC: A country totally exposed to malaria has on average between 12 and 20 fewer ABCC points (depending on the model) than a country without a disease environment in which malaria prevails. The negative influence of Islam and malaria is therefore consistent with the suggestions discussed in section 4.

Figure 3.7: Relationship between the share of Muslim population and the ABCC index early 20th century



Country codes: bf=Burkina Faso, bi=Burundi, bj=Benin, bw=Botswana, cf=Central African Republic, cm=Cameroon, cv=Cape Verde, dz=Algeria, eg=Egypt, et=Ethiopia, gh=Ghana, gm=Gambia, gw=Guinea-Bissau, ke=Kenya, km=Comoros, lr=Liberia, ma=Morocco, mg=Madagascar, mu=Mauritius, mw=Malawi, mz=Mozambique, na=Namibia, ng=Nigeria, re=Reunion, sc=Seychelles, st=Sao Tome and Principe, sz=Swaziland, tg=Togo, tn=Tunisia, tz=Tanzania, ug=Uganda, za=South Africa, zm=Zambia, zw=Zimbabwe.
Note: For variable definitions and sources see Appendix.

Population density data for early 20th-century Africa are collected from *Hübners Geographisch-Statistische Tabellen (1932),* a compilation of national statistical reports worldwide, including protectorates and colonies. As with the infrastructure variable, the coefficients of this variable do not point to an influence on basic numeracy.[27]

Models 6 through 8 test for the added effects of ethnic fractionalization. In this study fractionalization data from Alesina et al. (2003) are used. As assumed, the influence of fractionalization on numeracy turns out to be negative (albeit insignificant): the higher the fractionalization the lower the ABCC level. The coefficients in these models indicate that a country with high ethnic fractionalization scores approximately 20 ABCC points lower than a country with no fractionalization.

Models 7 and 8 include variables for the pre-colonial state and settlement structure. The variable measuring the settlement pattern of the indigenous population ranges between 1 for nomadic patterns and 5 for complex settlements. The variable measuring the pre-colonial political structure ranges from 1 for no political authority beyond the local community to 5 for large states (see Appendix for a precise variable description). Both yield no additional explanatory power to the model, nor do they show a clear influence on numeracy. As discussed in the previous section, the hypothesis is that the more complex a society, the higher the numeracy level. Model 8 bears out this expectation, but the settlement variable in model 7 shows the opposite of what was expected. The other coefficients are unaffected. Even if this regression model does not give deep insight into the explanation of numeracy, a look at the correlation matrix (Table A.3) reveals these characteristics may still play a role: as the indigenous settlement pattern can be interpreted as a kind of urbanization variable, it is not surprising to see that it is correlated with population density and school enrolment rates. Formal education is

[27] One explanation for this might be inaccuracy of the population data as well as maybe the construction of the variable: Actually one should take into account as basis for the ratio, not the whole area of the country but the habitable area, excluding e.g. deserts.

more likely in permanent settlements than nomadic settlement structures. However, numeracy cannot be explained upon these data. Similar relationships are observable for the pre-colonial state structure. As discussed in the literature review, the correlation matrix reveals that a more complex state structure is linked to a less heterogenic population. In addition, Europeans tended to prefer to settle in areas with pre-existing state structures.

To conclude, the results of the regression analyses indicate that enrolment ratio is the main determinant of basic numeracy. Additionally, they confirm that the ABCC index proxies an output factor of human capital. It also became clear that numeracy levels in Africa during the period under consideration were highly dependent on European settlement policies. Colonies with European settlers had significantly higher numeracy levels than non-settler colonies. Unfortunately, the data at hand cannot disentangle the exact mechanism behind this finding. It seems however, that the effect can be attributed to variations in schooling policies. Additionally, local circumstances such as the prevalence of malaria and Islam, seem to have had some influence on numeracy. The ethnic heterogeneity and state structure of a pre-colonial society also did not have an impact on numeracy directly, but they seem to have had an effect on the settlement patterns of the Europeans. This is in line with the argument that colonizers established institutions consistent with the existing distribution of political power (Gallego 2010).

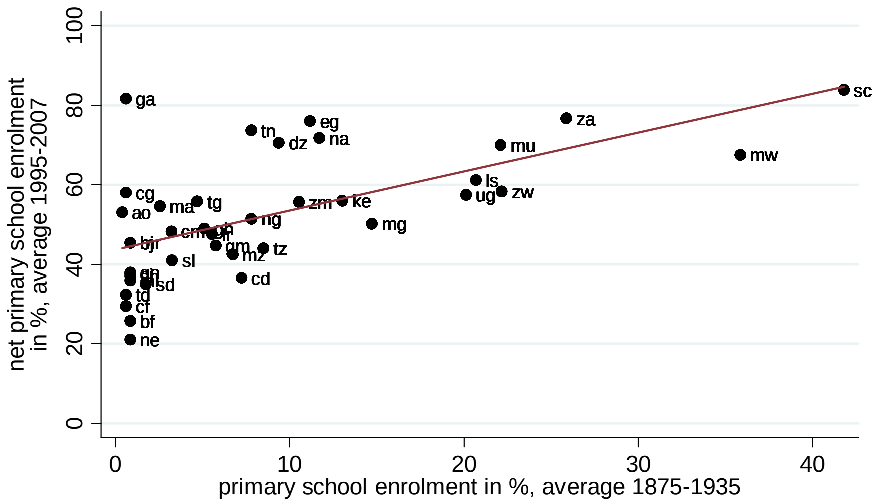
The results point to the presence of a strong influence of the settlement pattern of the Europeans on the educational situation in African countries. European settlers brought themselves and their institutions and school systems, but their presence likely generated additional spill-over effects. This seems to have had a significant and long-lasting effect on education in Africa.

3.6. Path dependency of human capital formation

This section addresses the question of the persistence of the observed early human capital levels in Africa in the long run. Gallego (2010) showed the high inertia of schooling attainment among former colonies during the 20th century, i.e. he found a high correlation between primary school enrolment in 1900 and years of schooling at the end of the 20th century. Figure 3.8 shows the correlation between the average enrolment ratio around 1900 and the average enrolment ratio around 2000. He attributes this correlation to differences in conditions faced by colonizers (e.g. the potential settler mortality, factor endowments, or density of the native population) which had a significant influence on past educational policies that are still in effect today. He identified political institutions and the level of development as driving forces behind the influence of historical factors on schooling. He explains this inertia through the general costs of setting up institutions (schools belong to the cluster of institutions) and through the endogenous character of human capital accumulation. Additionally, intergenerational inertia and peer effects certainly play a role in the persistence of school attainments over several cohorts.

Similar findings on the persistence of human capital are reported in studies by Bolt and Bezemer (2009), Huillery (2009), and Frankema (2012). Bolt and Bezemer (2009) found a high correlation between the educational standards in Africa in colonial times and Africa's educational achievements in 1995. Here, the colonial educational standard is measured in total numbers of pupils divided by total population. Huillery (2009) identified the number of teachers per capita around 1910/20 as a good predictor for school attendance found today in former French West Africa. Similarly, Frankema (2012) found a high correlation between gross primary school enrolment rates in 1938 and literacy rates today in sub-Saharan Africa. These studies presented estimates for input measures of human capital during colonial times. Now, with the new basic numeracy estimates, an assessment of an output measure of human capital in the early 20th century is possible.

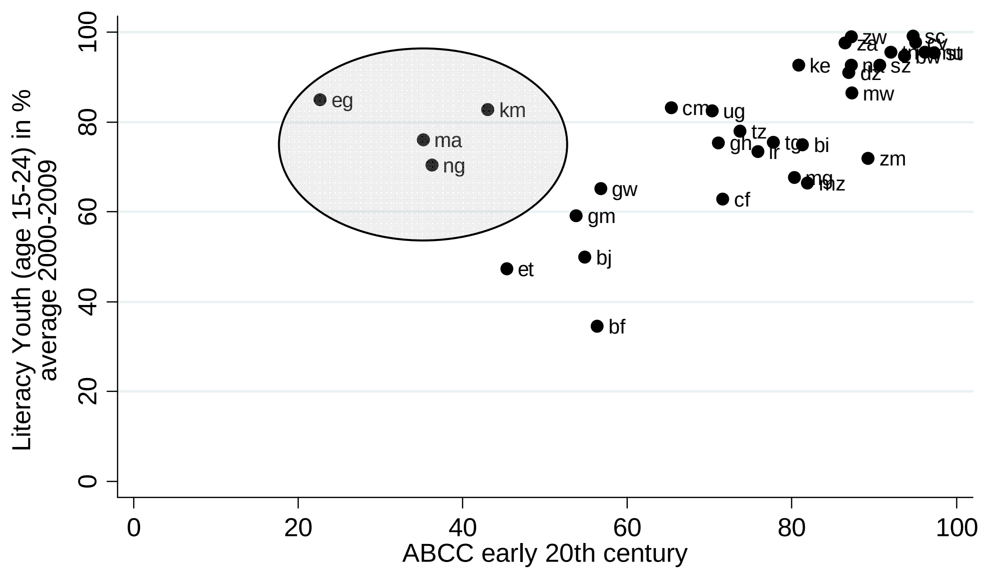
Figure 3.8: Relationship between average enrolment around 1900 and average enrolment around 2000 in Africa



Country codes: bf=Burkina Faso, bi=Burundi, bj=Benin, bw=Botswana, cf=Central African Republic, cm=Cameroon, cv=Cape Verde, dz=Algeria, eg=Egypt, et=Ethiopia, gh=Ghana, gm=Gambia, gw=Guinea-Bissau, ke=Kenya, km=Comoros, lr=Liberia, ma=Morocco, mg=Madagascar, mu=Mauritius, mw=Malawi, mz=Mozambique, na=Namibia, ng=Nigeria, re=Reunion, sc=Seychelles, st=Sao Tome and Principe, sz=Swaziland, tg=Togo, tn=Tunisia, tz=Tanzania, ug=Uganda, za=South Africa, zm=Zambia, zw=Zimbabwe.
Note: For variable definitions and sources see Appendix.

If one assumes a high inertia of education within a society and over time, one would expect that countries on the lower bound of the country range with reference to the performance of the other countries under consideration during colonial times would still be on the lower bound of this range today. Comparison of ABCC-levels around 1900 with actual literacy levels today in Africa reveals a similar persistence. Figure 3.9 displays this relationship. If we ignore the data for the Comoros, Egypt, Nigeria, and Morocco a high and positive correlation between past performance in basic numeracy and current performance in literacy today is observable: Roughly three generations lie between the numeracy levels and the literacy levels. This correlation provides strong evidence for the high degree of persistence of human capital and supports the findings of the other studies. Unfortunately, this result is rather discouraging, as it indicates that today's educational performance was determined 100 years ago.

Figure 3.9: Relationship between basic numeracy at the beginning of the 20th century and literacy today

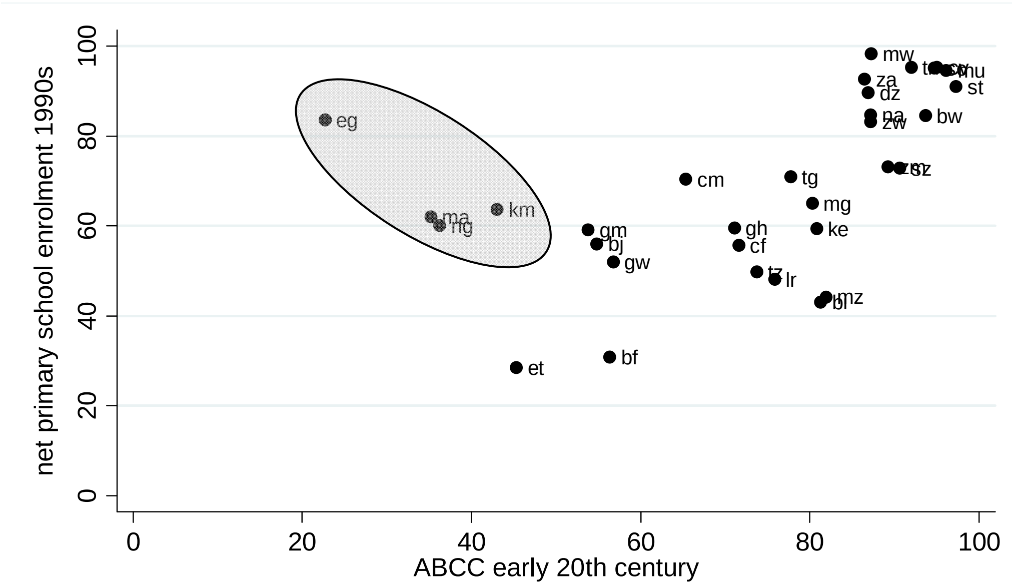


Country codes: bf=Burkina Faso, bi=Burundi, bj=Benin, bw=Botswana, cf=Central African Republic, cm=Cameroon, cv=Cape Verde, dz=Algeria, eg=Egypt, et=Ethiopia, gh=Ghana, gm=Gambia, gw=Guinea-Bissau, ke=Kenya, km=Comoros, lr=Liberia, ma=Morocco, mg=Madagascar, mu=Mauritius, mw=Malawi, mz=Mozambique, na=Namibia, ng=Nigeria, re=Reunion, sc=Seychelles, st=Sao Tome and Principe, sz=Swaziland, tg=Togo, tn=Tunisia, tz=Tanzania, ug=Uganda, za=South Africa, zm=Zambia, zw=Zimbabwe.
Note: For variable definitions and sources see Appendix.

However, the countries that prove exceptions to this pattern - namely, the Comoros, Egypt, Nigeria, and Morocco - offer an alternative, more encouraging story: The data indicate that the four worst performers in basic numeracy were better at acquiring literacy skills in comparison to the rest of the countries in the sample. The comparison of Egypt with Algeria is interesting. Today both North African countries have nearly the same level of literacy (85 percent and 91 percent, respectively). Looking at historical numeracy levels (ABCC Egypt's ABCC value was at 16, Algeria's at 79 at the turn of the century) one would expect Egypt to perform worse in literacy today than Algeria. However, in actuality Egypt has almost caught up with Algeria. Somehow countries like Egypt were able to escape the 'trap' of early educational underdevelopment.

Can we explain the deviation of these countries from the overall pattern? What did these countries do to enhance the educational levels of their populations so dramatically in comparison to the other countries under study? One might consider the share of public spending for education, the introduction of compulsory education, or the attitude of the state towards education (also towards the education of girls). The first factor that comes to mind is schooling rates. And indeed, if we look at the correlation between basic numeracy in the early 20th century and net primary school enrolment in the 1990s (Figure 3.10), we see that exactly four countries (Egypt, Morocco, the Comoros, and Nigeria) outperformed the other countries in the sample in terms of enrolment ratios. Egypt, Morocco, and Nigeria underperformed in this context during the early 20th century (see Figure 3.5), yet they managed to transform their educational underperformance to overperformance over the course of the 20th century.

Figure 3.10: Relationship between basic numeracy at the beginning of the 20th century and net primary school enrolment today



Country codes: bf=Burkina Faso, bi=Burundi, bj=Benin, bw=Botswana, cf=Central African Republic, cm=Cameroon, cv=Cape Verde, dz=Algeria, eg=Egypt, et=Ethiopia, gh=Ghana, gm=Gambia, gw=Guinea-Bissau, ke=Kenya, km=Comoros, lr=Liberia, ma=Morocco, mg=Madagascar, mu=Mauritius, mw=Malawi, mz=Mozambique, na=Namibia, ng=Nigeria, re=Reunion, sc=Seychelles, st=Sao Tome and Principe, sz=Swaziland, tg=Togo, tn=Tunisia, tz=Tanzania, ug=Uganda, za=South Africa, zm=Zambia, zw=Zimbabwe.
Note: For variable definitions and sources see Appendix.

So what determines the high variation in literacy rates today in Africa? How strongly does the past state of a country's education situation impact human capital development later on? In a study on global literacy, Verner (2005) identifies the following as main determinants of literacy: formal education (enrolment rates, average years of schooling); life expectancy; and income from a threshold value of around $2200 upward. Yet, the quality of education as well as institutions turns out to have no significant influence on literacy. Verner also did not find that Africa generally displays lower literacy rates than other world regions.

One has to distinguish between three levels of possible determinants of literacy. The first level is decisions made by individuals or households. The second is represented by decisions about education spending and policy made on the macro level by governments or other institutions. The third level of influences is external factors that impact a country yet are not largely in the control of that country. The main decision of the first group is clearly whether parents send their children to school or not. In poor societies, this is influenced by the trade-off between sending children to school and sending them to work. Household income and 'number of mouths to feed' are the determining factors. The return on education is also influenced by expected life expectancy. If parents are aware that their children might not survive childhood, the willingness to invest in their children's future is probably low.

On the macro level the government can influence the educational system by increasing spending on education; lowering the pupil-teacher ratio through increasing the number of schools and teachers in the country (and especially in rural areas); and influencing schooling ratio through compulsory schooling and the abolishment of school fees. The third category, i.e. external factors that influence literacy, counts features such as the general climate and the disease environment; whether the country is involved in internal or external conflicts; the predominant attitude towards education; the rate of urbanization or more generally development; population density; and type of government.

In the following analysis the impact of these determinants on literacy is tested. Several constraints appear in this analysis. First, the definition of literacy between the countries may differ. However, this possible cause of measurement error should not be overstated, as the underlying age group is the same in our sample, and the data - which is obtained from official censuses supervised by institutions such as the United Nations - is reliable. Second, since literacy is measured at a national level, differences on a more disaggregated regional level or between population groups are not examined. The same applies to decisions made on a household level. For example, in this analysis it is not possible to distinguish different mortality rates for different social groups; we can only observe the general mortality rate for the whole population of a country. The demand for education by parents for their children on the micro level is visible in the schooling rates. The schooling rates are also influenced by decisions made by the government. In such a case the following analysis can not disentangle the exact shares of the two channels. To examine the decisions pro or contra literacy on the micro level is beyond the scope of this paper and is left to other studies.

The regression results confirm the high persistence of human capital as well as previous findings on important determinants of literacy (Table 3.2, the corresponding correlation matrix can be found in the Appendix (Table A.5)). The ABCC level of the early 20th century alone can explain around 30 percent of the literacy level of young adults today (model 1). Excluding the four deviating countries increases the explanatory power of the ABCC to 70 percent. The next three models (3-5) reveal important determinants on the micro decision level. The prevalence of child labour has a clear negative impact on literacy. Child mortality is negative, as predicted, but loses its significance when ABCC is included. The role of GDP remains unclear in all specifications despite a clear positive correlation between GDP per capita and youth literacy in general. This result is similar to Verner's (2005) finding of an ambiguous role of GDP in the context of explaining literacy rates. The variables enrolment ratio, pupil-teacher ratio and public expenditure on education show the expected correlations and remain robust if ABCC in the early 20th century is included. This finding indicates that the 'colonial legacy of education' still influences the educational outcome today in Africa.

Table 3.2: OLS regression results, dependent variable: Literacy Youth (age 15-24), average over 2000 to 2009

	(1) OLS	(2) OLS Egypt, Morocco, Nigeria, and the Comoros excluded	(3) OLS	(4) OLS	(5) OLS	(6) OLS	(7) OLS	(8) OLS
Child mortality			-0.136**	-0.129**	-0.0642			
			(0.0532)	(0.0514)	(0.0685)			
Child labour			-0.413***	-0.366**	-0.359***			
			(0.140)	(0.141)	(0.119)			
ABCC early 20th century	0.462***	1.013***			0.374**	0.194**		0.228*
	(0.160)	(0.118)			(0.164)	(0.0790)		(0.121)
GDPc (log)				4.201	4.889			
				(4.148)	(3.715)			
Enrolment ratio						0.521***	0.601***	0.270**
						(0.102)	(0.152)	(0.110)
Pupil-teacher ratio						-0.259***	-0.214	-0.238***
						(0.0868)	(0.137)	(0.0774)
Public expendit. on education							1.621***	2.039*
							(0.582)	(1.071)
Constant	45.27***	-0.487	107.1***	77.20**	38.99	38.86***	39.03***	44.63***
	(13.20)	(10.06)	(7.288)	(30.16)	(29.19)	(8.395)	(13.32)	(10.89)
Observations	33	29	31	31	19	32	35	23
R-squared (adj.)	0.323	0.713	0.482	0.492	0.572	0.761	0.648	0.740

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.
See Appendix for variable definitions and sources, the summary statistic of the variables used are displayed in Table A.6.

3.7. Conclusion

This paper addressed human capital formation in Africa in the long run. New estimates for colonial human capital for 34 countries were presented and discussed. These estimates represent numerical abilities of the population and were obtained by using the age-heaping strategy. Numeracy levels were generally highest in the Southern region of Africa, including South Africa, Botswana, and Namibia, and the populations of the islands of the Seychelles, Mauritius, Cape Verde, and La Réunion showed high numerical abilities at the turn of the century. The two French settler colonies Algeria and Tunisia belong to this group of high performers as well. Egypt, Morocco, Nigeria, Ethiopia, and the Comoros were the countries with ABCC values less than 50 points during this period which ranks them low not only in Africa but also worldwide. All in all, the African continent displayed a high variation in human capital in terms of basic numeracy during the colonial era.

To explain this variation regression analysis was applied which revealed that primary school enrolment ratios can explain about 30 percent of the variation in numeracy across countries. Essential for the development of high numeracy levels seems to be the presence of European settlers in African colonies. However, it was probably not their presence itself that resulted in higher numeracy. This more indirect effect on the educational level could be explained with spill-over effects of the European population on the local population: where Europeans settled, European-styled education dominated the school systems and therewith European curricula. Exemplars for this pattern are Tunisia and Algeria, both former French colonies that fully adopted the school systems and curricula of the colonial power. Local conditions like the prevalence of malaria and Islam played a role as well. Even after controlling for enrolment and settlement patterns of the Europeans, these factors show some effect on numeracy levels.

The second part of this paper addressed the question of the persistence of human capital. Using the new human capital estimates from the colonial period and comparing them to current literacy levels in Africa, a strong path-dependency is observable. This result confirms on the one hand previous findings on the high persistence of human capital, and on the other hand it reveals that the roots for educational underdevelopment in Africa can be traced back to the colonial period. However, it is not an absolute that countries that underperformed in education during the colonial period are a lost cause. On the contrary, using descriptive statistics as well as regression analysis this study presents strong support for the possibility of escaping this “trap of early human capital underdevelopment” through investment in schooling (also emphasized by Gallego 2010:19). Egypt, Morocco, Nigeria, and the Comoros had over proportional high schooling ratios compared to other African countries under study in the late 20th century. This turned out to be a successful way to improve significantly the literacy ratios of their population, even though it is still a very far way to universal primary education and especially universal literacy. Thus, to reach at least a few of the Second Millennium Development Goals, developing countries must invest more in the development of their school systems and reduce barriers to school attendance.

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3.9. Appendix I: Variable definitions and sources

Variables in Table 3.1

ABCC
Proxy for basic numerical skills. Linear transformation of the Whipple index. See section 2 for details.
List of the underlying census data:
Algeria: 1966; Benin: 1979, 1992; Botswana: 1971, 1981, 1991, 2001; Burkina Faso: 1975, 1985; Burundi: 1979; Cameroon: 1976; Cape Verde: 1990; Central African Republic: 1975; Comoros: 1980; Egypt: 1907, 1947; Ethiopia: 1994; Gambia: 1973, 1983, 1993; Ghana: 1970; Guinea-Bissau: 1979; Kenya: 1969, 1989, 1999; Liberia: 1962, 1974; Madagascar: 1975; Malawi: 1977, 1987, 1998; Mauritius: 1952, 1962, 1972, 1990, 2000; Morocco: 1960; Mozambique: 1980; Namibia: 1946, 1991, Nigeria: 1991; Reunion: 1967, 1982, 1990, 1999; Sao Tome and Principe: 1991; Seychelles: 1960, 1971, 1977, 1987, 1994, 1997; South Africa: 1904, 1946, 1970, 1980, 1985; Swaziland: 1997; Tanzania: 1967, 1978; Togo: 1958, 1970; Tunisia: 1966, 1984, 1994; Uganda: 1969, 1991; Zambia: 1980, 1990; Zimbabwe: 1982, 1992, 1997.
Sources: Data come from United Nations (various issues) *Demographic Yearbook* (New York: UN), supplemented with the Census of the Colony of the Cape of Good Hope 1904 (p.212-214), and the Census of Egypt, taken in 1907 (Table IX).

Settler colony
Dummy variable: 1 if share of Europeans in 1900 is more than 1 percent.
Source: Acemoglu et al. (2001) supplemented with data from Juraschek (1932).

Malaria
Share of 1995 population living in areas with malaria, 1946.
Source: Gallup et al. (1999).

British colony
Dummy variable: 1 if Britain was the colonial power during most of the period between 1885 and independence.

Railway (log)
Length of railway line open in kilometres (average over decade) per land area in square kilometres.
Source: Mitchell for railways (1982). Nunn for land area (2008).

Enrolment ratio (log)
Primary school enrolment ratios 1870 to 1940. The values for 1870-1875 were assigned to the decade 1870. For the decade 1930 the mean of the values for 1930 and 1935-1940 was assigned.
Source: Benavot and Riddle (1988).

Ethnic fractionalization
Measure of ethnic fractionalization: likelihood that two people chosen at random will be from different ethnic groups.
Source: Alesina et al. (2003).

Islam
Share of Muslim population.
Source: Parker (1997) as cited by Nunn (2008).

Pre-colonial state structure
Pre-colonial data on hierarchy beyond local community. Ranked by complexity: 1=no level (no political authority beyond community), 2=one level (e.g., petty chiefdoms), 3= two levels (e.g. larger chiefdoms), 4= three levels (e.g. states), 5= four levels (e.g. large states).
Source: Müller (1999).

Pre-colonial settlement patterns
Pre-colonial data on settlement patterns of the indigenous population. Ranked by complexity: 1= nomadic or fully migratory, 2= seminomadic, 3= semisedentary, 4= compact but impermanent settlements, 5= compact and relatively permanent settlements to complex settlements.
Source: Müller (1999).

Population density (log)
People per square kilometres. Varying base years: 1920-1931.
Source: Juraschek (1932).

Variables in Table 3.2

Literacy
Usually defined as the ability to read and write (for details see:
http://stats.uis.unesco.org/unesco/tableviewer/document.aspx?FileId=203)
Literacy Adult (15+): Average of available data from the years 2000 to 2009
Literacy Youth (15-24): Average of available data from the years 2000 to 2009
Source: UNESCO Institute for Statistics, Download: 2011-07-12.
Available at:
http://stats.uis.unesco.org/unesco/TableViewer/tableView.aspx?ReportId=210

Mortality rate, under-5 (per 1,000) (in regression: 1990s)
Under-five mortality rate is the probability per 1,000 that a newborn baby will die before reaching age five, if subject to current age-specific mortality rates.
Source: World Development Indicators, World Bank, Download: 2011-07-21.
Available at: http://data.worldbank.org/indicator

Economically active children, total (% of children ages 7-14) (in regression: 2000s)
Economically active children refer to children involved in economic activity for at least one hour in the reference week of the survey.
Source: World Development Indicators, World Bank, Download: 2011-07-21.
Available at: http://data.worldbank.org/indicator

ABCC early 20th century
ABCC values of 1910, if missing, than taken from 1920.

GDP per capita (in regression: 1980s)
Variable name: cgdp, unit: international dollar, PPP Converted GDP Per Capita, Geary-Khamis method, at current prices (in I$)
Penn World Table Version PWT 7.0 (2005 as reference year).
Source: Heston et al. (2011), Download: 2011-07-21.
Available at: http://pwt.econ.upenn.edu/

School enrolment, primary (% net) (in regression: 1990s)
Net enrolment ratio is the ratio of children of official school age based on the International Standard Classification of Education 1997 who are enrolled in school to the population of the corresponding official school age.
Source: World Bank, Download: 2011-07-21.
Available at: http://data.worldbank.org/indicator

Pupil-teacher ratio, primary (in regression: 1990s)
Primary school pupil-teacher ratio is the number of pupils enrolled in primary school divided by the number of primary school teachers (regardless of their teaching assignment).
Source: World Bank, Download: 2011-07-21.
Available at: http://data.worldbank.org/indicator

Public spending on education, total (% of GDP) (in regression: 1990s)
Public expenditure on education consists of current and capital public expenditure on education includes government spending on educational institutions (both public and private), education administration as well as subsidies for private entities (students/households and other privates entities).
Source: World Bank, Download: 2011-07-21.
Available at: http://data.worldbank.org/indicator

3.10. Appendix II: Additional Graphs and Tables

Figure A.1: Age distribution in Morocco, Census 1960

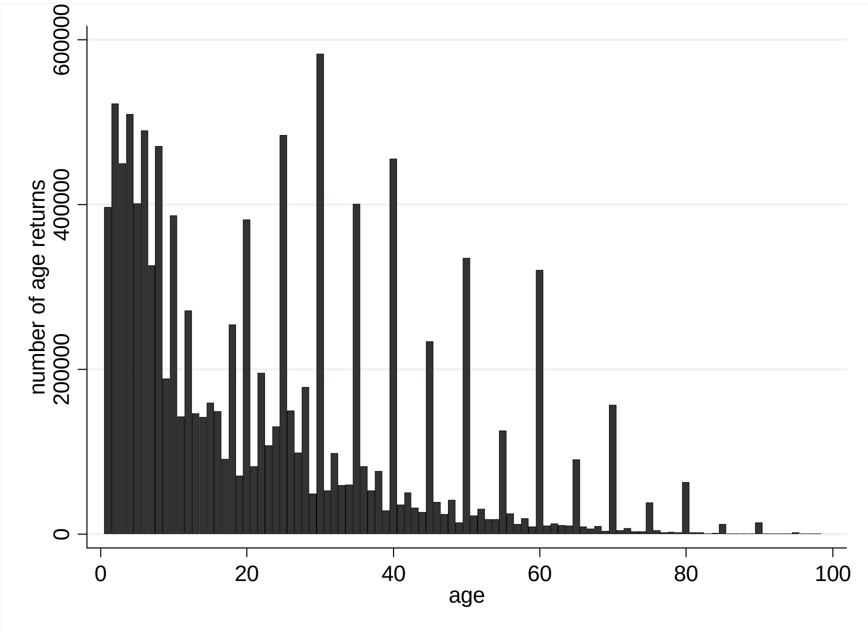


Figure A.2: ABCC trends of selected African countries in comparison to the ABCC trends of France and the UK

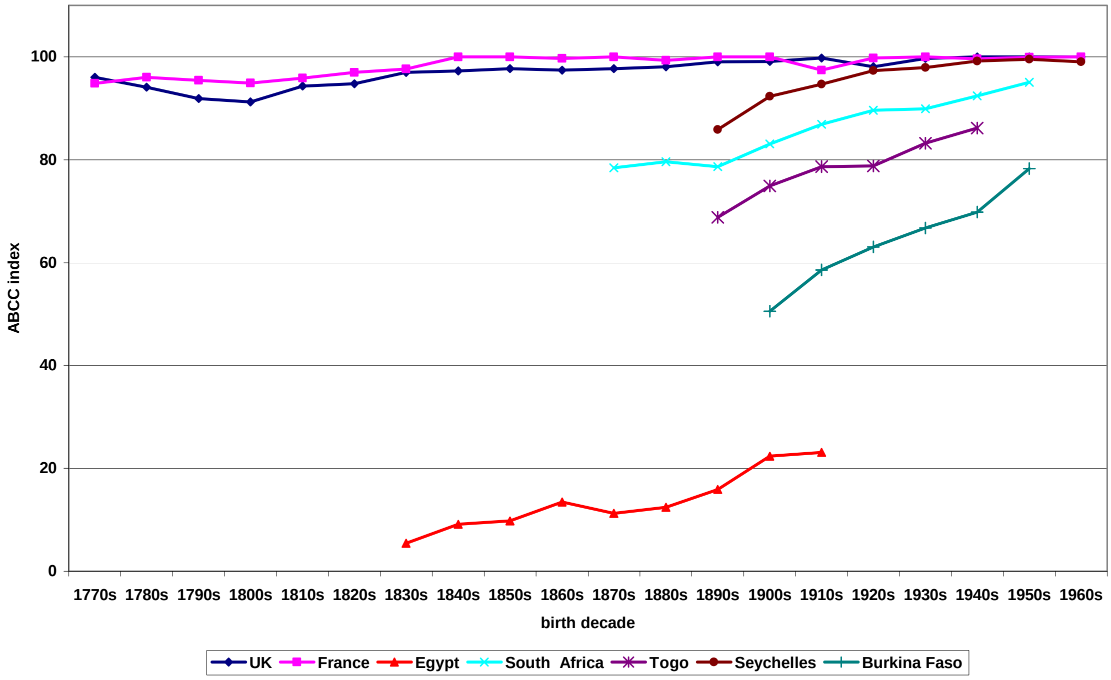


Table A.1: ABCC values in Africa for the birth decades 1830 to 1970

Birth decade	1830s	1840s	1850s	1860s	1870s	1880s	1890s	1900s	1910s	1920s	1930s	1940s	1950s	1960s	1970s
Algeria							79	84	88	89	90				
Benin									54	55	60	67	74	73	
Botswana								93	93	96	96	96	99	99	100
Burkina Faso								48	59	63	67	70	78		
Burundi									82	81	81	84	87		
Cameroon								58	69	69	74	75			
Cape Verde										95	95	93	98	98	
Central African Republic									69	74	82	83			
Comoros									40	47	48	59	65		
Egypt	5	9	10	14	11	12	16	22	23						
Ethiopia										45	46	46	55	58	
Gambia								54	54	53	57	60	65	70	
Ghana								68	75	71	78	81			
Guinea-Bissau									55	59	59	66	70		
Kenya								81	80	82	85	85	85	88	88
Liberia							71	75	77	76	78	82			
Madagascar								78	81	82	85	86			
Malawi								89	87	86	87	90	90	85	88
Mauritius						95	93	97	95	97	99	98	100	99	99
Morocco							25	27	36	43	45				
Mozambique									81	83	82	87	87		
Namibia					76	78	73	82	87*	93*	98	98	99	98	
Nigeria										36	39	41	47	51	
Reunion							100	99	100	100	99	99	100	100	99
São Tomé and Principe										97	100	99	99	100	
Seychelles							86	92	95	97	98	99	100	99	
South Africa	71	77	76	80	81	80	79	83	87	90	90	92	95		
Swaziland										91	92	91	94	97	
Tanzania							64	74	73	74	76	81	84		
Togo							67	75	80	79	83	86			
Tunisia							76	86	94	96	97	100	100	99	
Uganda								67	74	70	77	78	81	85	
Zambia									90	89	91	93	96	95	
Zimbabwe									87	88	90	88	95	98	

* These values are based on a linear interpolation between the earlier and the later census.

Table A.3: Pairwise correlation coefficients of the variables used in the regression models reported in Table 3.1

Variable	ABCC (lagged by one decade)	Enrolment ratio (log)	UK colony	Settler colony	Railway per qkm (log)	Islam	Malaria	Population density (log)	Ethnic fract.	Pre-colonial settlement pattern	Pre-colonial state structure
ABCC (lagged by one decade)	1										
Enrolment ratio (log)	0.4914*	1									
UK colony	-0.0325	0.5799*	1								
Settler colony	0.6570*	0.5306*	0.0694	1							
Railway per qkm (log)	0.3251	0.329	0.3001	0.4657*	1						
Islam	-0.3983*	-0.3152	-0.3602*	-0.0009	-0.0431	1					
Malaria	-0.3319	-0.4304*	-0.3509*	-0.5093*	-0.7461*	0.1863	1				
Population density (log)	0.0285	0.1474	0.292	0.0028	0.6822*	0.0711	-0.5078*	1			
Ethnic fractionalization	0.1262	0.0126	0.1225	-0.3674*	-0.3771*	-0.7781*	0.0637	-0.2242	1		
Pre-colonial settlement pattern	-0.1623	0.1204	0.3786*	-0.1819	0.2489	0.0335	-0.1442	0.8056*	-0.42	1	
Pre-colonial state structure	-0.0814	0.0138	-0.2432	0.4614*	0.4835*	0.6950*	-0.4505*	0.1554	-0.7397*	0.1379	1

See Appendix for variable definitions and sources. * indicates significance on 0.01-level.

Table A.5: Pairwise correlation coefficients of the variables used in the regression models reported in Table 3.2

Variables	Literacy youth (age 15-24)	Child mortality	Child labour	ABCC early 20th century	GDPc (log)	Enrolment ratio	Pupil-teacher ratio	Public expenditure on education
Literacy youth (age 15-24)	1							
Child mortality	-0.7293*	1						
Child labour	-0.6190*	0.6005*	1					
ABCC early 20th century	0.5682*	-0.3647	-0.1026	1				
GDPc (log)	0.5078*	-0.6998*	-0.4404	0.2216	1			
Enrolment ratio	0.8371*	-0.7444*	-0.388	0.5215*	0.6221*	1		
Pupil-teacher ratio	-0.4759*	0.6963*	0.4694	-0.0269	-0.5670*	-0.4124	1	
Public expenditure on education	0.6618*	-0.5929*	-0.2511	0.3575	0.5911*	0.5451*	-0.4507	1

See Appendix for variable definitions and sources. * indicates significance on 0.01-level.

Table A.2: Summary statistics of the number of single age returns underlying the ABCC values in Table A.1

Age Group	No. of censuses	Mean	Std.Dev.	Min	Max
23-32	72	1,628,727	4,286,904	5,719	33,171,000
33-42	72	1,102,605	2,994,942	4,608	23,746,000
43-52	72	727,535	1,951,691	3,836	15,594,000
53-62	72	455,266	1,173,069	2,889	9,395,000
63-72	71	269,879	664,270	1,861	5,245,000

Table A.4: Summary statistics of the variables used in the regression models reported in Table 3.1

Variable	No. of obs.	Mean	Std.Dev.	Min	Max
ABCC (lagged by one decade)	73	75.1966	20.5255	12.4023	100
Enrolment ratio (log)	73	2.2703	1.1747	-1.2040	4.0092
UK colony	73	0.4658	0.5023	0	1
Settler colony	73	0.5068	0.5034	0	1
Railway per qkm (log)	69	-5.8049	1.4120	-9.5558	-2.0816
Islam	65	34.4046	38.2020	0	99
Malaria	65	82.3568	32.5890	0	100
Population density (log)	65	2.2002	1.3279	-1.2040	5.4072
Ethnic fractionalization	65	0.6216	0.2519	0.0394	0.9302
Pre-colonial settlement pattern	57	4.7785	0.3750	3.3459	5
Pre-colonial state structure	57	3.0511	0.9702	1.4478	4.6280

See Appendix for variable definitions and sources.

Table A.6: Summary statistics of the variables used in the regression models reported in Table 3.2

Variable	No. of obs.	Mean	Std.Dev.	Min	Max
Literacy youth (age 15-24)	33	79.1082	16.3776	34.4846	99.0648
ABCC early 20th century	33	73.3165	20.1640	22.7154	97.3624
Child mortality	31	174.7710	55.2049	77.2	289.5
Child labour	31	37.0301	15.8051	7.9	74.4
GDPc (log)	31	6.4022	0.4937	5.5408	7.3729
Enrolment ratio	32	69.0864	19.9023	28.3763	98.3038
Pupil-teacher ratio	35	42.7602	13.8576	15.4847	83.7040
Public expenditure on education	35	4.0614	2.3463	0.8476	14.0634

See Appendix for variable definitions and sources.

4. Women count. Gender (In-)Equalities in the Human Capital Development in Asia, 1900-60

Abstract

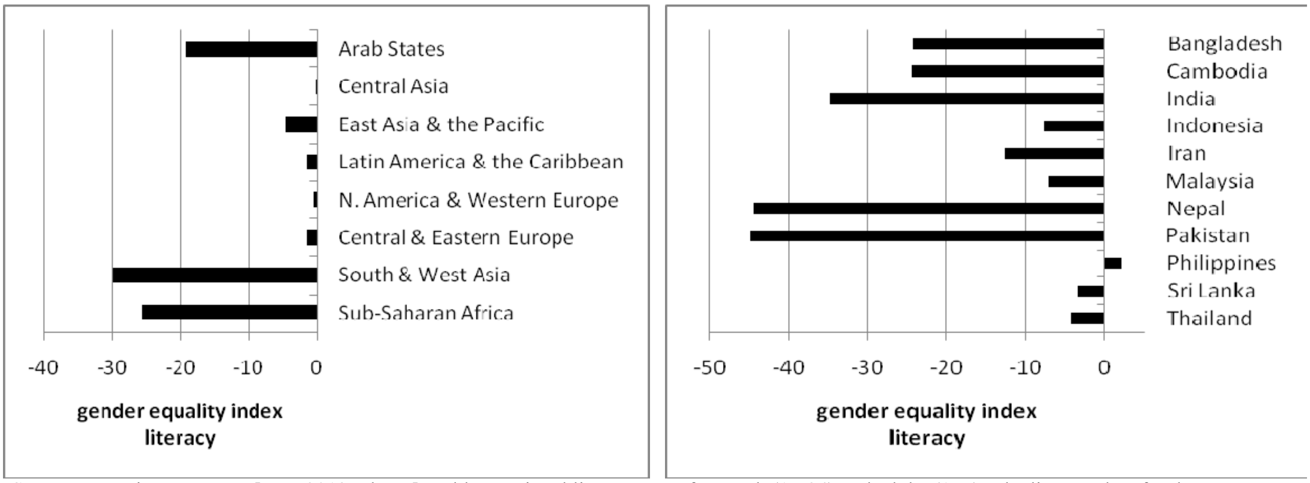
This paper traces the human capital development disaggregated by gender of 14 Asian countries for the period 1900s-60s, using the age-heaping method. Enrolment rates, GDP per capita as well as female voting rights turned out to be important driving forces of basic numeracy. We place special emphasis on the gender gap in numeracy and its determinants. In particular, we test the validity of a 'U-hypothesis of gender equality', implying that gender equality in numeracy declines at initial stages of development and increases again as numeracy levels rise. The U-shaped pattern is confirmed by our data.

This chapter is based on a working paper with the same title, co-authored with Julia Friesen and Jörg Baten. The concept for the paper was developed jointly; the analyses and writing were equally shared.

4.1. Introduction

Gender inequality is one of the large burdens for economic development because the economic potential of women is left largely untapped in the growth process. Gender inequality in education is particularly harmful for development because it restricts the opportunities of women in the labour market. Further, as women usually take on the majority of child-rearing, their level of education has also important socio-economic implications for future generations. Today, most world regions exhibit gender inequalities in education. Figure 4.1 (left side) displays the current gender equality index values for adult literacy. The magnitude of the gender differences in South and West Asia is especially striking, where the index value is -30, followed by Sub-Saharan Africa and the Arab States with values as low as -19. Central Asia is the world region with an almost equal distribution of literacy between the genders, relegating North America and Western Europe to second place. In this study we are especially interested in the situation in Asia. Today's high variation in gender differences across Asian countries are further highlighted in the right part of Figure 4.1.

Figure 4.1: Gender equality index for adult literacy (age 15 plus) by world region (2005-2011) and within the Asian region (2000-2005)



Source: stats.uis.unesco.org [May 2013 release], Table: Regional literacy rates for youth (15-24) and adults (15+). The literacy data for the world regions refer to the years 2005-2011, for Asia the data refer to the years 2000-2005. Gender equality index = (literacy females in % - literacy males in %) / (literacy males in %) * 100.

Klasen[28] shows that gender inequality in education negatively impacts long-term economic growth. He argues that South Asian countries could have grown by 0.9 percentage points per year faster if they had started off with better educational levels in the 1960s. Further, a large part of the difference in the growth performance between South and East Asia can be explained by differences in gender inequality in education.

This high variation of today's educational gender inequality worldwide, and particularly within the Asian region, raises a number of questions which require an economic history approach: Did these disparities in education already exist in earlier times? How did the gender gap develop over time? Which factors played a role in determining the different levels of educational attainment of men and women? Did factors that are intrinsic within a society, such as social and cultural norms, matter more than factors influenced more directly by the political decision-makers?

In this study we explore the human capital development in 14 Asian countries during the period 1900s-60s. We place special emphasis on the gender gap in education that arises from distinct opportunities open to men and women. Since literacy information is rare for the decades before 1950 - especially information that is disaggregated by gender - we use the age-heaping method to estimate the basic human capital level of different Asian countries. The age-heaping method assesses the basic numerical skills of a population by looking at the share of persons reporting an exact age. This is based on the observation that less numerate individuals tend to round their ages to multiples of five.[29]

We find not only a substantial gender gap, but also that this gap had an interesting development path: At low education levels the gender gap was quite small, but it increased with overall education. Beyond a threshold point it began to narrow

[28] Klasen, *Low Schooling for Girls, Slower Growth for All?*
[29] Crayen and Baten, *Global trends*.

again. We explain this pattern with the same mechanism Goldin[30] and Mammen and Paxson[31] use for explaining the development of female labour force participation. They hypothesise that the relationship between female labour force participation and economic development is U-shaped. At low income levels women work on family farms and constitute a large portion of the labour force. With economic progress, female share of the labour force declines as the industrial sector expands at the expense of the subsistence economy. Men move into the new blue-collar jobs, while social stigma hinders women from accepting such jobs. At the same time the necessity for women to work might be reduced as a result of higher incomes that men earn during this middle stage of development. Further economic development in the final stage stimulates white-collar employment that is socially attainable for women and economically attractive because of higher wages. Apart from that, economic development is associated with higher educational levels and a drop in fertility rates, increasing educational opportunities for women and decreasing the amount of time spent outside the job market due to child bearing.[32] Female labour force participation has implications for the relative educational level of women. First, since expected returns on investment in girls' education are the basis upon which parents decide whether or not to send their daughters to school, and returns are a function of the prospects of female employment, it follows that female education rates might follow the same U-shaped pattern with respect to development. Second, the same social stigma that hinders women from accepting jobs in the paid industrial labour force might undermine female education.

This paper is organised as follows. The next section begins with an overview of available human capital indicator data for the first half of the 20th century. Then we

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[30] Goldin, *The U-Shaped Female Labour Force Function*.
[31] Mammen and Paxson, *Women's Work*.
[32] Psacharopoulos and Tzannatos, *Female Labour Force Participation*, p. 192.

explain our approach which uses the age-heaping methodology as a proxy for basic numeracy as an additional indicator of human capital and describe the data we use. Section 4.3 presents the development of basic numerical skills of the 14 Asian countries under study and corresponding gender gaps. We link these trends to an overview of the situation of formal basic education in Asia and the status of women in society, education, and working life. Section 4.4 discusses factors that influence numerical skills as well as the U-hypothesis and the results of the corresponding panel regressions. Section 4.5 concludes.

4.2. Assessing human capital via the Age-Heaping Methodology

4.2.1. Educational indicators for Asia 1900s-1960s

Evidence of conventional human capital indicators such as literacy, school enrolment or years of schooling in Asia is scarce for the period prior to WWII. For the period 1870 to1940, the primary school enrolment estimates collected by Benavot and Riddle[33] are a valuable source: according to these data, enrolment varied widely in Asia across countries and over time. Among the countries with available data, Sri Lanka (Ceylon) and the Philippines display the highest enrolment rates during this period. Sri Lanka's enrolment rate was around seven per cent in the 1870s and steadily improved, reaching an enrolment ratio of up to 54 per cent by the 1940s. Taiwan and Thailand show the greatest increases: Within 50 years their governments raised the enrolment ratio from around two per cent to over 50 per cent. India and Burma on the other hand show nearly stagnant enrolment ratios over time: India raised its enrolment rate from the 1870s to the 1940s by a mere 10 to 12 per cent. During the 1950s and 1960s most countries were able to boost their primary school enrolment ratios, but they were all still far from universal education by the mid-20th century. Unfortunately,

[33] Benavot and Riddle, *The expansion of primary education*.

enrolment and literacy data are not given separately for male and female pupils until the late 1950s for most of the Asian countries.[34]

An overview of the available enrolment and literacy data disaggregated by gender for our Asian sample in the 1950s is displayed in Table 4.1. According to these data, the shares of enrolled female and male pupils were almost equally distributed in Sri Lanka, the Philippines, and Thailand. These were also the countries with the highest enrolment ratios in this sample. Afghanistan and Nepal had the lowest enrolment ratios. In these countries, the gender inequality is extremely pronounced: from all pupils enrolled at the first level, only four per cent were female pupils. This observation shows clearly that if schooling is introduced, boys are first to benefit, while girls experience a delay in enrolment.

Table 4.1: Enrolment rates (1955) and literacy rates (1951-1961) disaggregated by gender in Asia

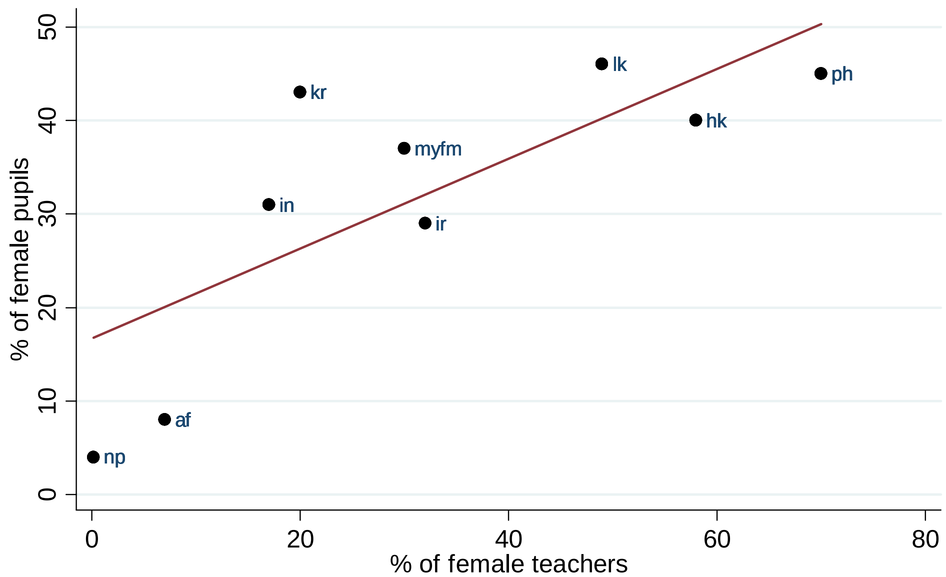
	% school enrolment (undadj.) at first level	% females of pupils enrolled at first level	% males of pupils enrolled at first level	Gender equality index enrolment*	% literacy, age 15+	% literacy females, age 15+	% literacy males, age 15+	Gender equality index literacy**
Afghanistan	4	4	96	-95.83				
Cambodia	22	30	70	-57.14	30.8	5.3	57.6	-90.80
Federation of Malaya	49	37	63	-41.27	47	26.5	66	-59.85
Hong Kong	29	42	58	-27.59	71.4	51.8	90.2	-42.57
India	27	31	69	-55.07	19.3	8.4	29.4	-71.43
Indonesia	39	43	57	-24.56				
Iran	18	30	70	-57.14	12.8	5.5	19.8	-72.22
Nepal	3	4	96	-95.83	5.1	0.6	9.1	-93.41
Pakistan***	19	9	91	-90.11	18.8	7.4	28.9	-74.39
Philippines	54	48	52	-7.69	74.9	72	78	-7.69
Sarawak	33	34	66	-48.48	21.5	12.1	30.9	-60.84
Sri Lanka	56	46	54	-14.81	67.7	52.7	80.5	-34.53
Thailand	51	47	53	-11.32	67.7	56.1	79.3	-29.26

* GE enrolment= (%enrolment female-%enrolment male)/%enrolment male*100, ** GE literacy= (%literacy female-%literacy male)/%literacy male*100, ***today's Bangladesh included. Source: UNESCO (1964) UNESCO Statistical Yearbook 1963, p. 33-34, 103-105, 136-141.

[34] We found literacy data disaggregated by gender before the 1950s only for three countries of our sample (see UNESCO (1953)): India for 1901, Ceylon (resp. Sri Lanka) for 1901, and the Philippines for 1918. However, the definition of literacy varied, so that a direct comparison is difficult.

The UNESCO Statistical Yearbook of 1963 provides additional data on the percentage of female teachers employed. Figure 4.2 displays the relationship between the percentage of female teachers employed and the percentage of female pupils enrolled at the first level of education (data refer to the years 1954-57). Although only data for nine countries are available for the region of our interest, a clear positive relationship is visible. This supports the hypothesis that the presence of female teachers removes one barrier to school attendance for young girls whose parents would not allow their daughters to be taught by male teachers. As these data stem from the late 1950s, they also give us a hint about the educational status of women in the preceding decades, since teachers must be formally educated. Additionally, a high ratio of female teachers can signal a society with a liberal attitude toward the education of females.

Figure 4.2: Relationship between the percentage of female teachers employed and the percentage of female pupils enrolled

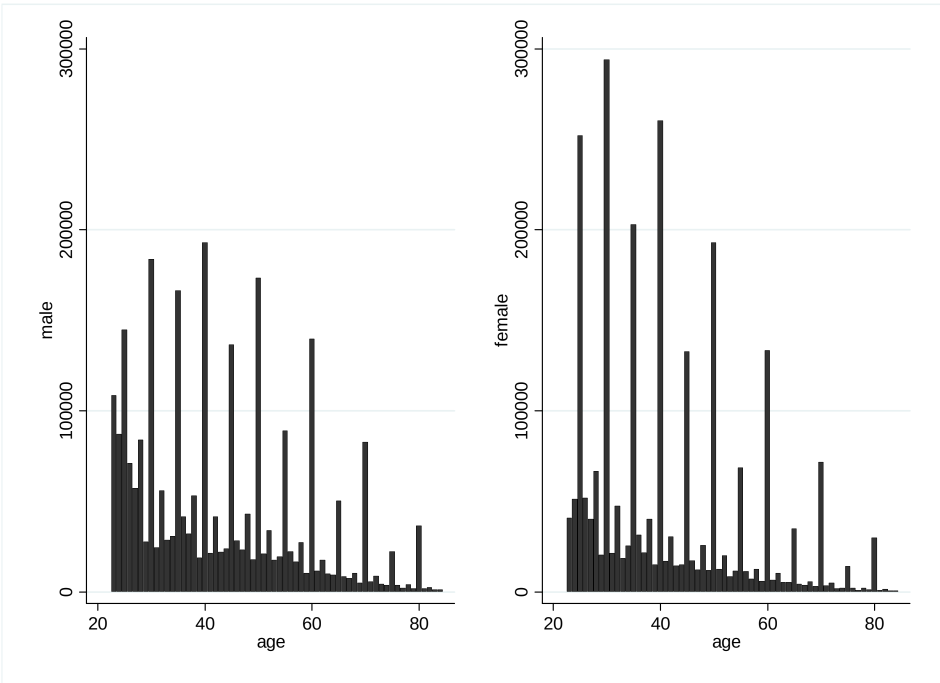


Note: af=Afghanistan, hk=Hong Kong, in=India, ir=Iran, kr=Korea (South), lk=Sri Lanka, myfm=Federation of Malaya, np=Nepal, ph=Philippines
Source: UNESCO, Statistical Yearbook 1963, pp.136-141.

4.2.2. *Age-Heaping as a Proxy for Basic Numeracy*

To close the gap in this fragmentary evidence on human capital indicators for Asia in this period, we will employ a proxy approach in this study: the age-heaping method. This method is based on the phenomenon that people in less educated societies tend to round their age if they are unable to recall or calculate their exact age when asked. Typically, people choose ages on digits ending in multiples of five, i.e. they state their age as 30 if they are in fact, for example, 29 or 32 years old. Figure 4.3 displays the pronounced age-heaping of males and females in Afghanistan as reported in the 1979 census.

Figure 4.3: Age-heaping behaviour of males (left hand side) and females (right hand side) in Afghanistan according to the census of 1979



In contrast to most demographers who treat age-heaping as a mere statistical challenge, we interpret this phenomenon from a different point of view, namely as an indicator for a lack of numerical skills of the population. The usefulness of age-heaping as a proxy for lack of basic numerical skill was first suggested by Bachi[35] who found an inverse correlation between age-heaping and educational levels within and across countries. Mokyr[36] pioneered its use in economic history. Crayen and Baten[37] found that age-heaping tends to be more pronounced in population groups with lower incomes and/ or lower-status occupations.

To measure the extent of age-heaping within a certain population, the Whipple index was developed and became widely accepted (n_x is the population of age x):[38]

$$(1) \quad WI = \left(\frac{n_{25} + n_{30} + ... + n_{65} + n_{70}}{1/5 \times (n_{23} + n_{24} + n_{25} + ... + n_{72})} \right) \times 100 \text{ if } WI \geq 100; \text{ else } WI = 100.$$

To spread the final digits of 0 and 5 more evenly across the age ranges, the age group intervals are defined 23-32, 33-42, and so forth. In demographic analyses this index is usually restricted to the age 23 to 72, as people older than 72 are prone to forget or overstate their age or might be positively selected due to a possible mortality bias. People younger than 23 are not considered, as they often show a heaping pattern deviating from the typical multiples of 5; additionally, in the case of children, usually the parents state the age and not the children themselves. We follow the same restriction.

A'Hearn, Baten, and Crayen[39] propose a linear transformation of the Whipple index, the so-called ABCC index, that is more intuitive for interpretation as this index ranges between 0 and 100: 0 indicates an age distribution with ages ending only on multiples of five whereas 100 implies no age-heaping at all:

[35] Bachi, *The tendency to round off age returns*.
[36] Mokyr, *Why Ireland Starved*.
[37] Crayen and Baten, *New evidence*.
[38] Whipple indices below 100 (ABCC indices above 100, respectively) in the 20th century rich countries are normally caused by random variation, hence those values are set to 100. Additionally, the adjustment for theyoungest age group (23-32) as suggested by Crayen and Baten (2010a, Appendix) are applied.
[39] A'Hearn, Baten and Crayen, *Quantifying Quantitative Literacy*.

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

We calculate the gender equality index in numeracy (GE_{num}) as the ratio of the difference between the Whipple index of females (WI_f) and the Whipple index of males (WI_m) to the Whipple index of males, multiplied by -100:

$$(3) \quad \text{GE}_{\text{num}} = -\left(\frac{(\text{WI}_\text{f} - \text{WI}_\text{m})}{\text{WI}_\text{m}}\right) \times 100$$

The higher the gender equality index, the more women who know their exact age in comparison to men. We expect the gender equality index to be negative; negative gender equality indices imply better numerical discipline for men. Although our countries are rather characterised by gender inequality, we use a gender equality measure to make our results more easily comparable with the literature on female labour force participation by Goldin[40] and Mammen and Paxson[41] and to follow the methodology used by Manzel and Baten.[42]

Recently, several studies confirmed a positive correlation between this indicator and other human capital indicators. In their global study on age-heaping for the period 1880 to 1940, Crayen and Baten[43] identified primary school enrolment as a main determinant of age-heaping: an increase of enrolment rates led to a significant decrease in the age-heaping level. This close correlation between schooling and basic numeracy is not only found among this global data set but is also confirmed by other studies for regional age-heaping sub-samples (e.g. Manzel et al.[44] for Latin America around 1870 to 1930, Baten et al.[45] for Chinese immigrants in the US, Prayon[46] for

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[40] Goldin, *The U-Shaped Female Labour Force Function*.
[41] Mammen and Paxson, *Women's Work*.
[42] Manzel and Baten, *Gender Equality and Inequality in Numeracy*.
[43] Crayen and Baten, *Global trends*. For each decade in the period under investigation the relationship between age-heaping and schooling is remarkably stable and has almost the same coefficient in each period. The coefficient varies only between -0.20 and -0.27 between the 1890s and the 1940s.
[44] Manzel, Baten and Stolz, *Convergence and divergence*.
[45] Baten, Ma, Morgan and Wang, *Evolution of living standards*.

early 20th-century Africa). A'Hearn, Baten, and Crayen[47] examined the U.S. censuses of 1850, 1870, and 1900 and found for the overall sample, as well as for sub-samples, a positive and statistically-significant relationship between literacy and basic numeracy. They also found that this relationship varies by census, ethnic group, and birth region. For early modern Europe they could confirm a positive correlation of signature ability as a proxy for literacy and age-heaping as a proxy for numeracy. Hippe[48] examined systematically the relationship of numeracy and literacy on a regional basis for seven European countries in the 19th century. He found for each individual country a high correlation between the two indicators. In the same way, we collected literacy data for the Asian region to check whether we could find the same positive relationship between basic numeracy and literacy. We took literacy data from the United Nations Demographic Yearbooks (UNDYB) and assigned age groups to the corresponding birth decades.[49] Comparing the two human capital indicators on the basis of these birth cohorts we find indeed a strong positive correlation (with a Pearson's correlation coefficient of 0.85). Unfortunately, due to limited data availability, only nine countries with overlapping data are left for this analysis (Figure 4.4).

Based on the results of these studies it can be concluded that the correlation between numeracy and other education indicators can be regarded as well-established and age-heaping can be interpreted as a proxy for (lacking) basic numerical skills.

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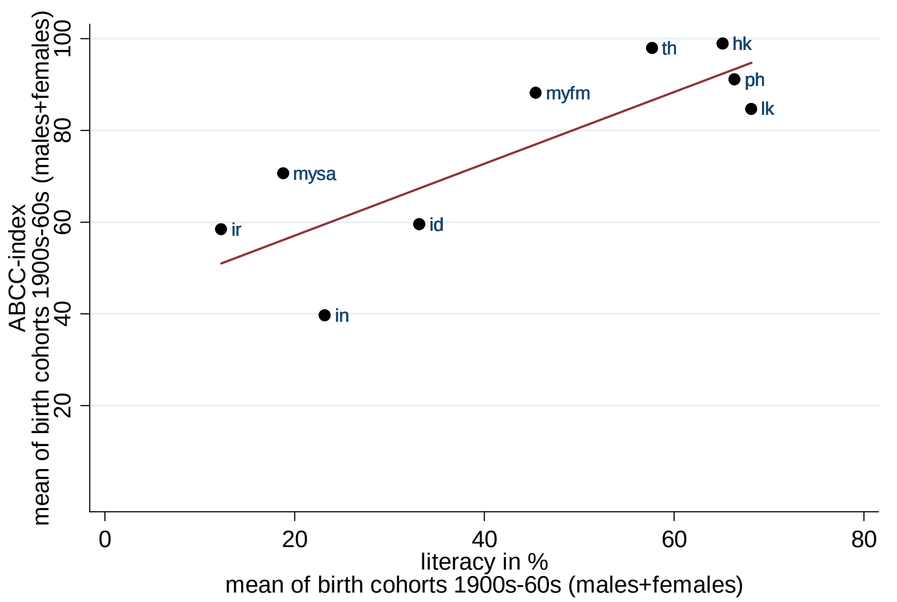
[46] Prayon, *Development and persistence of human capital in Africa.*

[47] A'Hearn, Baten, and Crayen, *Quantifying quantitative literacy.*

[48] Hippe, *How to measure human capital?*

[49] We took the literacy data from the same UNDYB sources as for the ABCCs (see census list in the Appendix). As for the ABCCs, we assigned the literacy rates of the different age groups to the corresponding birth decades and took the mean of the birth decades 1900s-1960s. Figure A.2 in the Appendix displays the relationship of gender equality in numeracy and gender equality in literacy with the same data set, disaggregated by birth decade. We observe a positive correlation between the two indicators; however, as the upper bound of the numeracy index is usually reached earlier than universal literacy, the scatterplot displays a somewhat 'compressed' pattern.

Figure 4.4: Relationship of literacy and the ABCC-index in Asia



Note: hk=Hong Kong, id=Indonesia, in=India, ir=iran, lk=Sri Lanka, myfm=Federation of Malaya, mysa=Sarawak, ph=Philippines, th=Thailand

Indeed, the age-heaping method possesses advantages that literacy and enrolment evidence lack. Due to its consistent calculation, age-heaping results might be easier to compare across countries, whereas comparisons of literacy and enrolment rates might be misleading due to significant measurement differences (especially due to different definitions of literacy) and different school systems. Further, owing to the typical high drop-out rates in developing countries and heterogeneous teacher quality, it can be argued that enrolment rates are less conclusive for our goal as enrolment ratios are an input measure of human capital. Although a country might have high enrolment ratios, these ratios do not permit conclusions about the quality of education. Age-heaping on the other hand is - like literacy - an output measure of human capital. Another convenient advantage of the method is that it can applied to a wide range of sources, for instance census data, passenger lists, or any other kind of individual age recording. This way we can trace basic numerical skills of populations from periods and areas for which no other human capital indicators exist yet. This applies especially to this study: We do not have another human capital indicator disaggregated by gender that covers so many Asian countries for the period 1900-1960.

Like other proxies, the age-heaping measure has its limitations. It only captures age-heaping on multiples of five, although people in their late teens and early 20s tend to round on multiples of two. In addition, some cultures have specific number preferences, for example the 8 or the dragon year in China.[50] Similarly, if individuals were asked for their date of birth instead for the age at their last birthday, a birth year-heaping pattern could arise. In both cases the age-heaping method does not return unbiased estimates, so the age-heaping patterns should be checked carefully. Further, due to its upper boundary and therefore lacking variation, we do not get meaningful results in populations where no or only marginal age-heaping exist.[51]

4.2.3. Data

For the numeracy trends we collected age distribution data for 14 Asian countries from 23 different censuses conducted between 1947 and 2001, i.e. for seven countries we have more than one census at hand (see the census list in the Appendix). For most of them we could access these data via their publication in the UNDYB. For Bangladesh and Pakistan we consulted the original publications from the national statistic departments. Based on these age distributions data we calculated Whipple, ABCC and Gender Equality indices for each country and birth decade according to the formulas (1), (2), and (3). First, the indices are calculated for the age groups 23-32, 33-42, …, 63-72, then these are assigned to the corresponding birth decades. In the case that data overlap for one or several birth decades within a country, because more than one

[50] Baten, Ma, Morgan and Wang, *Evolution of living standards,* examine this possible bias, but could not find a significant influence of preferred numbers on the Whipple index.

[51] For this reason we hat to exclude the East Asian countries China, South Korea, and Vietnam from our data set as the populations of these countries did not display age-heaping any more at the turn to the 20th century. Hong Kong is the only exception in the Eastern part of Asia which had high basic numeracy, but still some age-heaping remains. Hence, we included Hong Kong. As a robustness check we ran all our regression models also with China, South Korea, and Vietnam included: the coefficients turned out to be robust (results available from the authors).

census was available for this country, we calculated the arithmetic average of the overlapping indices. The calculated Whipple and ABCC indices disaggregated by gender as well as the Gender Equality indices for the countries under study are available in the Appendix (Table A.1). Additionally, Table A.2 in the Appendix presents the number of single-age returns upon which the Whipple and ABCC indices are based. Although not all of these censuses captured the whole population, every single index value is calculated on the basis of at least 8,000 observations, and the maximum is 83,000,000. This broad data base should keep possible selectivity biases within our indices to a minimum.

4.3. The Development of Numeracy and Gender Equality in Asia

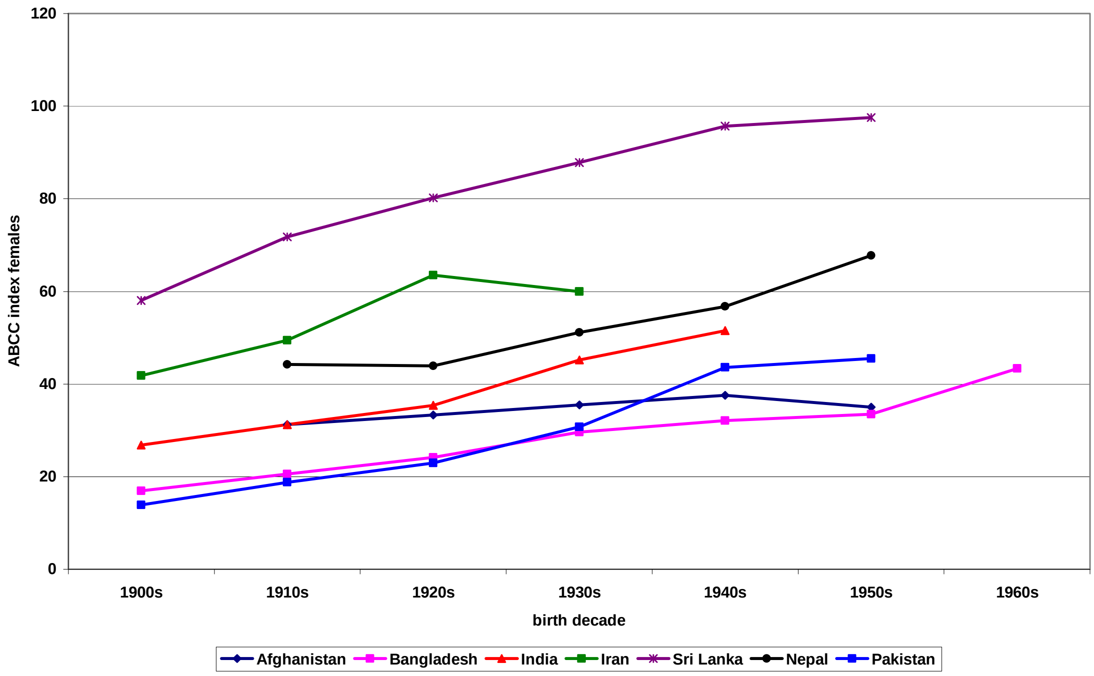
Now we turn our attention to the country-specific characteristics and historical experiences that shape the attitude of a country's population towards education. In the following overview we outline the situation of formal basic education and shed light on the status of women in society and working life. Selected interesting cases are presented to show the diversity in Asia with respect to gendered education. Figures 4.5 and 6 display the female numeracy trends (ABCC index) for the 14 countries in our sample for the birth decades 1900s to 1960s, so we can check whether the developments mentioned in the literature are mirrored by our empirical evidence.[52] The countries are grouped by their geographic location: South and West Asia on the one hand, and East and South East Asia on the other hand. Likewise, Figure 4.7 and Figure 4.8 present the corresponding gender equality trends.

Since we use numerical abilities as a proxy for education, we have to consider that skills of basic numeracy, rather than literacy skills, are not exclusively acquired through formal schooling, even though it is the primary source. It is also possible that

[52] Due to space constraints we decided to present only the figures of the female numeracy development in the text.

numerical skills are trained to some extent in the household if women are responsible for complex tasks in the household, e.g. financial issues. Therefore, the level of female numeracy might not only depend on formal schooling but also on the social and economic role of women within the society in general and within the family in particular.

Figure 4.5: Numeracy (ABCC index) of the female population in South and West Asia, birth decades 1900s-60s



The figures reveal large differences in the numeracy levels between the countries: Whereas most Southeast Asian countries had almost full numeracy in terms of the ABCC index already around 1910, the South Asian countries Pakistan, Bangladesh, and Afghanistan are the countries with the lowest numeracy levels in our sample. Although they improved in terms of numeracy during the first half of the twentieth century, numeracy levels remained very low and did not even reach 50 ABCC points by the 1950s. The pace of development also varied. Sri Lanka, e.g., shows a rapid improvement in numeracy within six decades. The country worked its way up from 65 points on the ABCC index at the beginning of the century to a numeracy level of 98 ABCC points in the 1950s. In contrast, the ABCC levels of e.g. Sarawak and the Federation of Malaya were almost stagnate during the first half of the 20th century. Here it is also interesting to note that the colonised Federation of Malaya and independent Sarawak had the same trend of stagnation, however, the level in the Federation of Malaya was around 20 ABCC points higher than in Sarawak. This could be due to the fact that a great part of the population in the Federation of Malaya consisted of well-educated Chinese immigrants.[53]

4.3.1. Government and Religious Groups as Suppliers of Education

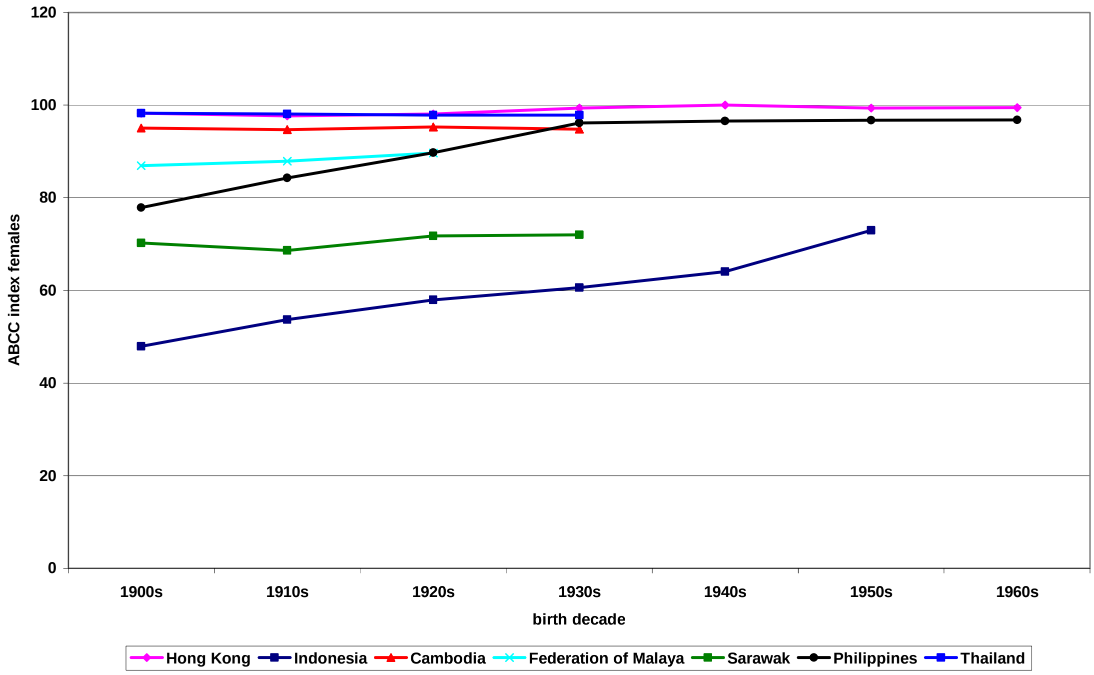
Formal education is determined by supply and demand. On the supply side we have the national and local governments, charities and religious organisations. The demand for education is influenced by economic incentives, such as labour market perspectives, or by economic constraints, such as poverty and the dependence on child labour. In addition, culture and religion play a role because there is variation in the importance that is placed on education and the social and (re)productive role ascribed to women. The profound economic changes that come along with industrialisation can erode cultural and religious traditions and the status of women. Furthermore, organisational issues, such as good infrastructure and the availability of female teachers, clearly matter.

Given that most of the countries were colonised during the sample period, colonial governments were in the position of providing universal education that did not exist in Asia at that time. However, the colonial administrators established Western-style schools on a small scale, mostly in urban areas, and often exclusively for Europeans and the national aristocracy. Additionally, as Benavot and Riddle[54] point out, different attitudes towards the expansion of primary schooling in the colonies can

[53] Sidin, *Malaysia*, p. 123.
[54] Benavot and Riddle, *The expansion of primary education*.

be observed among the European powers. In worldwide comparison, Britain pursued a more active education agenda than France, whose colonies recorded primary school enrolment rates in 1940 that the British colonies had already attained around 40 years earlier. Interestingly, this pattern for the worldwide sample of colonies is not confirmed in Asia; for example, British India had low primary schooling rates. Chaudhary explains that social heterogeneity and hierarchical differences between castes exacerbated the provision of primary schools as the elites, such as Brahmans, supported secondary schools for their children instead of primary schools for the masses.[55]

Figure 4.6: Numeracy (ABCC index) of the female population in East and South East Asia, birth decades 1900s-60s



Apart from colonial governments, religious groups, notably Christian missionaries, built schools and taught indigenous pupils. This occurred in all countries,

[55] Chaudhary, *Determinants of Primary Schooling, p. 300.*

both colonised and independent. In harmony with Christian egalitarian precepts, these schools usually admitted girls. Still, the national population often refused to send their children to Western schools.[56]

Despite this disappointing situation in British India, educational institutions were built for women in the 1870s and 1880s and a special commission, the Indian Education Commission, was set up to forward policy recommendations.[57] The Viceroy of India, Lord Curzon, took initiatives to enhance female education with the Resolution on Educational Policy in 1904, which increased public funds for the establishment of girls' primary schools and training colleges for female teachers. The Resolution on Educational Policy of 1913 proposed to grant scholarships to female students, but financial problems delayed further achievements.[58] The transfer of responsibility to the provinces, the social awakening of women in the 1920s, and Mahatma Gandhi's postulation of gender equality helped improve opportunities for women, although on the whole progress in education was poor before independence.[59] The Census of British India 1911 reports female literacy rates for the British districts: the values vary between 0.3 per cent (Central Provinces and Berar) and 1.4 per cent (Bombay).[60] Overall, the literacy rate for females age 10 years and older was at 1.1 per cent; twenty years later, in 1931, it was still low, at 2.4 per cent.[61]

The British Education Inspectors did not make significant efforts to improve education for the Muslim population predominantly situated in (the area of today's) Bangladesh and Pakistan. Despite the Woods Despatch of 1854 which demanded better education (also for girls) and the Resolution on Muslim Education in 1871

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[56] Law, *Schooling in Hong Kong,* p. 88.
[57] Agrawal, *Women's Education in India*, p. 21.
[58] Pruthi and Sharma, *Education and Modernisation*, pp. 79-80.
[59] Gosh and Talbani, *India*, p. 167.
[60] See Table 1 in Chaudhary, *Determinants of Primary Schooling, p. 277.* In the census of 1911, persons were considered as literate, if they could both read and write any language, see India. Census Commissioner *Census of India, 1911*, p.113.
[61] UNESCO, *Progress of literacy*, p.110.

which established quotas for Muslim pupils, Muslim participation in education remained low, and Muslims continued to be underrepresented in government positions.[62] The numeracy evidence supports these observations mentioned in the literature: Bangladesh, India, and Pakistan are countries with very low ABCC indices for both genders (see Figure 4.5 and Table A.1); in fact, they are the countries with the lowest numeracy levels in the sample. Although these countries improved in terms of numeracy during the first half of the 20th century, numeracy levels remained low. In Bangladesh and Pakistan the numeracy was still below 50 ABCC points by mid-century. The difference between males and females is small in these countries, which corresponds with a quite equal distribution of numeracy between the genders (see Figure 4.7).

In the Philippines we see a different, much more progressive picture. Advances in the expansion of primary schools (also for girls) had already been made under Spanish rule since 1863.[63] With the Education Act of 1901 American administrators in the Philippines established free public schools staffed with American teachers and with English as the language of instruction, encouraging female education.[64] The rapid expansion in the number and variety of schools brought education to a large part of the population. With it, a range of new (Western) ideas came to the Philippines, eroding foundations of authority patterns within the traditional system.[65]As a result, by the mid-20th century 30 per cent of working women were employed in the modern sector – the highest figure among the developing countries.[66] This positive development in education described in the literature is reflected by figures of human capital indicators: The census of 1939 reports a literacy rate for the male population (age 10+) of 54.4 per

[62] Amin, *Schooling in Bangladesh*, p. 41. Chowdhury, *Pakistan*, p. 189.
[63] Torralba, Dumol and Manzon, *Schooling in the Philippines*, p. 280.
[64] Gomez and Pedro, *The Philippines*, p. 265.
[65] McHale, *The Philippines in transition*, p. 336. He reports also enrolment numbers for the first half of the 20th century.
[66] Boserup, *Woman's Role*, p. 182.

cent and for females 43.2 per cent. In the census of 1948 the gender gap was further reduced, with male literacy at 64.4 per cent and female literacy at 58.3 per cent.[67] Our numeracy estimates confirm the same trend (see Figure 4.6 and 4.8): By 1930 age-heaping almost vanished among males and females, and the gender gap closed by 1930, even turning slightly positive in 1940.

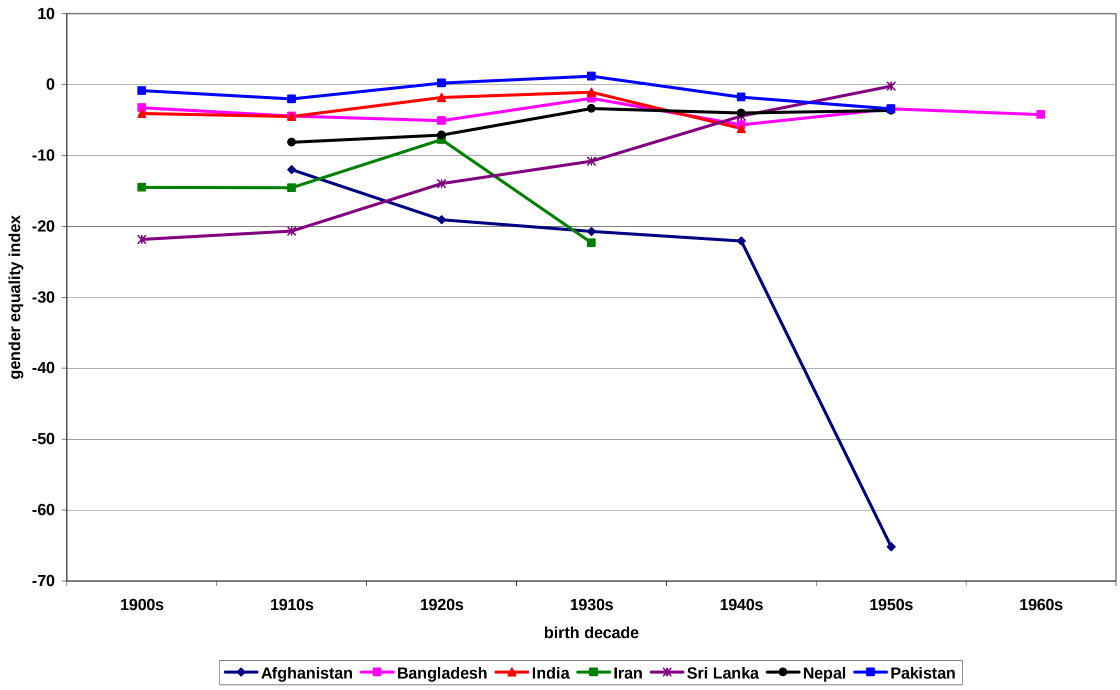
In Cambodia the French introduced modern secular education but did not explicitly support the education of girls. Their interest concentrated on the recruitment of male civil servants for the colonial bureaucracy. At the beginning of the 20th century *wat* schools (schools in Buddhist monasteries) were modernised, bringing access to education to the rural areas of Cambodia. Since Buddhist monks were not supposed to associate with girls, however, girls usually did not benefit from the reforms.[68] In the 1950s only about five per cent of females were literate in contrast to 58 per cent of males. Nevertheless, age awareness was very high for females and males alike in Cambodia at this time, revealing almost no gender inequality in terms of basic numeracy.

Afghanistan is an interesting case because of the conflict that arose between the clergy and the government when attempts were made to modernise education. Boys were taught reading, writing, and Islamic practices by the *mullah* in mosques, while girls received a basic education in reading the Qur'an and praying at home. With the aim to offer free and secular education, King Habibullah (reign: 1901-19) made efforts to bring education under the control of the government. He founded several schools but the opposition from the *mullah* slowed the process considerably. When his successor Amanullah (1919-29) wanted to introduce compulsory education for boys and girls and reform the laws and customs that abased Afghan women, he was forced

[67] UNESCO, *Progress of literacy*, p.123. In both censuses the definition of being literate was to be able to read and write.
[68] Sopheak and Clayton, *Schooling in Cambodia*, pp. 41-4.

to resign by the *mullah*. Although Zahir Shah (1933-73) managed to increase the number and quality of schools in Afghanistan with international, especially American, assistance, only five per cent of the primary school-age population was enrolled by the mid-20th century.[69] The ABCC trends reflect this low level of success in introducing schooling on a broad basis. Females remained below 40 ABCC points in the midst of the 20th century, while males increased 17 ABCC points between the 1940s and 1950s. The results for males were likely due to the efforts undertaken in the education sector by the government. Meanwhile, the female ABCC almost stagnated for four decades. From the 1940s to the 1950s the index even decreased. These deviating trends of male and female basic numeracy led to the significant decline of the gender equality index we observe in Figure 4.7.

Figure 4.7: Gender Equality index of numeracy in South and West Asia, birth decades 1900s-60s



[69] Shirazi, *Schooling in Afghanistan*, pp. 20-6. UNESCO, *UNESCO Statistical Yearbook 1963*, p.103, 137 reports for the year 1955 a primary school enrolment ratio of 4 percent, and only 4 percent among them are females.

According to Kazemzadeh, the situation was quite different for women in the neighbouring state of Iran: Women in Iran enjoyed mass education after the Constitutional Revolution of 1905-11 and by the 1960s even entered blue-collar employment.[70] The school enrolment ratio for females was at that time higher in Iran than in Afghanistan. The 1955 UNESCO statistics report that out of the 18 per cent enrolled in primary schools, 30 per cent were females.[71] Nevertheless, our gender equality index of numeracy indicates that the improvements in schooling increased faster for males than for females. In Thailand (Siam) the progressive Kings Rama IV (1851-1868) and Rama V (1868-1910) modernised the country's education system in the mid-19th century and suggested a strand of Buddhism compatible with science. The first government school for girls was established in 1901.[72] In the 1950s Thailand had an enrolment ratio in primary schools of 51 per cent, almost half of which was female. The numeracy index in Thailand for both genders was already almost 100 ABCC points around 1900, the same picture we have seen in Cambodia.

4.3.2. Cultural and Social Norms as Barriers for Female Education

In South and West Asia, the role of women in social, political and economic life was strongly influenced by the Hindu and Muslim religions – and still is today. Most Hindu and Muslim families did not invest in a girl's education because the expected returns to sending a daughter to school did not exceed the costs of doing so.[73] The benefits would go to the future husband's family with whom the woman would reside after marriage.[74] Furthermore, the opportunity costs of sending a girl to school were too expensive for many families, as daughters assumed a great deal of domestic tasks in contrast to their

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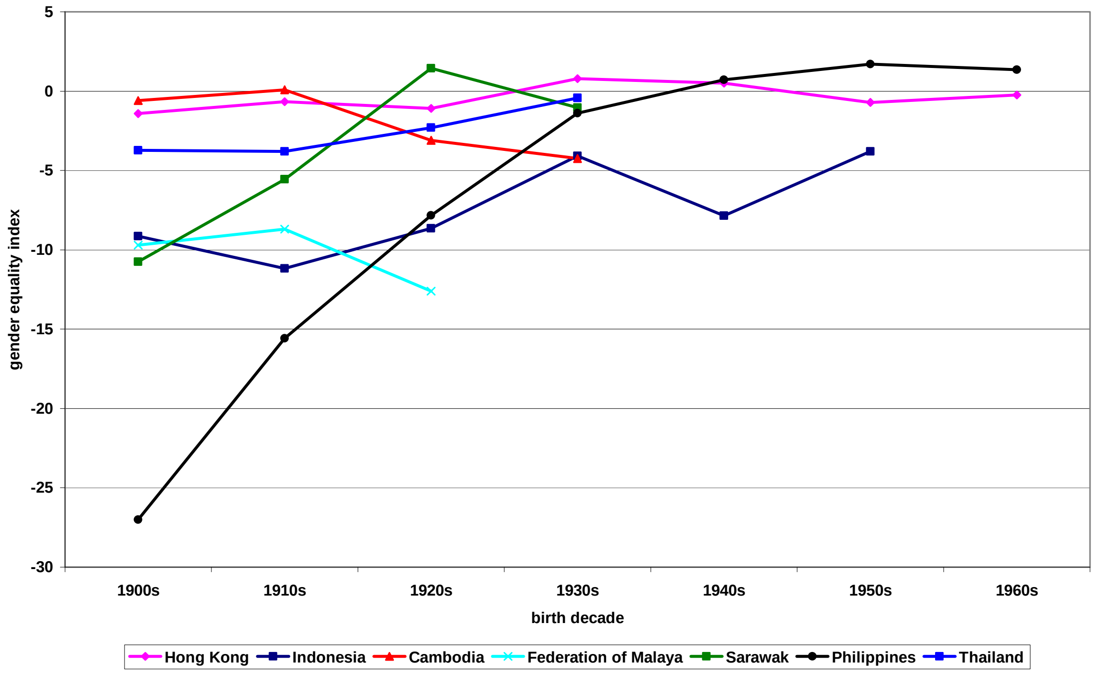
[70] Kazemzadeh, *Iran*, pp. 177-8.
[71] UNESCO, *UNESCO Statistical Yearbook 1963*, p.104, 138.
[72] Sinlarat, *Schooling in Thailand*.
[73] Hill and King, *Women's Education*, pp. 23-4.
[74] Khan, *South Asia*, p. 228.

brothers.[75] Early marriage was common and presented another barrier to female education, even after the British colonial government set the age for marriage at 14 years for girls in 1929.[76] Subordinate to a man's will, wives were not supposed to have a higher education than their husbands. This made the education of girls 'socially costly'.[77] Since Hindus and particularly Muslims adhered to female seclusion and veiling, girls were usually not sent to co-educational schools or to schools lacking female teachers.[78] This norm further restricted educational opportunities for girls, as girls' schools were rare at that time and mostly located in the cities.[79]

Figure 4.8: Gender Equality index of numeracy in East and South East Asia, birth decades 1900s-60s



Although the above holds true for most of South and West Asia, Southern India and Sri Lanka stand out. The Indian state Kerala had the lowest gender gap in literacy

[75] Chowdhury, *Pakistan*, p. 202.
[76] Gulati, *Impact of the Development Process*, p. 298.
[77] Chowdhury, *Pakistan*, p. 199.
[78] Ahmed, *Pakistan*, p. 270.
[79] Gosh and Talbani, *India*, pp. 170-81.

in India; additionally, female work participation was higher in South than North India.[80] Ghosh and Talbani attribute this incidence to the matriarchal system, a dominantly Christian population, and the absence of *purdah* (veiling) in the Muslim communities. Compared to Hindu and Muslim women who usually did not participate in the organised labour force, Sri Lankan (and mostly Buddhist) women traditionally worked with men in the agricultural and industrial sectors.[81] In Sri Lanka, missionary education constituted the official school system and influenced society insofar that Saram speaks of a 'Protestant Buddhism' that shaped Sri Lankan social life.[82] These attitudes towards the role of women likely influenced the positive educational progress in Sri Lanka: it virtually achieved gender equality in education in terms of enrolment rates and numeracy by the midst of the 20th century (see Table 4.1 and Figure 4.7), similar to the Philippines and Thailand.

In Southeast Asia, women enjoyed a relatively higher status in society and had more legal rights than women in South Asia. They were not concerned by seclusion and separation but managed household finances, had command over productive resources and participated in market activities.[83] In Vietnam for example, daughters could inherit land, and wives were allowed to hold a share in family property and participate in religious rituals.[84] In 1932, Thailand was one of the first Asian countries to introduce universal male and female suffrage in 1932. Buddhism, the major religion in most of the Southeast Asian countries, prescribed – unlike Hinduism – duties for both marriage partners. Not only dowries were paid, but also bride prices, hence enhancing women's self-confidence. Also, women were given a say in the choice of their future husbands. Although education was mainly provided for boys in monastic

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[80] Rajeswari, *Demographic Perspective*, p. 341.
[81] Mittra and Kumar, *Encyclopedia of Women in South Asia*, pp. 33-8.
[82] Saram, *Sri Lanka*, p. 348.
[83] Elson, *International Commerce*, pp. 173-4, see also Boserup, *Woman's role*, p. 91.
[84] Rambo, *Vietnam*, p. 412.

schools until its secularisation in the late-19th century, sophisticated Buddhist monks did not oppose female education in general.[85]

Not all countries in Southeast Asia are characterised by a Buddhist tradition. Filipinos are largely Roman Catholic, whereas Indonesia and Malaysia[86] are predominantly Muslim. The Muslim societies in Indonesia and Malaysia differed in several ways from those in Afghanistan, Bangladesh, and Pakistan. First, Indonesia was a secular state where women were active and financially-independent members of society.[87] Second, the Muslim population in both countries did not practice veiling.[88] And third, Indonesia and especially Malaysia became multiethnic countries through the influx of immigrants, particularly from China, who supported their children's educational aspirations, regardless of gender.[89] The plurality of Malaysian society produced a variety of school types, from public schools to Christian missionary schools and Chinese schools.[90]

In summary, we observe that the numeracy level of both men and women rose in almost all countries during the first half of the 20th century. But even though women's legal and social status improved in some countries, the overall demand for the education of girls was low and gender inequality persisted during the period under study. Interestingly, high gender equality is also evident in the countries with very low overall numeracy levels, e.g. in Pakistan and India. We can take this incidence as a hint of the applicability of the U-hypothesis that we will investigate in the next section: We anticipate that the numeracy level of men increases more rapidly relative to the

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[85] Buddhist countries promoted co-education and trained women as teachers and administrators; they did so even better than India, Muslim countries, and many Latin American countries. See Carroll, *Women, Religion and Development*, pp. 89-104.
[86] This paper distinguishes between the Federation of Malaya and Sarawak. Sarawak became part of Malaysia in 1963. If we speak of 'Malaysia', we refer to the Federation of Malaya.
[87] Oey-Gardiner and Suprapto, *Indonesia*, p. 95.
[88] Tilak, *East Asia*, p. 269.
[89] Loo, *Schooling in Malaysia*, p. 211.
[90] Means, *Malaysia*, p. 477.

numeracy level of women in the first stages of development, which will be reversed later.

4.4. Evidence for the U-Hypothesis of Gender Equality from Asia

Before we explore the development of educational gender (in-)equality in Asia, we want to examine which social, cultural, and economic factors influence the level of numeracy. As we are interested in the differences between male and female levels of numeracy, we examine these factors disaggregated by gender; i.e. we analyze possible factors one time for males only, the other time for females only. This way we can identify important determinants of numeracy; additionally, differences of the effects of these determinants on male and female numeracy might tell us what drives gender inequality. As already discussed in the methodology section, school enrolment has proven to be a main determinant of numeracy. Enrolment rates are an alternative way of measuring the level of human capital; however, it is an input factor whereas numeracy is an output factor of human capital. In this study, we use the estimates made by Benavot and Riddle[91] for the period 1870-1940 and supplement their data with unadjusted enrolment rates from the UNESCO Statistical Yearbook of 1963[92]. Since children usually enrol in school at ages five to ten, while the ABCC data are constructed on the basis of birth decades, the enrolment rates are postponed by one decade in our analysis. As a general welfare indicator we use the GDP per capita data from Maddison.[93]

[91] Benavot and Riddle, *The expansion of primary education*.
[92] UNESCO, *UNESCO Statistical Yearbook*.
[93] Maddison, *The world economy*.

Table 4.2: Summary statistics

	Obs	Mean	Std. Dev.	Min	Max
Gender equality numeracy	73	-6.93	9.67	-65.18	2.72
ABCC	73	66	27	14	100
ABCC squared	73	5,079	3,428	210	10,000
ABCC female	73	64	27	17	100
ABCC male	73	68	26	15	100
Female voting right	73	0.29	0.46	0	1
Hinduism	73	0.14	0.35	0	1
Buddhism	73	0.19	0.40	0	1
Christianity	73	0.10	0.30	0	1
Islam	73	0.48	0.50	0	1
Confucianism	73	0.10	0.30	0	1
GDP per capita	59	992.10	638.11	349	4,318
GDP per capita squared	59	1,384,541	2,576,345	121,801	18,645,124
Enrolment rates	61	13.01	13.24	0.50	64.00
Population density	30	72.22	71.96	9.28	399.14
Land productivity	30	1.30	0.40	0.41	2.16

Note: For variable definitions and sources see Appendix.

Additionally, we consider female voting rights as an indicator for the social status of women within society.[94] Granting women political participation can be regarded as a first and important step on the path towards gender equality as it reflects a change in public perception of women's role in society. Such an official statement by the government might also encourage women to invest in their own education or in that of their daughters. In most of the countries under study, voting rights were granted to women between 1930 and 1960. We extracted this information from the UN's Human Development Report 2009.

Next, to measure cultural factors, we include dummies for four predominant religions in the Asian region - Buddhism, Christianity, Confucianism, and Hinduism – with Islam as reference category. The dummies take a value of one if the majority of a country's population avowed itself to one of these religions. A priory, we have no clear

[94] See the Appendix for all variable definitions and sources.

expectation about the effects of the various religions, but based on our discussion in the second section, the coefficients of Islam and Hinduism might show a negative effect on female basic human capital since traditional practices, e.g. veiling (*purdah*), might form an obstacle to sending girls to school.

Table 4.3: Explaining basic numeracy (ABCC index) disaggregated by males and females

	(1) ABCC males	(2) ABCC females	(3) ABCC males	(4) ABCC females	(5) ABCC males	(6) ABCC females	(7) ABCC males	(8) ABCC females
Female voting rights			11.39***	13.83***	11.07***	13.55***	6.402**	8.147***
			(1.509)	(1.739)	(1.619)	(1.858)	(2.524)	(2.947)
Hinduism					-10.10	-7.818	-4.463	1.325
					(11.29)	(11.77)	(15.62)	(13.98)
Buddhism					35.25***	38.80***	28.80	34.07
					(10.09)	(12.31)	(17.97)	(21.53)
Chrstianity					30.71***	32.91**	21.64**	25.76**
					(9.455)	(14.59)	(11.03)	(12.42)
Confucianism					38.71***	43.88**	25.33	32.64
					(14.54)	(18.18)	(24.87)	(26.67)
Enrolment rates (log)	6.141*	8.052**					3.334	4.235
	(3.239)	(3.974)					(2.868)	(3.413)
GDP per capita (log)	14.51*	15.17*					8.656	8.721
	(7.816)	(8.582)					(7.268)	(7.948)
Constant	-40.23	-54.03	66.57***	61.83***	55.50***	49.15***	-5.625	-16.98
	(48.37)	(51.37)	(6.837)	(7.253)	(7.531)	(7.177)	(47.78)	(50.79)
Observations	55	55	73	73	73	73	55	55
Number of countries	12	12	14	14	14	14	12	12
R-squared (within)	0.44	0.48	0.4	0.49	0.4	0.49	0.52	0.56

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. For variable definitions and sources see Appendix. Dependent variable is the ABCC index for males, respectively females. Estimation technique: Panel regression, random effects. In model 5, 6, 7, and 8 the reference category is an Islamic country with no female voting rights.

Table 4.3 presents the results of four different panel regression models, each carried out for males and females separately. Table 4.2 shows the summary statistics of the variables used in all regressions of this study.[95] The corresponding pairwise correlation coefficients can be found in the Appendix (Table A.3). Models 1 and 2

[95] The Hausman test suggests random effects for our models. We conducted all regression as both fixed and random effects models. The coefficients were similar, only the significance was lower for the FE models. We decided to show the RE results, as this way, also the dummy variables could be shown explicitly. The results of the FE regression are available from the authors.

examine the influence of (unadjusted) enrolment rates and GDP per capita on numeracy level. Models 3 and 4 test only the influence of female voting rights in a country on ABCC levels. Models 5 and 6 introduce the dummy variables for the different religions, and models 7 and 8 present all considered variables together.

Enrolment rates, GDP per capita, and female voting rights have all a positive and significant effect on numeracy. However, a possible correlation and endogeneity between these four coefficients might bias the results to a certain extent: higher GDP enables more investment in education. Higher education enables people to be more productive. Economic progress might additionally subvert cultural traditions that are prejudice against women, changing their social status and leading eventually to the right to vote. Female voting rights as a proxy for the status of women might also capture degree of economic progress. The same mechanism can drive the relationship of enrolment rates and the status of women: If the status increases, parents invest more in the education of their daughters and the overall level of education within a society increases. At the same time, higher education might result in changes of the attitude towards women and might additionally lead to voting rights. To some extent we reduce this endogeneity by the timing of the factors: ABCC is organised by birth decades, i.e. the values of GDP per capita reflect the economic situation and therefore the possible investment in education during that particular birth decade. Hence, the direction of influence should run from GDP to ABCC. The same applies to female voting rights. We measure the effect of having female voting rights during the birth decade, i.e. at the early phase of education. Similarly, enrolment rates are lagged by one decade to capture this time dimension.

The coefficient of the female voting right variable stays significant throughout the different models. That this factor also has a strong impact on the numeracy level of males is not surprising as education and social change are highly linked to each other.

Enrolment rates and GDP per capita turn insignificant when voting rights are included; the sign, however, stays positive. Here it is highly likely that the aforementioned links between the effects drives this outcome.

In this analysis at hand the coefficients for Buddhism, Christianity, and Confucianism turn out to have a positive effect on ABCC for both genders compared to Muslim countries (reflected by the constant), whereas countries where the majority of the population adheres to Hinduism have on average a lower ABCC index as Muslim countries. Five of the seven Muslim countries show an average ABCC below the median of the average ABCC of all countries under study. The Christian, Confucian, and Buddhist countries display all average ABCC levels greater than the median. However, one should be careful to interpret these results as a general pattern or assume that certain religious orientations or traditions are generally a hindrance to economic or educational development. The Federation of Malaya for example is a Muslim country with an average ABCC level nearly the same as that of the Philippines. Our results might also be driven to some extent by the special characteristic of this sample of countries: the sample consists of only one Christian country (The Philippines), one Confucian country (Hong Kong), two Hindu countries (India and Nepal), three Buddhist countries (Cambodia, Sri Lanka, and Thailand), and yet seven Muslim countries (Afghanistan, Bangladesh, Federation of Malaya, Indonesia, Iran, Pakistan, and Sarawak). In models 7 and 8 we include GDP per capita and enrolment rates to control for the economic and educational status of each country. The coefficients in most models turn insignificant and are smaller than in models 5 and 6, however the overall pattern stays the same.

Comparing now directly the pairs of male and female regressions, we see throughout the different models that the coefficients of the independent variables are higher in the ‘female-only regressions’ than in the ‘male-only regressions’.

Additionally, the constant always reflects a lower overall ABCC level for females than for males. Interpreting the coefficients would mean that the increase per unit is higher for females than for males. However, a direct comparison between the male and female coefficients is not possible, as the different coefficients must always be interpreted in relation to the constant. And these are always different. For extracting the driving forces behind gender (in-)equality, we have to look at a measurement relationship index, as the GE-index presented above in the methodology section.

Based on the findings of the previous section, we assume a U-shaped development of gender equality in numeracy: gender equality in numeracy will be high at low numeracy levels but will decline with increasing numeracy levels down to a point at which gender equality starts to rise again. The theoretical consideration behind this process is that parents base their decision regarding the education of their daughter(s) on the labour market and income prospects for women. If these are promising, parents will send their daughter(s) to school. With the expansion of primary education, boys might be enrolled first while dominant social customs retain girls in the traditional household. Only with further development will social norms be challenged and girls enrolled.

Thus, GDP per capita should have a positive impact on gender equality, since the basic assumption is that female labour market prospects perspectives eventually improve with economic development. Economic progress might additionally subvert cultural traditions. Furthermore, population density might positively influence gender equality in numeracy. For example, it can be argued that with higher population density the availability of schools increases, spreading education more evenly, including for girls.

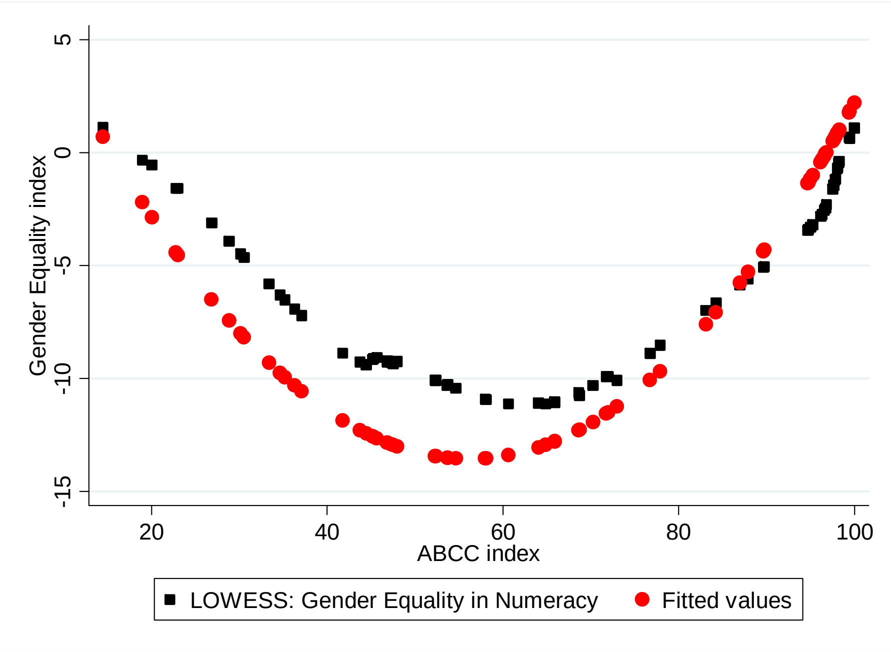
We will also test whether we find Boserup's observation confirmed in our data. The colonialists in South and Southeast Asia promoted advanced techniques in agriculture, especially in irrigation. Boserup argues, however, that in this process, the previously important female agricultural skills were not developed further.[96] Hence there might have been the paradoxical effect that higher land productivity could have augmented the differential between men and women, reducing gender equality. To assess this possible influence, we include land productivity - here measured by rice output per rice area - in one of our regression models.

In the following we test this U-hypothesis systematically by carrying out a panel data analysis (unbalanced panel) with gender equality in numeracy (see formula (3)) as the dependent variable.[97] Before we start, we check whether the assumption of a U-shaped function between the overall numeracy level and gender equality in numeracy (GE_{num}) is justified. We apply a LOWESS regression smoothing with GE_{num} as the dependent variable and ABCC as the independent variable, which works somewhat similar to a moving average in time series analysis.[98] We find indeed a clear U-shaped pattern (displayed by the curve composed of the square symbols in Figure 4.9): Gender equality in numeracy first declines and then increases with the level of numeracy. Hence, using a squared function in our estimation model is justified. The other curve in Figure 4.9 represents the fitted values of the mere regression of gender equality in numeracy on ABCC and ABCC squared, i.e. without controlling for other possible explanatory variables. The U-curve with the fitted values looks similar in shape but with a turning point at the minimum situated slightly left to the one of the

[96] Boserup, *Woman's role*, pp. 54-6.
[97] We follow here Manzel and Baten (2009) who did similar analyses for Latin America and the Caribbean. As discussed above, we excluded China, South Korea, and Vietnam from the following analyses to reduce the probability that our results are driven by those countries. We decided to keep Hong Kong in the sample as it still shows some variation in the numeracy index and the gender equality index. As a robustness check, we conducted all regressions also with the East Asian countries and Vietnam included and found our results confirmed (results available from the authors).
[98] LOWESS (**lo**cally **we**ighted **s**catterplot **s**moothing) carries out a locally weighted regression of the dependent variable on the independent variable, i.e. in our case of GE_{num} on ABCC, and displays the graph. Thereby, the LOWESS estimator does not impose a specific functional form (see Cleveland 1979).

LOWESS curve. This deviation can be explained with the quadratic shape which we imposed on the raw data in the regression.

Figure 4.9: Relationship between gender equality in numeracy and numeracy, LOWESS scatterplot and fitted values



In Table 4.4 we present the results of our panel regressions. With model 2 we add a Least Square Dummy Variable (LSDV) estimation with additional country and time fixed effects in order to check for the robustness of the results in model 1. In all eight specifications we see that gender equality in numeracy declines at low numeracy levels – shown by the negative sign of the ABCC coefficient – and increases at higher levels, as indicated by the positive coefficient of ABCC squared. The dummy for female voting rights indicates a positive influence on gender equality in all the models presented in Table 4.3. The dummy variables for the religions are not that robust but indicate that gender equality is lower (i.e. the gender inequality is higher) in Christian and Buddhist countries and higher in Hindu countries than in the reference group, i.e. Islamic countries. In the first instance, this finding might be surprising. However, if we look at the trends in Figures 4.5 through 4.8 we see that most of the Islamic and Hindu countries had low overall numeracy levels paired with relatively high gender equality. Those countries are mainly situated on the left downward sloped side of the U-curve, i.e. within the period of investigation they still had to undergo the process of an initially widening gender gap until it closes again with further development.

In models 3 through 6 we test the effects of enrolment rates, GDP per capita, and population density together with land productivity separately. All variables show a positive effect on gender equality, i.e. the effect we expected, with the exception of the effect of land productivity. Here we cannot confirm Boserup's theory of a negative influence on gender equality. On the contrary, we find a positive and significant coefficient. Models 7 and 8 provide additional robustness checks. In model 7 we reduce the sample further by restricting the observations to those that have less than 80 ABCC points, i.e. we cut off the upper bound of the ABCC index (the lower bound of 0 is not reached in our sample) to minimize problems that could arise from bounded variable issues. The results confirm our previous findings. In model 8 we replace the ABCC index with GDP per capita to test whether our U-curve is confirmed if we consider economic development instead of educational development. Even though the GDP coefficients are not significant, we find a U-shaped pattern here as well.[99] In summation, with our data we can confirm the U-hypothesis that gender equality in numeracy first declines and then increases with the level of numeracy.

[99] The GDP data from Maddison are fragmentary for this time and region. For that reason we had to interpolate several values of the GDP data (see Appendix). This is – despite the general challenge of measuring GDP adequately - a weakness of the GDP data and might also be a reason for the insignificant results.

Table 4.4: Regressions of Gender Equality in Numeracy in Asia, 1900-1960

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Estimation technique	RE	LSDV	RE	RE	FE	RE	RE	FE
		country and time FE					ABCC<80	
ABCC	-1.063***	-0.884***	-0.828***	-0.807***	-0.886***	-0.822***	-1.650***	
	(0.244)	(0.224)	(0.132)	(0.138)	(0.206)	(0.210)	(0.563)	
ABCC squared	0.00974***	0.00958***	0.00904***	0.00905***	0.00897***	0.00737***	0.0164***	
	(0.00185)	(0.00199)	(0.00125)	(0.00129)	(0.00152)	(0.00149)	(0.00588)	
Female voting rights	3.749***	7.320	1.244	1.121	1.038	3.346*	5.998**	4.565***
	(1.238)	(5.276)	(1.094)	(1.200)	(2.179)	(1.743)	(2.556)	(1.546)
Hinduism	7.280	20.01**				2.224	6.974**	
	(4.574)	(7.914)				(1.980)	(2.956)	
Buddhism	-6.629	0.660				-5.947**	-13.33***	
	(6.082)	(11.23)				(3.014)	(3.812)	
Christianity	-7.882	-2.911				-2.809	-24.13***	
	(8.898)	(10.51)				(3.231)	(3.526)	
Confucianism	-6.499	-2.179						
	(6.781)	(11.54)						
Enrolment rates (log)			1.007					
			(0.880)					
GDP per capita (log)				1.629				-1.594
				(3.412)				(41.28)
GDP per capita (log) squared								0.216
								(2.644)
Population density (log)					3.484	2.545**		
					(2.807)	(1.062)		
Land productivity (log)					7.480**	11.13***		
					(2.940)	(1.960)		
Constant	14.40***	-5.839	-4.087	-14.31	-10.90	-2.079	25.93***	-7.504
	(4.890)	(8.380)	(5.535)	(22.44)	(13.69)	(9.328)	(9.892)	(159.3)
Observations	73	73	61	59	30	30	45	59
R-squared	0.292	0.714	0.693	0.688	0.899	0.877	0.028	0.206
Number of countries	14	14	13	12	7	7	10	12

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. For variable definitions and sources see Appendix. In model 1, 2, 6 and 7 the reference category is an Islamic country with no female voting rights. The R-squared within is reported, except for model 2 (overall R-squared).

4.5. Conclusion

In this paper, we study the human capital development of both men and women in 14 Asian countries during the period 1900s-60s, with special emphasis on the gender gap in education. Using the age-heaping methodology we add data on basic numerical skills to the existing data base of educational indicators. Basic numerical knowledge plays an essential role for the economic and social development of a country as it is a precondition for the acquisition of more advanced skills. Our data confirm the high variation of educational levels among the countries in the Asian region: while most Southeast Asian countries have already high numeracy levels during the first half of the 20th century, most South and West Asian countries are characterised by low numerical skills. We identify enrolment rates, GDP per capita and female voting rights as important determinants of numeracy level. We interpret the latter as a proxy for the attitude of a society towards women's role in that society. Additionally, the regression results indicate that cultural factors (religion) impact the accumulation of human capital.

While examining the development of the relative differences between male and female numeracy during the first half of the 20th century, we find countries like Hong Kong and Pakistan with almost no gender inequality in numeracy. Afghanistan and Iran display an increase in gender inequality, and Sri Lanka and the Philippines improve greatly in terms of gender equality in numeracy during the period under consideration. The case with Hong Kong and Pakistan was particularly critical to our study: Both countries show nearly no difference in gender education, and yet Hong Kong has an almost fully numerate population, whereas Pakistan has a population that was mainly unaware of its age. This observation leads us to the hypothesis of a U-shaped pattern of the development of gender equality in numeracy: at low numeracy levels gender equality is high. As numeracy increases, gender equality decreases initially before rising to high levels again, declines and increases again with higher numeracy levels. We further test this by performing a panel analysis and found support for the U-hypothesis for Asia during the first half of the 20th century. The results indicate that the attitude of a society towards women's role in social life as well as the level of economic development of a country are particularly important determinants of equal distribution of education between the genders.

We excluded the East Asian countries Vietnam, South Korea, and China from our analysis as these countries reached full basic numeracy by 1900, as well as gender equality in basic numeracy. Nevertheless, these countries are good examples of the mechanism behind the U-hypothesis because they reached relatively good numeracy levels and gender equality early on. The situation of women in East Asia at the beginning of the 19th century resembled post-war conditions in South Asia, but underwent radical transformations under European and Japanese influence. In China, e.g., Confucian teachings lost their relevance and Western-style education gained popularity eventually with the abolishment of the competitive and prestigious civil service examinations.[100] The government at the time also founded public schools for girls as an alternative to private and missionary schools. In Korea, primary schools were established by the Yi government, in addition to Christian missionary schools, before the Japanese annexed Korea and adapted the Korean school system to their modern education system.[101] With the rise of industrialisation under Japanese colonial rule, Korean women started to take up work in factories. After independence, Koreans valued educational achievements to such a great extent that is has been said that

[100] Mann, *Women in East Asia*, pp. 49-57.
[101] Choi, *Schooling in South Korea*, p. 323.

parents would sell their properties to afford to educate their children.[102] Today, Korean students lead with high scores in mathematics and science on international tests.

Part of the success of the East Asian economies from the 1970s onwards was the employment of women in export industries. This was possible because these countries could build on advanced levels of male and female human capital, and women had access to the labour market. Women in these countries continued to achieve higher educational levels and increase participation in the economic sector throughout the first half of the 20th century, giving these countries an advantage over others in the region which had neglected to improve the educational situation of females.

[102] Kwak, *Korea*, p. 205.

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4.7. Appendix I: About data quality

In this short additional chapter we address typical concerns surrounding the reliability of the Whipple/ABCC index as a proxy for basic human capital. As for all data used in empirical studies, the method of data collection, and thus the data quality, is highly relevant for the explanatory power of ABCC indices. Likewise, it is important to know if age information is elicited from statements made by the person himself, from a second party (e.g., a wife's husband), or estimates made by the enumerator. The known facts about the census data and the way in which the data were collected justify our assumption that the quality of our data base in this study can be considered reliable.[103] First, the 23 censuses used in this study were all conducted between 1947 and 2001, with most occurring between 1960 and 1990, by which most countries had adopted international census standards as promoted by the United Nations. This means most of the personnel was trained and briefed before conducting the census, ensuring a degree of quality in and of the data collection procedure. Second, in countries with prevailing illiteracy, censuses are usually conducted with the help of canvassers instead of self-enumeration. This should lower the probability that the interviewee made up answers, since the canvasser could directly intervene if the answer seemed implausible.[104]

However, the latter could give rise to another possible bias: 'If that [age] is not known, then an estimate of the age is made by the trained canvasser following determined guidelines, for example, that are based on a calendar of local historical

[103] The high variation of the quality of age returns, varying from "Age data were considered highly accurate and were tabulated […] in single years" (comment on the China census of 1982, *Domschke and Goyer*, p.607) to "Age data were considered 'a matter of guess work'." (comment on the Bangladesh census of 1974, *Domschke and Goyer*, p.569) is the result of differing age awareness of the different populations and not the quality of the census data per se.
[104] To this, see for example the explanation in the Census of India 1911 (Volume XVI), p.113: "With a view to secure as correct an age return as possible, the enumerators were further instructed that, when the reply given appeared grossly absurd from the appearance of the person enumerated, they should consult one or two sensible persons in the locality and put down the age which may be deemed to be the most likely."

events.'[105] It is remarkable that strong age-heaping exists even when the historical calendar method or the periodic cycle of animal years are used in developing countries as one could assume that this would lower age-heaping significantly, with individuals able to better narrow down their true age (e.g. census of Afghanistan 1979).[106] Is the historical calendar method therefore a problem for the age-heaping method? We do not think so as it does not make a difference whether the individual or the canvasser reports a wrong age if the true age is unknown. A study by Scott and Sabagh[107] supports this view. They investigated the behaviour of canvassers during the Moroccan Multi-Purpose Sample Survey of 1961-1963 and found that canvassers also tended to report rounded ages for people who did not know their age. The interesting feature in this context is that between 70 and 90 per cent (dependent on the underlying age group) of the people interviewed did not know their age, and so the historical calendar method was applied. Expressed in ABCC values this would imply an overall numeracy level somewhere between 10 and 30 ABCC points. And indeed, this fits well the calculated age-heaping level observed in Morocco for the census of 1960, namely an ABCC level between 20 and 40.[108]

Another concern is related to the usefulness of female age-heaping data. Földvári, van Leeuwen, and van Leeuwen-Li[109] claim that only unmarried females should be considered in gender studies that use age-heaping data as married women tend to adjust their age statements to the age statements of their spouses. They motivate this concern with the finding that gender differences in age-heaping are smaller for married individuals than for the rest of the population. Stolz[110] brought

[105] Domschke and Goyer, *The handbook of national population censuses*, p. 20.
[106] „Age was considered to be one of the major areas of error in spite of use of a historical calendar", Domschke and Goyer's comment on the census of Afghanistan 1979, see *Domschke and Goyer*, p.551.
[107] Scott and Sabagh, *The historical calendar*.
[108] Prayon and Baten, *Human capital.*
[109] Földvári, van Leeuwen, and van Leeuwen-Li, *How did women count?*
[110] Stolz, *Essays on Human Capital Formation*, 212-3.

forward several reasons why this assumption may not be justified. First, age awareness is usually acquired at very young age, i.e. much earlier than marriage takes place, and there is no convincing reason why married women should adjust their age statement to that of their husbands' after marriage voluntarily. In the case that only the husband is interviewed, there is also no plausible reason why a husband should report an inaccurate age for his wife if her correct age is known. In case the correct age is known neither to him nor to her, it is irrelevant for the explanatory power of the age-heaping evidence if he or she reports on her age – either way, the reported age is incorrect and likely to be rounded. Second, Földvári et al. disregard the economics of marriage markets. Stolz correctly summarizes the findings in the literature on marriage markets, namely that human capital endowment is an important distinguishing mark of the participants of the marriage market for both genders. Additionally, empirical studies point in the direction that couples tend to show similar human capital characteristics. In summary, the finding of Földvári et al. that gender differences in age-heaping for married individuals are smaller than for the rest of the population is not rooted in the status of "married" per se; it is much more likely that the mechanisms of the marriage market are the driving forces behind this, namely that females with better numerical abilities are also more successful in marrying better-educated males.

Last, we address the assumption that basic numerical skills are acquired in the early stages of life and that the Whipple index is not influenced significantly by learning effects later in life. Crayen and Baten[111] discussed these assumptions in detail in their global study on age-heaping. To provide evidence, they examine whether age-heaping behaviour is influenced significantly by age. They found only a systematic influence of age on the heaping behaviour among the youngest age group, i.e. the 23 to 32-year-olds. People in this age group tend indeed to heap their age less than older age

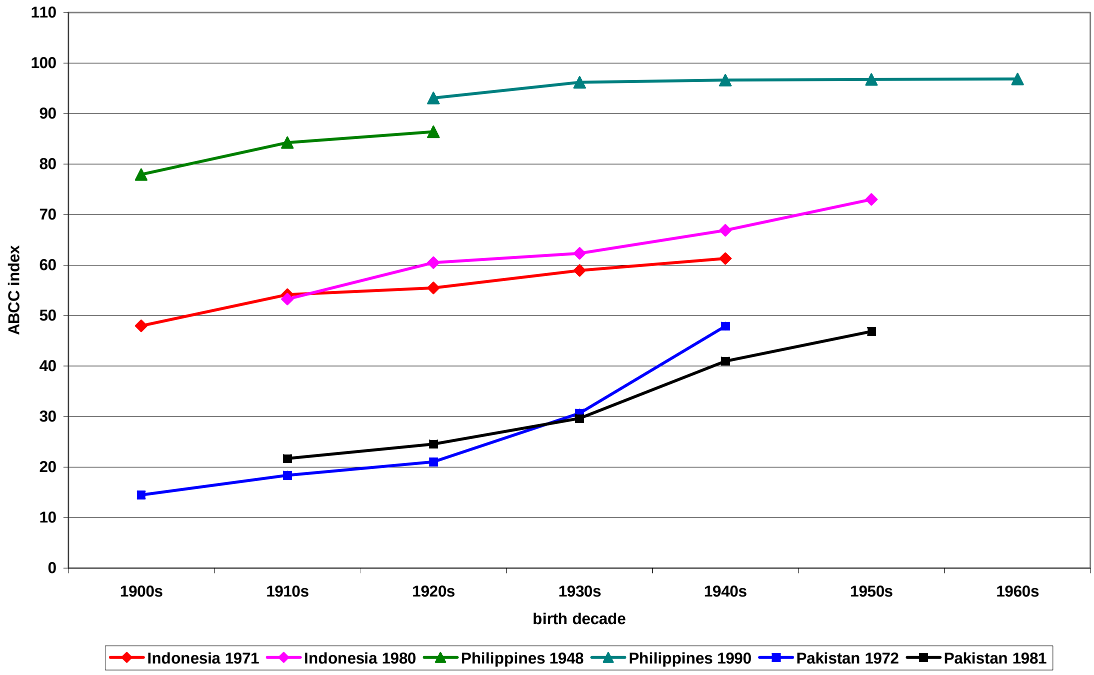
[111] Crayen and Baten, *Global trends*.

groups. In contrast, those in older age groups rounded on average as strongly as would have been expected for their birth cohort. Based on this observation Crayen and Baten suggested an adjustment of the numeracy index only for the youngest birth cohort, a practice that is now standard procedure in the age-heaping methodology.[112] Figure A.1 shows three examples from Asia where overlapping census data is available. The youngest age group (i.e. always the last data point of each trend line) already underwent the suggested adjustment. What we can see is that the overall levels of the trends do not differ strongly, even though they are based on different census years. Even in the case of the Philippines, where 42 years exist between the first and the second censuses, the last data point (i.e. the youngest age group) in the trend line of the census of 1948 and the first data point (i.e. the oldest age group) of the 1990 census trend line do not differ significantly. These trends show that, although the data come from different census years, they correspond quite well, i.e. no effects of better 'census-taking' or learning effects among adults are visible. This finding confirms the assumption that basic numeracy is acquired mainly during the first decade of life. If we do the same procedure with literacy rates, we often find quite strong differences between different census years for the same birth cohorts. Reasons are often different definitions of 'being literate' or learning effects later in life, e.g. adult literacy programs in developing countries.[113]

[112] Crayen and Baten (2010a, Appendix) suggest the following adjustment for the youngest age group (23-32): (WI-100)*0.25+WI.

[113] See for example Stolz and Baten (*Brain Drain in the age of Mass Migration*): they find this pattern for migrants to the United States.

Figure A.1: Example for numeracy trends based on overlapping census data



4.8. Appendix II: Census Data

East Asia:
Hong Kong (hk): Census of 1976 for birth decades 1900s-40s, Census of 1986 for birth decades 1910s-50s, Census of 1991 for birth decades 1920s-60s.

South Asia:
Bangladesh (bd): Census of 1974 for birth decades 1900s-40s, Census of 2001 for birth decades 1930s-60s; **India (in):** Census of 1971 for birth decades 1900s-40s; **Nepal (np):** Census of 1981 for birth decades 1910s-50s; **Pakistan (pk):** Census of 1972 for birth decades 1900s-40s, Census of 1981 for birth decades 1910s-50s; **Sri Lanka (lk):** Census of 1963 for birth decades 1900s-1930s, Census of 1971 for birth decades 1900s-40s, Census of 1981 for birth decades 1910s-50s.

Southeast Asia:
Cambodia (kh): Census of 1962 for birth decades 1900s-1930s; **Federation of Malaya (myfm):** Census of 1957 for birth decades 1900s-1920s; **Indonesia (id):** Census of 1971 for birth decades 1900s-40s, Census of 1980 for birth decades 1910s-50s; **Philippines (ph):** Census of 1948 for birth decades 1900s-1920s, Census of 1990 for birth decades 1920s-60s; **Sarawak (mysa):** Census of 1960 for birth decades 1900s-1930s; **Thailand (th):** Census of 1947 for birth decades 1900s-1910s, Census of 1960 for birth decades 1900s-1930s.

West Asia:
Afghanistan (af): Census of 1979 for birth decades 1910s-50s; **Iran (ir):** Census of 1966 for birth decades 1900s-1930s

Sources: Data come from United Nations (various issues) *Demographic Yearbook* (New York: UN), supplemented with Bangladesh Bureau of Statistics (2003) *Population Census 2001* (Dhaka), Pakistan Population Census Organisation (1977) *1972 Census Report of Pakistan* (Islamabad), and Pakistan Population Census Organisation (1984) *1981 Census Report of Pakistan* (Islamabad).

4.9. Appendix III: Variable Definitions and Sources

ABCC
Proxy for basic numerical skills. Linear transformation of the Whipple index. The ABCC index ranges between 0 and 100 (100 = no age-heaping, 0 = only ages ending on multiples of 5 are reported). See section III for more details.
Sources: See Appendix: Census Data.

GE_{num}
Measure of gender equality in respect of basic numerical skills. See section III for more details.
Sources: same as for ABCC.

GDP per capita (log)
Gross domestic product per capita (measured in 1990 international Geary-Khamis dollars), average over decade. Missing values were generated by linear Interpolation.
Source: Maddison, A. (2001).

Population density (log)
Population estimates per land area, average over decade. Missing values were generated by linear Interpolation.
Source: Maddison, A. (2001).

Land productivity (log)
Rice output (measured in thousand metric tons) per rice area (measured in thousands of hectares), average over decade.
Source: Mitchell, B.R. (1998).

Enrolment ratios (log)
Unadjusted primary school enrolment ratios: percentage ratio based on the enrolment at this level related to the estimated population 5-14 years old.
Sources: For 1870 to 1940 the data come from Benavot and Riddle (1988). The value for the period 1935-1940 was assigned to the decade 1940. For 1950 and 1960 the data come from UNESCO (1964). For 1950 we took the mean of the values of 1950 and 1955, for 1960 we took the value of 1960.

Female voting right
Dummy variable coded 1 for the decades in which female voting rights are granted.
Source: United Nations Development Programme (2009).

Buddhism, Christianity, Confucianism, Hinduism, Islam
Dummy variable coded 1 if majority of the population adheres to one of these religions.
Buddhism: Cambodia, Sri Lanka, Thailand. Christianity: The Philippines.
Confucianism: Hong Kong. Hinduism: India, Nepal. Islam: Afghanistan, Bangladesh, Federation of Malaya, Indonesia, Iran, Pakistan, Sarawak.
Source: Barro, R. (2011).

4.10. Appendix IV: Additional Tables

Table A.1: The numeracy estimates

Country	Birth decade	Whipple index	Whipple index male	Whipple index female	ABCC index	ABCC index male	ABCC index female	Gender Equality numeracy
Afghanistan	1910	351.65	334.9	375.02	37.09	41.28	31.24	-11.98
Afghanistan	1920	332.93	307.93	366.62	41.77	48.02	33.35	-19.06
Afghanistan	1930	325.09	296.51	357.95	43.73	50.87	35.51	-20.72
Afghanistan	1940	318.88	286.48	349.58	45.28	53.38	37.6	-22.03
Afghanistan	1950	290.79	218.04	360.16	52.3	70.49	34.96	-65.18
Bangladesh	1900	424.11	418.32	432.09	18.97	20.42	16.98	-3.29
Bangladesh	1910	407.91	400.03	417.89	23.02	24.99	20.53	-4.47
Bangladesh	1920	392.58	383.75	403.26	26.85	29.06	24.19	-5.08
Bangladesh	1930	377.83	374.43	381.68	30.54	31.39	29.58	-1.94
Bangladesh	1940	361.47	351.45	371.46	34.63	37.14	32.14	-5.69
Bangladesh	1950	359.25	353.9	365.98	35.19	36.52	33.51	-3.41
Bangladesh	1960	319.41	313.29	326.5	45.15	46.68	43.38	-4.22
Cambodia	1900	119.94	119.59	120.3	95.01	95.1	94.92	-0.6
Cambodia	1910	121.17	121.22	121.13	94.71	94.7	94.72	0.07
Cambodia	1920	118.92	117.11	120.74	95.27	95.72	94.82	-3.1
Cambodia	1930	120.9	118.33	123.35	94.78	95.42	94.16	-4.24
Federation of Malaya	1900	152.12	145.86	160	86.97	88.53	85	-9.69
Federation of Malaya	1910	148.32	142.32	154.69	87.92	89.42	86.33	-8.69
Federation of Malaya	1920	141.45	133.04	149.81	89.64	91.74	87.55	-12.6
Hong Kong	1900	106.86	106.01	107.5	98.29	98.5	98.12	-1.41
Hong Kong	1910	109.32	108.96	109.69	97.67	97.76	97.58	-0.67
Hong Kong	1920	107.7	107.15	108.32	98.07	98.21	97.92	-1.09
Hong Kong	1930	102.41	102.77	101.96	99.4	99.31	99.51	0.79
Hong Kong	1940	100	100.5	100	100	99.87	100	0.5
Hong Kong	1950	102.41	102.05	102.78	99.4	99.49	99.31	-0.71
Hong Kong	1960	102.07	101.94	102.19	99.48	99.52	99.45	-0.25
India	1900	384.67	377.35	392.69	28.83	30.66	26.83	-4.06
India	1910	366.52	358.91	374.98	33.37	35.27	31.25	-4.48
India	1920	355.04	352.09	358.54	36.24	36.98	35.36	-1.83
India	1930	317.35	315.77	319.11	45.66	46.06	45.22	-1.06
India	1940	285.2	276.61	293.83	53.7	55.85	51.54	-6.22
Indonesia	1900	308.18	294.06	320.96	47.96	51.48	44.76	-9.14
Indonesia	1910	285.11	269.39	299.54	53.72	57.65	50.12	-11.19
Indonesia	1920	268.06	256.98	279.2	57.98	60.75	55.2	-8.65
Indonesia	1930	257.5	252.3	262.6	60.63	61.93	59.35	-4.08
Indonesia	1940	243.79	233.89	252.25	64.05	66.53	61.94	-7.85
Indonesia	1950	208.07	204.12	211.89	72.98	73.97	72.03	-3.8
Iran	1900	310.74	290.5	332.7	47.31	52.37	41.83	-14.52
Iran	1910	281.43	263.83	302.32	54.64	59.04	49.42	-14.59
Iran	1920	236.38	228.36	246.06	65.9	67.91	63.48	-7.75
Iran	1930	236.44	212.66	260.08	65.89	71.84	59.98	-22.3
Nepal	1910	310	298.69	322.99	47.5	50.33	44.25	-8.13
Nepal	1920	312.81	302.73	324.35	46.8	49.32	43.91	-7.14
Nepal	1930	290.47	285.91	295.62	52.38	53.52	51.09	-3.4
Nepal	1940	267.57	262.37	272.94	58.11	59.41	56.77	-4.03

Nepal	1950	225.12	220.94	229.05	68.72	69.77	67.74	-3.67
Pakistan	1900	442.06	440.47	444.36	14.48	14.88	13.91	-0.88
Pakistan	1910	419.81	416.19	424.79	20.05	20.95	18.8	-2.07
Pakistan	1920	408.79	409.12	408.27	22.8	22.72	22.93	0.21
Pakistan	1930	379.37	381.47	376.95	30.16	29.63	30.76	1.18
Pakistan	1940	322.23	319.8	325.55	44.44	45.05	43.61	-1.8
Pakistan	1950	312.58	307.57	318.07	46.86	48.11	45.48	-3.41
Philippines	1900	188.4	166.28	211.17	77.9	83.43	72.21	-26.99
Philippines	1910	162.96	151.16	174.72	84.26	87.21	81.32	-15.58
Philippines	1920	141.01	135.5	146.11	89.75	91.13	88.47	-7.83
Philippines	1930	115.31	114.49	116.09	96.17	96.38	95.98	-1.4
Philippines	1940	113.71	114.11	113.31	96.57	96.47	96.67	0.7
Philippines	1950	113.06	114.02	112.09	96.74	96.5	96.98	1.69
Philippines	1960	112.66	113.42	111.91	96.83	96.64	97.02	1.34
Sarawak	1900	218.97	209.05	231.53	70.26	72.74	67.12	-10.75
Sarawak	1910	225.48	219.87	232.07	68.63	70.03	66.98	-5.55
Sarawak	1920	212.91	214.42	211.35	71.77	71.39	72.16	1.43
Sarawak	1930	212.03	210.87	213.08	71.99	72.28	71.73	-1.05
Sri Lanka	1900	240.54	219.88	267.85	64.87	70.03	58.04	-21.81
Sri Lanka	1910	192.97	176.53	213.04	76.76	80.87	71.74	-20.68
Sri Lanka	1920	167.57	157.29	179.28	83.11	85.68	80.18	-13.98
Sri Lanka	1930	141.27	134.18	148.71	89.68	91.45	87.82	-10.83
Sri Lanka	1940	114.67	112.22	117.19	96.33	96.95	95.7	-4.43
Sri Lanka	1950	109.79	109.67	109.92	97.55	97.58	97.52	-0.23
Thailand	1900	107.1	105.14	109.07	98.23	98.71	97.73	-3.74
Thailand	1910	107.56	105.54	109.54	98.11	98.61	97.61	-3.79
Thailand	1920	108.72	107.48	109.97	97.82	98.13	97.51	-2.31
Thailand	1930	108.53	108.3	108.76	97.87	97.93	97.81	-0.42

Table A.2: Summary statistics of the number of single age returns underlying the Whipple and ABCC values in Table A.1

	Age group	No. of censuses	Mean	Std.Dev.	Min	Max
all	23-32	23	8,789,462	17,496,318	107,101	83,132,100
	33-42	23	6,622,933	13,354,702	83,390	63,474,500
	43-52	23	4,514,572	9,303,066	58,189	44,436,300
	53-62	23	2,800,827	5,786,845	35,381	27,833,800
	63-72	23	1,437,925	2,774,374	16,896	13,288,400
male	23-32	23	4,327,294	8,721,851	50,688	41,646,500
	33-42	23	3,430,582	7,022,422	42,269	33,491,500
	43-52	23	2,393,528	5,024,054	31,410	24,095,300
	53-62	23	1,470,886	3,043,834	19,706	14,666,600
	63-72	23	748,946	1,448,829	8,929	6,944,300
female	23-32	23	4,462,168	8,780,791	56,413	41,485,600
	33-42	23	3,192,351	6,336,201	41,121	29,983,000
	43-52	23	2,121,041	4,283,441	26,779	20,341,000
	53-62	23	1,329,940	2,745,017	15,670	13,167,200
	63-72	23	688,979	1,328,823	7,967	6,344,100

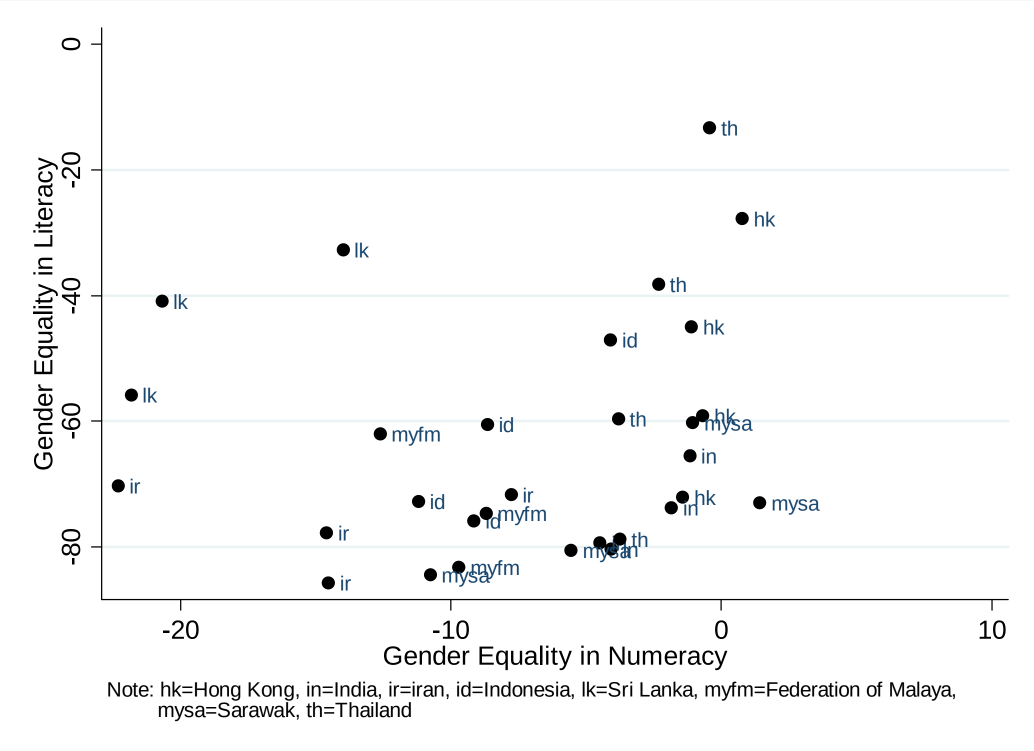
Table A.3: Pairwise correlation coefficients

	GEnum	ABCC	ABCC males	ABCC females	Female vot.	Hindu	Buddh.	Christ.	Muslim	Confuc.	GDPc	Enrol.	Pop. dens.	Land prod.
GEnum	1													
ABCC	0.127	1												
ABCC males	0.036	0.9944*	1											
ABCC females	0.224	0.9926*	0.9807*	1										
Female vot.	0.284	0.196	0.176	0.222	1									
Hindu	0.105	-0.290	-0.2998*	-0.274	0.040	1								
Buddh.	0.025	0.4571*	0.4568*	0.4622*	0.103	-0.216	1							
Christ.	0.002	0.3094*	0.3101*	0.3065*	0.109	-0.115	-0.147	1						
Muslim	-0.224	-0.5816*	-0.5671*	-0.6007*	-0.183	-0.4065*	-0.5203*	-0.2760*	1					
Confuc.	0.221	0.4053*	0.3914*	0.4143*	0.027	-0.115	-0.147	-0.078	-0.2760*	1				
GDPc	0.003	0.8176*	0.8190*	0.8107*	0.196	-0.3528*	0.094	0.196	-0.187	0.5032*	1			
Enrolment	0.140	0.214	0.199	0.231	0.5626*	-0.077	-0.026	0.3264*	-0.223	0.193	0.3927*	1		
Pop. dens.	0.4189*	0.071	0.039	0.119	0.3811*	0.152	-0.110	0.005	-0.3732*	0.6571*	0.100	0.4671*	1	
Land prod.	0.5696*	-0.226	-0.260	-0.201	0.173	0.013	-0.215	-0.3924*	0.4914*	-	0.275	-0.154	-0.269	1

Note: Enrolment rates, GDPc, population density, and land productivity are in logs. * indicates significant on .01-level.

4.11. Appendix V: Additional Figures

Figure A.2: Relationship between gender equality in numeracy and gender equality in literacy, birth cohorts 1900s-60s



5. Assessing Adolescents’ Age-Heaping on Multiples of Two

Abstract

This paper presents a reformulated Whipple index, respectively ABCC index, allowing for the capture of the special heaping behaviour of young adolescents. This age group tends to round its age to even numbers, which are 16, 18, 20, and 22, whereas the traditional ABCC index captures the heaping behaviour of adults, which is based on multiples of five. Graphical and analytical analyses show the high reliability of this new index. Thus, this new index allows extending (the already) existing age-heaping series by an additional age group, namely the 17- to 22-year-olds. Furthermore, when data sources provide only information on young adults and not on older age groups, it is possible to estimate the average heaping behaviour of the older population on the basis of the heaping level of adolescents.

5.1. Motivation

Age-heaping, i.e. the tendency of individuals to report a rounded age instead of exact age, is characteristic for low educational levels. The conventional Whipple index captures the age-heaping pattern based on multiples of five, e.g. 25, 30, 35, and so on. This kind of heaping behaviour is typical for adults age 23 and older. Among younger individuals, however, a preference for rounding one's age to an even number is observable, e.g. 16, 18, 20, and 22. Thus far, this digit preference of adolescents and young adults has not been exploited for the study of age-heaping since no suitable method has been available to do so.

The aim of this research note is to formulate a modified age-heaping index for the age group 17 to 22 and assess its reliability. This new index can extend the existing age-heaping series by an additional age group, namely the 17- to 22- year-olds. Furthermore, when data sources provide only information on young adults and not on older age groups, it is possible to estimate the average heaping behaviour of the older population on the basis of the heaping behaviour of the adolescents.

5.2. How to assess age-heaping patterns on multiples of two

Age-heaping is a well-known phenomenon among demographers. They treat it as a statistical challenge, as it distorts age distributions, and they often try to address this inaccuracy by applying smoothing techniques. To measure the accuracy of age statistics, most demographers, including those at the UN's statistical departments, calculate Whipple indices, with high Whipple indices indicating unreliable age distribution data.[114] The Whipple index is constructed as follows (n_x is the population of age x):

[114] See for example the descriptions in the United Nations Demographic Yearbook 1963, p.18-21 or 1993, p.19.

$$(1) \quad WI = \left(\frac{n_{25} + n_{30} + ... + n_{65} + n_{70}}{1/5 \times (n_{23} + n_{24} + n_{25} + ... + n_{72})} \right) \times 100 \text{ if } WI \geq 100; \text{ else } WI = 100.$$

This index measures the ratio of people who state an age ending in a five or zero to the underlying population, with the assumption that each last digit will appear with the same frequency as in the 'true' age distribution. A value of 500 represents an age distribution with ages ending only in multiples of five, whereas a value of 100 indicates no heaping pattern on multiples of five, that is 20 percent of the population reported an age ending in a multiple of five. Formula (1) calculates the Whipple index for the age group 23 to 72. Correspondingly, it is possible to adjust the formula to other age groups. This is important if one is interested in the development of age-heaping over time within a population. To trace this development, the standard procedure is as follows: In the first step, ABCC indices for age groups ranging from 23 to 32, 33 to 42, …, 63-72 are calculated. In a second step they are assigned to the corresponding birth decades. This procedure is based on the assumption that numerical skills necessary to calculate one's age is acquired during the first decade of life and is not influenced significantly in later decades (for a detailed discussion on this procedure as well as on the underlying assumptions, see Crayen and Baten 2010, especially the discussion in Appendix A).

A'Hearn, Baten, and Crayen (2009) suggest an alternative index, the so-called ABCC index. It is a simple linear transformation of the Whipple index, ranging between 0 and 100, with 0 indicating that only ages ending in 0 and 5 are reported and 100 indicating no age-heaping. Using a range of 0 to 100 makes interpretation of the ABCC index more intuitive than the Whipple index: The higher the ABCC value, the higher the number of people who know their exact age. The following formula demonstrates how Whipple values are transformed into ABCC values:

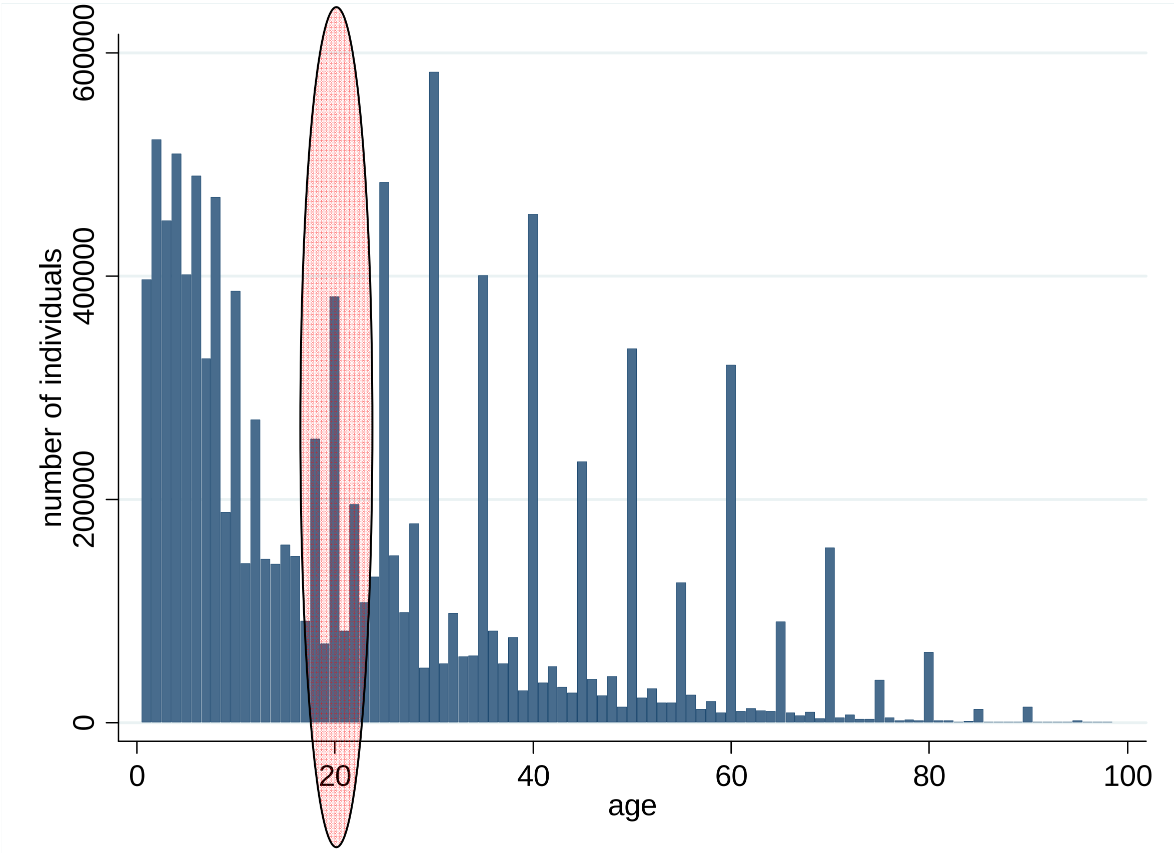
$$(2)\quad \text{ABCC} = \left(1 - \frac{(\text{WI} - 100)}{400}\right) \times 100 \quad \text{if WI} \geq 100\text{; else ABCC} = 100.$$ [115]

The existing age-heaping methodology only allows for the investigation of numeracy among age groups between 23 and 72. Among the very old, a certain tendency for exaggeration or simple obliviousness makes the age-heaping method for these individuals unreliable. Additionally, a possible survivor bias has to be taken into consideration, as more educated individuals are usually part of the wealthier social strata and therefore tend to have a longer life expectancy. Thus far, individuals younger than 23 have been disregarded in this methodology, as their heaping behaviour usually deviates from the typical heaping pattern based on multiples of five and the Whipple index cannot capture this pattern adequately.

Figure 5.1 displays the distribution of actual stated ages of the Moroccan population reported in the census of 1960. This is an example of very strong heaping behaviour and shows clearly the different heaping patterns of adults versus adolescents. The extreme peaks at multiples of five of the adult population are immediately apparent Also clearly visible is the heaping on even ages among adolescents, i.e. ages 18, 20, and 22 are stated much more often than 17, 19, or 21. Therefore, in the following equations an index for the age group 17 to 22 is formulated. Younger teenagers and children are not taken into consideration in this study, as a clear heaping pattern is not identifiable among this young age group, and it is highly likely that parents state the age of their children. In the latter case we would erroneously be measuring the age awareness of the parents and not of the children.[116]

[115] Whipple indexes below 100 (ABCC indexes above 100, respectively) in the 20th century rich countries are normally caused by random variation, hence those indexes are normally set to 100.
[116] See for example the study of Bairagi et al. (1982) on age misstatement for young children in Bangladesh, where a very strong heaping on six and twelve months among little children is visible in the age statistics.

Figure 5.1: Age distribution in Morocco according to the census of 1960



The idea proposed in the study at hand is a reformulated Whipple index measuring heaping patterns of adolescents and young adults between the ages of 17 and 22. The reformulated Whipple index is as follows:

$$(3) \quad WI2 = \left(\frac{n_{18} + n_{20} + n_{22}}{1/2 \times (n_{17} + n_{18} + n_{19} + n_{20} + n_{21} + n_{22})} \right) \times 100 \;\text{ if }\; WI2 \geq 100;\text{ else } WI2 = 100,$$

with a value of 200 indicating absolute heaping on multiples of two, and a value of 100 indicating no heaping at all. Obviously, the value range of this index is different to the range of the conventional Whipple index. Here, the ABCC index is again a very convenient alternative: converting the WI2 index into an equivalent ABCC index enables us to compare the two ABCC indices on the same scale. The reformulated ABCC index is then:

$$(4) \quad \text{ABCC2} = \left(1 - \frac{(\text{WI2} - 100)}{100}\right) \times 100 \quad \text{if WI2} \geq 100\text{; else ABCC2} = 100.$$

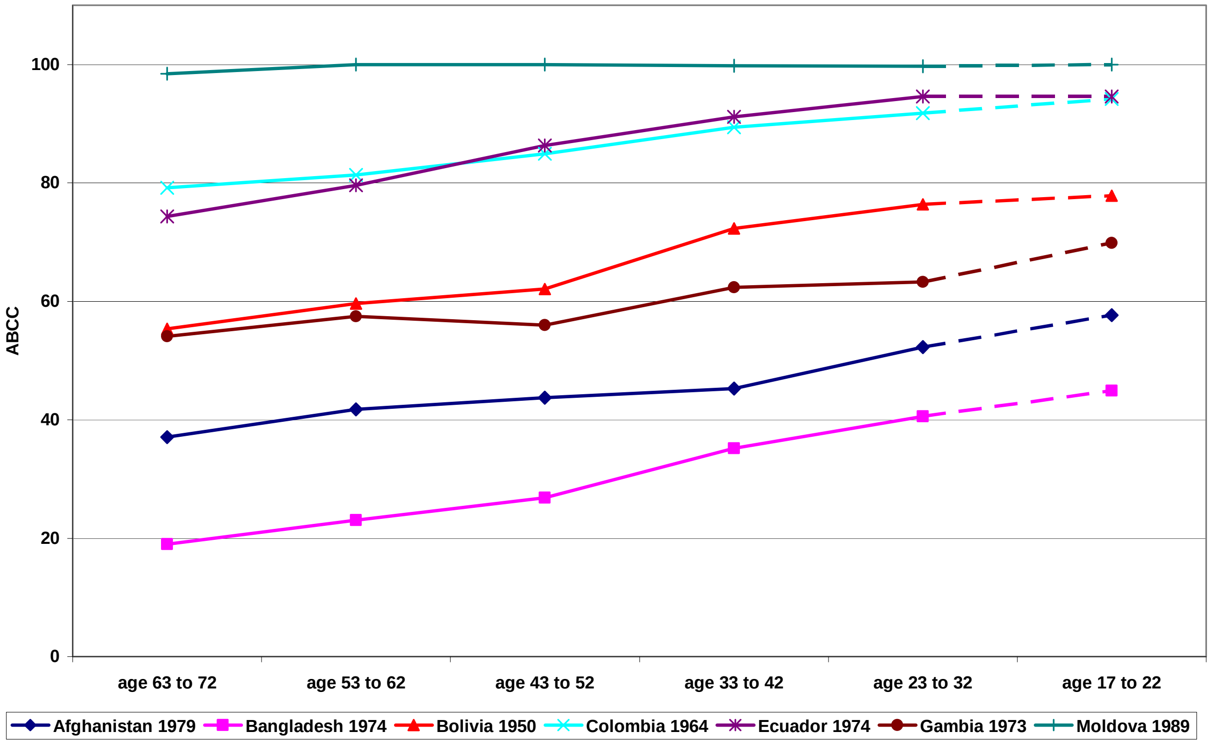
5.3. Robustness checks

How well does the new index fit? Do we need an additional adjustment for this new index, similar to the adjustment for the age group 23 to 32 as suggested by Crayen and Baten (2010, see their detailed discussion in Appendix A)? These authors examine a possible correlation between age and age-heaping and find only a systematic influence of age on the heaping behaviour among the youngest age group (age 23 to 32): People at this age tend to heap their age significantly less than older age groups. The authors argue that young people at this stage in life are more aware of their age, as they are closer to important life events (birth, recruitment/military service, marriage, etc.). Another reason might be more technical: In the early twenties, heaping on multiples of five and heaping on multiples of two do overlap sometimes. This might lead to downward (upward) biased Whipple indices (ABCC indices). Based on this observation, Crayen and Baten suggest an adjustment of the age-heaping index for the age group 23 to 32 which has been applied in this research note.[117]

Figure 5.2 displays seven ABCC trends generated from different population data, ranging from very low ABCC values (e.g., Bangladesh, population census 1974: extreme age-heaping) to very high ABCC values (e.g., Moldova, population census 1989: virtually no age-heaping). The ABCC values for the 17 to 22 age group are calculated according to formula (4), the new ABCC2 index (characterised by the dashed line). The ABCC values for the 23 to 32 age group are adjusted according to Crayen and Baten's recommended formula (see footnote 4). Looking at these exemplary chosen trends, the values calculated on the basis of the new ABCC2 index seem to fit very well.

[117] Crayen and Baten (2010, p.93-96, see especially Footnote 21 in the Appendix) suggest the following adjustment for the age group 23 to 32: $WI_{23\text{-}32}$: (WI-100)*0.25+WI.

Figure 5.2: ABCC trends extended with the ABCC values for the age group 17 to 22 based on the new ABCC2 formula



In the following sections more detailed data analyses are conducted to test whether this formula is valid overall (not only for these seven examples) and/or whether a further adjustment of the 17 to 22 age group is needed. To base these analyses as much as possible on a broad data base, we take a worldwide data set on age distribution data and calculate the corresponding age-heaping values for each age group in every census.[118] The ABCC values of the age groups 23 to 32, …, 62 to 72 are calculated according to formula (2), the ABCC values for the age group 17 to 22 are calculated using the new ABCC2 index (formula (4)).

As a first test on the reliability of this formula, we check by how much the calculated ABCC values for the age group 17 to 22 deviate from the corresponding

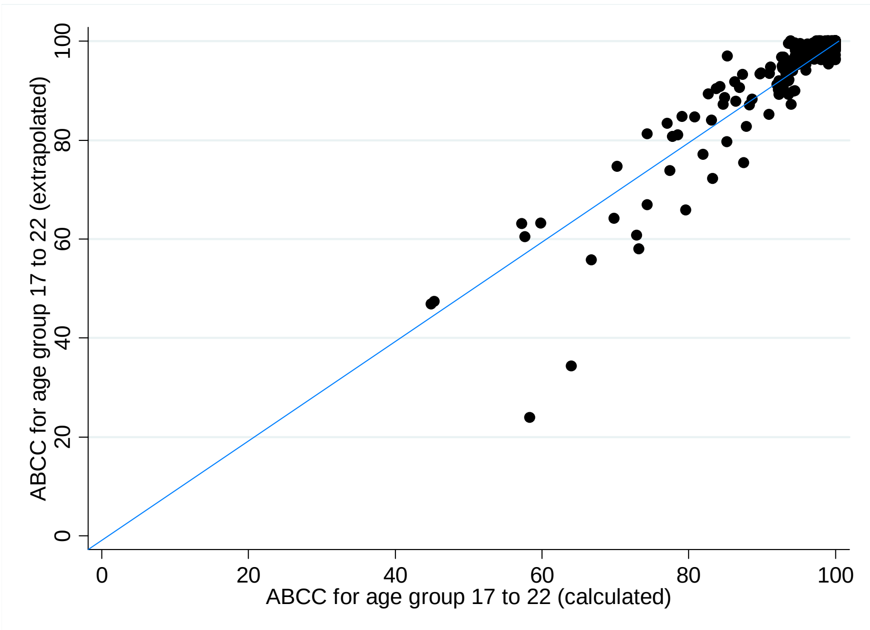
[118] The underlying data set consists of 221 census data from different countries and different periods; however, most population data were recorded in the second half of the 20th century (see census list and data description in the Appendix for more details, Tables A.1-A.5). Table A.1 reports a summary statistics of the number of single age returns the calculation of the ABCC values are based on (on average, each ABCC value represents the heaping behaviour of approx. 3 Mio. individuals). Please note the left-skewed distribution of these ABCC values, i.e. high ABCC values are overrepresented (see Table A.3 in the Appendix).

conventional ABCC values based on the same census data. We do so by extrapolating conventional ABCC trends in order to obtain a (hypothetical) ABCC value of the age group 17 to 22. The extrapolated values are calculated as follows:

$$(5) \quad ABCC2_{extrapolated} = ABCC_{23-32} \times \left(\frac{(ABCC_{23-32} - ABCC_{33-42})}{ABCC_{33-42}} + 1 \right),$$

assuming that the development pace of the educational environment of age group 33 to 42 relative to the age group 23 to 32 is the same in relativity as for the age group 23 to 32 to the age group 17 to 22.[119] Figure 5.3 shows the correlation between the calculated ABCC2 values (formula (4)) and the extrapolated ABCC values (formula (5)) for the age group 17 to 22.

Figure 5.3: scatter plot of calculated and extrapolated ABCC values for the age group 17 to 22



Overall, the values of the extrapolated and calculated ABCC values fit quite well. Regressing the extrapolated values on the calculated values yields an R^2 of .857 (n=221). The scatter plot does not reveal a systematic deviation pattern; however, the variation

[119] This is probably a quite strong assumption, however, the best we have at hand.

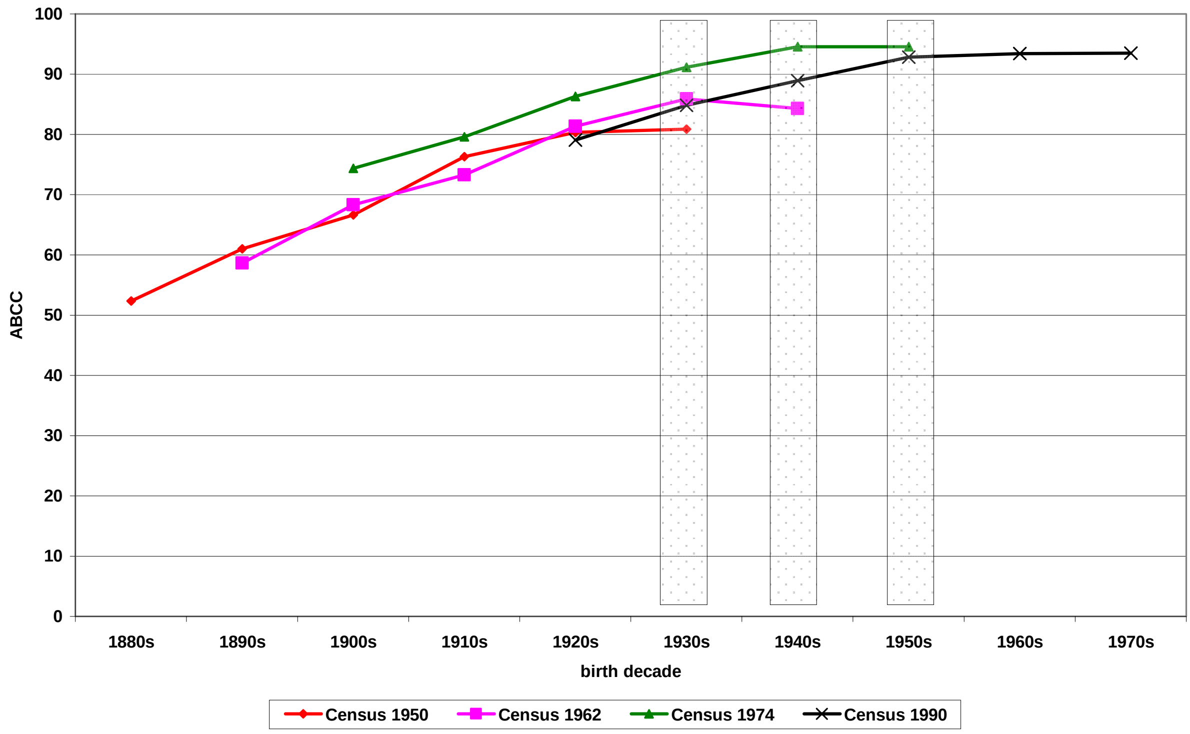
seems to be somewhat higher on low ABCC levels. At ABCC levels below 40, the calculated and extrapolated values deviate up to 35 ABCC points. This is driven by the two strongly deviating points in the lower right section of the scatter plot, representing the ABCC values of the age group 17 to 22 of the Egyptian census data of 1907 and 1947. This strong deviation from the extrapolated data indicates a much stronger and significant improvement of the ABCC for the age group 17 to 22, as expected. This observation is discussed further in the next robustness check.

As a second robustness check, we test whether the values of the 17- to 22- year-olds calculated using the ABCC2 index formula deviates significantly from the ABCC values obtained from another census of the same country and the same birth decade.[120] If the quality of age statements is independent of age, as Baten and Crayen find in their analysis (2010, Appendix A), then we should not find significant differences between the ABCC values of the same birth decade. For that we need at least two censuses from the same country where a value of the 17- to 22- year-olds overlaps with another ABCC value of the second census. This way, we can measure the difference between two ABCC values that represent the heaping behaviour of a certain birth cohort of a certain country. For a few countries (for example, the United States and Belgium) our data set has up to five overlapping censuses, so it is possible to countercheck the ABCC value of the 17- to-22-year-olds with data from the four other censuses. Figure 5.4 illustrates these differences using the example of Ecuador, where four ABCC trends derived from four different Ecuadorian censuses are available. Here it is possible to compare the ABCC value of the 17- to-22-year-olds (born during the 1930s) with three ABCC values of the same cohort measured at a later point in time. This comparison can also be made for cohorts born during the 1940s and 1950s, respectively. Thus, data from the four

[120] This is a stricter robustness check as the previous one as it is not based on the assumption of the homogenous educational environment over several age groups.

Ecuadorian censuses provide six overlapping data points that make possible the assessment of the reliability of the new ABCC2 index.

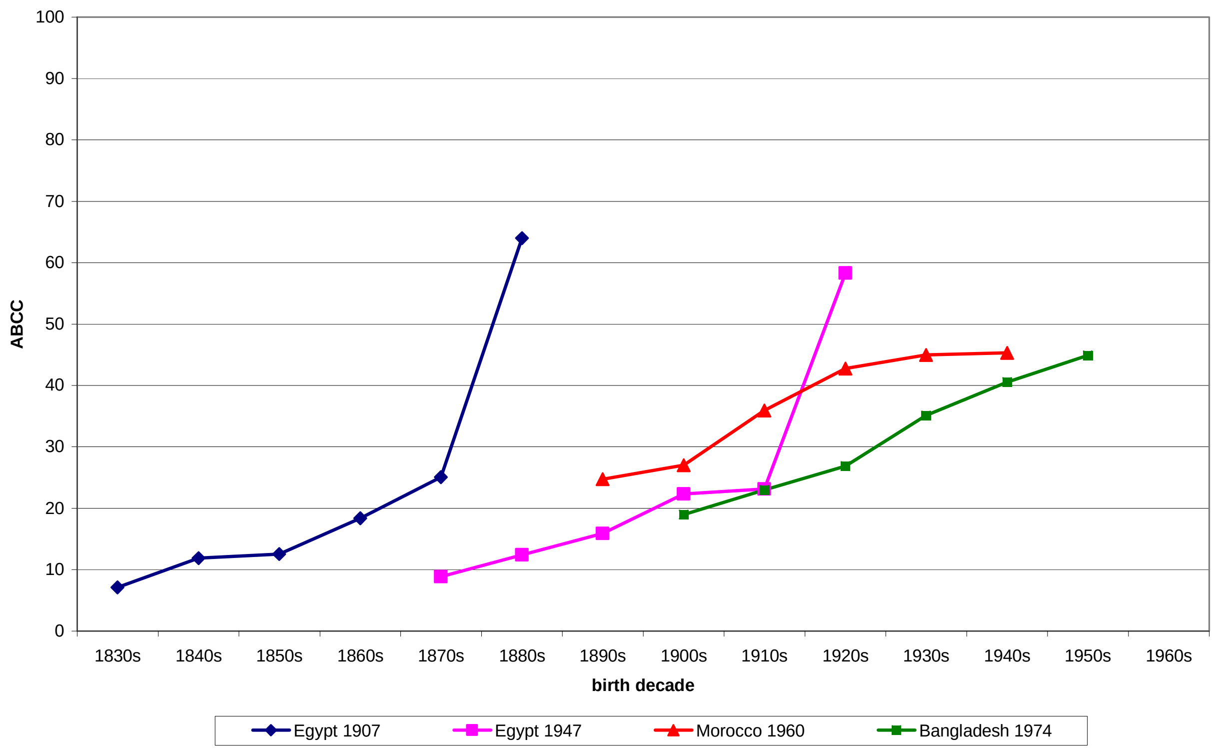
Figure 5.4: Four ABCC trends for Ecuador generated from four different censuses



In the example of Ecuador, the data points do deviate, but only to a maximum of five ABCC points, and – more importantly – the deviation does not show a systematic pattern. To test this analytically, we extract from the global data set all overlapping data points, yielding a data set of 205 observations of the difference between the ABCC2 and the ABCC value for a certain country and birth decade. The mean difference is -.3 ABCC points (standard deviation: 4.78), with a maximal positive difference of 51.6 ABCC points and a maximal negative difference of -12.8 ABCC points (see Table A.6 in the Appendix).

The extreme deviation of 51.6 ABCC points stems from the data on Egypt. Figure 5.5 displays the two Egyptian ABCC trends based on the age distributions of the censuses of 1907 and 1947. The strong increase from the second-youngest to the youngest age group could have two explanations: either the group of 17- to-22-year-olds heaps much less than the following age group, or the ABCC2 index is somewhat distorted in the Egyptian case. Since the two censuses for Egypt show an overall trend of similar levels of heaping, it is more plausible that the ABCC2 value is not an accurate reflection of the heaping behaviour of the youngest age group.

Figure 5.5: ABCC trends of Egypt, Morocco, and Bangladesh



However, it could be possible the ABCC index is generally more sensitive to changes in the heaping behaviour of the underlying population at the extreme low levels of the ABCC than at higher levels: the higher the ABCC level, the less variation is possible as the ABCC index is limited by an upper boundary. Additionally, the same increase in human capital possibly causes a greater increase in the ABCC value of the underlying population at high levels of age heaping than in societies where age heaping is no longer a significant problem. To serve as a comparison, trends in Morocco and

Bangladesh were added to the graph. These trends do not show as strong an increase in ABCC from the second-youngest to the youngest age groups, even though they are both at a high level of age heaping. This could hint at the possibility the very high heaping level is not the reason for the strong ABCC2 deviations in the case of Egypt. Based on the comparison of these country trends, it is more likely Egypt is a special case and should be treated accordingly in the analyses. Unfortunately, the global data set contains only data for four countries with such a low ABCC level (less than 50 ABCC points: Egypt, Bangladesh, Morocco, and Afghanistan). Thus, our assessment that Egypt is a special case should be treated as tentative until more data for similar high-heaping-levels are available.

Table 5.1 displays the results of different regression models explaining the difference between the ABCC value of the age group 17 to 22 and the ABCC value of another age group in the same birth decade and the same country. Model 1 examines whether the difference is influenced systematically by the overall heaping level. No effect is visible; only the group with the strongest age heaping (below 75 ABCC points) deviates strongly and significantly. However, this group is only represented in the Egyptian data. Model 2 excludes the Egyptian data and the results stay the same; therefore the overall heaping level has no explanatory power (note the very low R^2 in model 2). Model 3 looks at the different age groups. Recall that every observation in this data set represents the difference in ABCC values of the age group 17 to 22 and an older age group (taken from a different census conducted in the same country). If there were any age effects, it would be expected that the differences get higher the older the comparative age group. However, these regression results do not indicate such a relationship.[121] Model 4 shows the age group and heaping level effects together, while model 5 controls for birth decades (in both models, Egypt is excluded) to account for

[121] Please note: The coefficient of the age group 53 to 62 is again driven by Egypt. Excluding Egypt, leaves the other results constant, but turns this coefficient to .099 (statistically insignificant).

possible time effects. These regression analyses show clearly that the ABCC2 index fits well and is not dependent upon the overall level of age heaping or the birth decade and is not in need of additional adjustment. Additionally, these results confirm Crayen and Baten's finding (2010) that the ABCC is not influenced significantly by age effects.

Table 5.1: Regression results: Explaining the difference between the ABCC value of the age group 17 to 22 and the ABCC value of another age group in the same birth decade and the same country

	Model 1	Model 2 Egypt excl.	Model 3	Model 4 Egypt excl.	Model 5 Egypt excl.
ABCC 0 to 75	52.23*** (3.508)				
ABCC 75 to 85	ref.	ref.		ref.	ref.
ABCC 85 to 90	0.263 (3.883)	0.263 (3.874)		0.344 (3.871)	-0.533 (2.869)
ABCC 90 to 96	-1.497 (3.664)	-1.497 (3.655)		-1.579 (3.684)	-3.618 (2.727)
ABCC 95 to 98	1.151 (3.554)	1.151 (3.545)		1.112 (3.564)	-2.526 (2.762)
ABCC 98 to 99	1.289 (3.515)	1.289 (3.507)		1.294 (3.488)	-2.325 (2.660)
ABCC 99 to 100	-0.137 (3.513)	-0.137 (3.505)		-0.102 (3.498)	-2.509 (2.608)
age group 23 to 32			ref.	ref.	ref.
age group 33 to 42			0.556 (0.611)	0.615 (0.584)	0.282 (0.504)
age group 43 to 52			0.0315 (0.590)	0.133 (0.595)	0.545 (0.532)
age group 53 to 62			2.476 (2.426)	0.0654 (0.664)	-0.199 (0.693)
age group 63 to 72			0.816 (0.501)	0.820 (0.512)	-0.622 (0.599)
Constant	-0.610 (3.508)	-0.610 (3.499)	-0.763** (0.355)	-0.869 (3.433)	3.776 (2.753)
Observations	205	204	205	204	204
R-squared	0.601	0.045	0.025	0.054	0.457

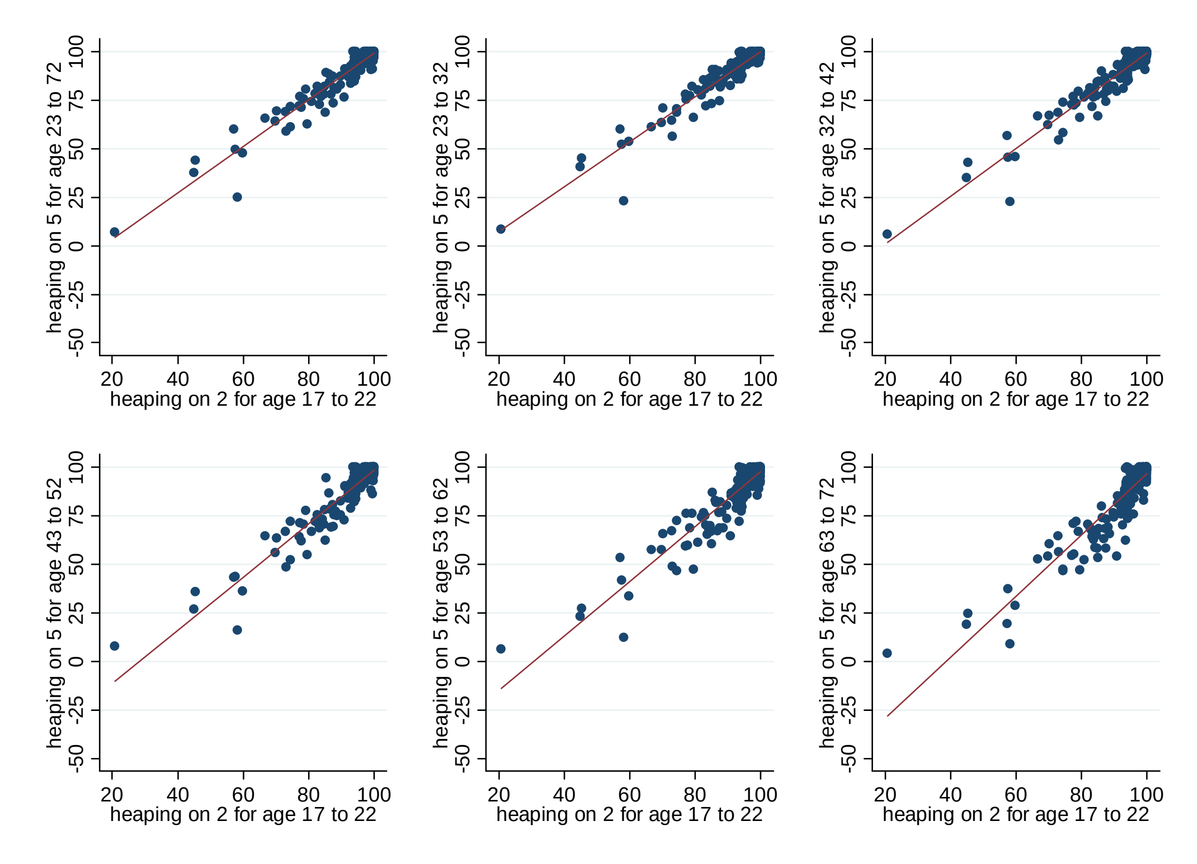
Note: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Dependent variable: Difference between the ABCC of the age group 17 to 22 and the ABCC value of another age group in the same birth decade and the same country. Coefficients of the birth decade dummies in model 5 not reported.

5.4. Prediction

Working with historical data often means dealing with insufficient or incomplete data. This is also true for historical data on age distributions. When data sources provide only information on young adults and not on older age groups (as is often the case for data on military recruits or from marriage registers), it is helpful to estimate the average heaping behaviour of the older population on the basis of the heaping level of the adolescents. In order to do this, we need estimated relationships of the ABCC2 index and the conventional ABCC index of the older age groups. Using the worldwide data set on age-heaping that has been extended by the ABCC2 index for the age group 17 to 22, we find almost linear relationships between the conventional ABCC index for age groups 23 to 72 and the new ABCC2 index (Figure 5.6). Each observation point represents the relationship between the ABCC value of heaping on multiples of 5 for the age group 23-72, 23-32, 33-42, … and the ABCC2 value on multiples of two for the age group 17 to 22 within a certain census.[122] The graphs show clearly that the variation of the ABCC2 index is higher at low ABCC values than at ABCC values over 25 points.

[122] Actually we would expect the regression constant to go through the origin. The deviation is probably due to too little low ABCC level observations and the resultant sensitivity of the low ABCC values mentioned above.

Figure 5.6: Scatter plots of heaping on multiples of two vs. heaping on multiples of five, disaggregated by different age groups, n=221



Regressing the ABCC values of the different age groups on the ABCC2 values of the age group 17 to 22 leads to the following conversion formulas:

$$(5)\ ABCC_{23-72} = -25.77 + 1.25 \times ABCC2 \quad \left(adj.R^2 = .89\right)$$

$$(6)\ ABCC_{23-32} = -20.49 + 1.20 \times ABCC2 \quad \left(adj.R^2 = .89\right)$$

$$(7)\ ABCC_{33-42} = -30.24 + 1.30 \times ABCC2 \quad \left(adj.R^2 = .89\right)$$

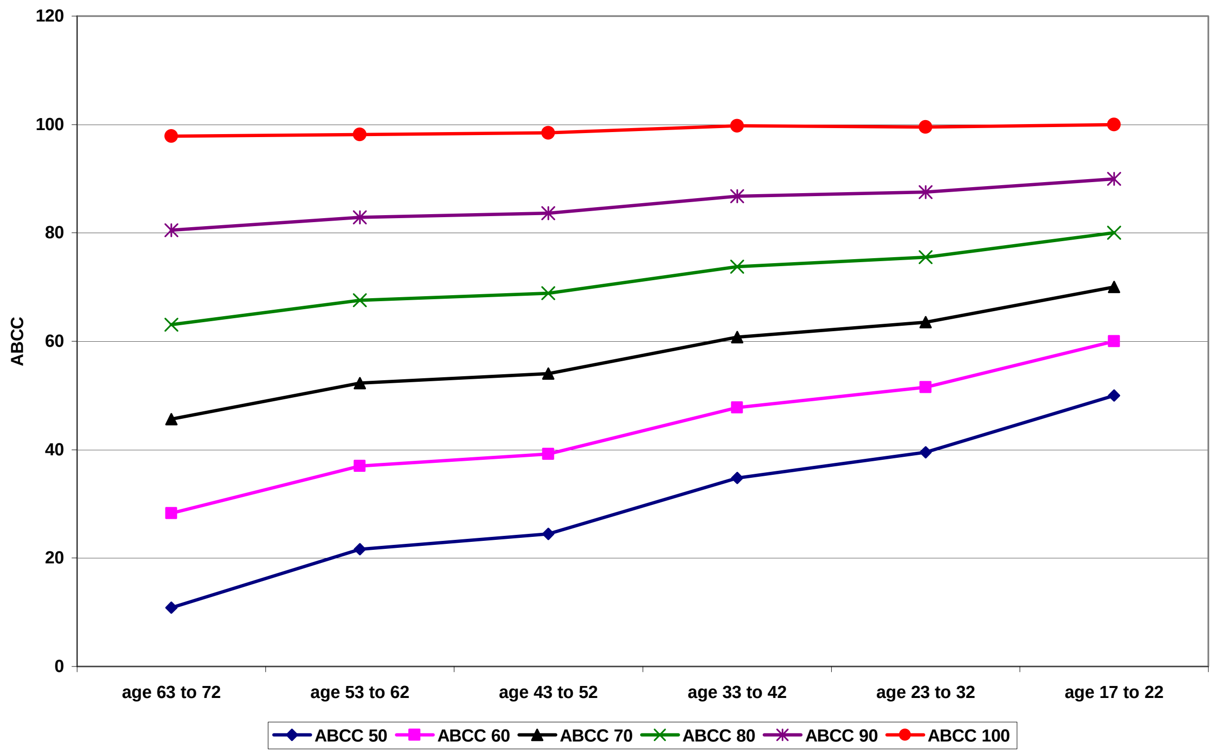
$$(8)\ ABCC_{43-52} = -49.56 + 1.48 \times ABCC2 \quad \left(adj.R^2 = .88\right)$$

$$(9)\ ABCC_{53-62} = -54.84 + 1.53 \times ABCC2 \quad \left(adj.R^2 = .86\right)$$

$$(10)\ ABCC_{63-72} = -76.15 + 1.74 \times ABCC2 \quad \left(adj.R^2 = .87\right)$$

Figure 5.7 displays a simulation of the ABCC development, based on notional ABCC values for the age group 17 to 22. Here, we note that, in general, the average increase in ABCC points from one age group to the preceding age group is strongest within the lowest overall ABCC group (“ABCC 50”).

Figure 5.7: Simulation of ABCC development, based on ABCC values of the age group 17-22



5.5. Conclusion

This study presents an extension of the Whipple (respectively ABCC) index, namely how the age-heaping methodology can be applied to the age group 17 to 22. The analyses show that this new index is a valuable and reliable tool for extending age-heaping analysis to the adolescents and young adult group and could spur further research in this field. However, further careful investigation is needed in cases where extreme age-heaping exists (below 50 ABCC points), as the relationship between the new index presented in this research note and the conventional index is not yet clear. This is due to the fact that the results for this group are based only on few observations. For heaping levels between 50 and 100 ABCC points - the interval into which 97 percent of observations fall - the proposed index proves robust.

5.6. References

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5.7. Appendix I: Data description

Table A.1: Summary statistics of the number of single age returns underlying the ABCCs values (worldwide data set)

Age Group	No. of censuses	Mean	Std. Dev.	Min	Max
17-22	221	3185731	11408378	204	152770886
23-32	221	4567567	15408239	223	200166987
33-42	221	3718567	12577400	155	163090299
43-52	221	2745457	8184737	114	99474476
53-62	221	2126155	6593730	66	81662685
63-72	221	1362486	4183358	22	50265294

Table A.2: Number of observations per birth decade (worldwide data set)

Birth decade	Freq.	Percent
1770	1	0.08
1780	7	0.53
1790	14	1.06
1800	19	1.43
1810	27	2.04
1820	32	2.41
1830	40	3.02
1840	44	3.32
1850	49	3.7
1860	52	3.92
1870	49	3.7
1880	58	4.37
1890	81	6.11
1900	110	8.3
1910	126	9.5
1920	150	11.31
1930	145	10.94
1940	131	9.88
1950	99	7.47
1960	60	4.52
1970	32	2.41
Total	1,326	100

Table A.3: Number of observations per age group (worldwide data set)

Age group	Freq.	Percent
17-22	221	16.67
23-32	221	16.67
33-42	221	16.67
43-52	221	16.67
53-62	221	16.67
63-72	221	16.67
Total	1,326	100

Table A.4: Number of observations per heaping level and age group (worldwide data set)

Age group/ Freq.	ABCC 0 to 50	ABCC 50 to 75	ABCC 75 to 85	ABCC 85 to 90	ABCC 90 to 95	ABCC 95 to 98	ABCC 98 to 99	ABCC 99 to 100
17-22	2	12	15	12	35	24	14	107
23-32	4	14	14	17	26	28	19	99
33-42	6	15	20	19	20	30	17	94
43-52	8	23	19	18	20	31	18	84
53-62	9	23	24	18	23	24	24	76
63-72	10	34	21	15	22	22	31	66
Total	39	121	113	99	146	159	123	526

Table A.5: Summary statistics of the ABCC, overall and per heaping level (worldwide data set)

heaping level	Obs	Mean	Std. Dev.	Min	Max
0 to 50	39	32.96	13.26	7.07	48.91
50 to 75	121	65.59	6.59	52.30	74.83
75 to 85	113	80.62	2.9988	75.19	84.92
85 to 90	99	87.56	1.4937	85.21	89.99
90 to 95	146	93.01	1.2939	90.36	94.92
95 to 98	159	96.76	0.8659	95.03	97.99
98 to 99	123	98.57	0.2948	98.00	99.00
99 to 100	526	99.75	0.3124	99.00	100.00
0 to 100	1326	90.91	14.81	7.07	100.00

Table A.6: Summary statistics of the difference between the ABCC value of the age group 17 to 22 and the ABCC value of another age group in the same birth decade and the same country

heaping level	Obs	Mean	Std. Dev.	Min	Max
0 to 75*	1	51.61	.	51.61	51.61
0 to 85	5	-0.61	8.62	-9.51	13.22
85 to 80	16	-0.35	6.76	-11.42	8.93
90 to 95	13	-2.11	3.90	-10.30	1.74
95 to 98	11	0.54	1.94	-3.06	3.04
98 to 99	25	0.68	1.14	-1.98	1.89
99 to 100	134	-0.75	2.17	-12.81	1.00
0 to 100	205	-0.30	4.78	-12.81	51.61

* This group is represented by Egypt (birth decade 1880) only.

5.8. Appendix II: Sources of age distribution data/ Census data

Afghanistan 1979 (United Nations Demographic Yearbook (UNDYB)); Armenia 1970 (Demoskop Weekly); Argentina 1980 (UNDYB); Austria 1880, 1890, 1900, 1910 (Rothenbacher 2002); Australia 1986, 1991 (UNDYB); Azerbaijan 1970 (Demoskop Weekly); Bosnia 1910 (Matic); Bangladesh 1974 (UNDYB); Belgium 1846, 1856, 1866, 1880, 1890, 1900, 1910, 1920 (Rothenbacher); Bahrain 1981 (UNDYB); Benin 1979 (UNDYB); Bolivia 1950, 1976, 1992 (UNDYB); Brazil 1950 (UNDYB); Botswana 1964 (UNDYB); Belarus 1959, 1970 (Demoskop Weekly); Canada 1976, 1981, 1991 (UNDYB); Switzerland 1860, 1870, 1880, 1888, 1900, 1910, 1920 (Rothenbacher), 1990 (UNDYB); Cote d'Ivoire 1988 (UNDYB); Chile 1970 (UNDYB); Cameroon 1976 (UNDYB); China 1990 (UNDYB); Colombia 1964, 1985 (UNDYB); Costa Rica 1927 (see Manzel & Baten 2009), 1973 (UNDYB); Serbia 1863 (see Crayen & Baten 2010); Cuba 1981 (UNDYB); Czechoslovakia 1921, 1930 (Rothenbacher); Germany 1910, 1925, 1933 (Rothenbacher); Denmark 1870, 1880, 1890, 1901, 1911, 1921 (Rothenbacher); Dominican Republic 1950 (UNDYB); Algeria 1966 (UNDYB); Ecuador 1950, 1962, 1974, 1990 (UNDYB); Estonia 1959, 1970 (Demoskop Weekly); Egypt 1907 (see Crayen & Baten 2010), 1947 (UNDYB); Finland 1880, 1900, 1910, 1920 (Rothenbacher), 1985, 1990 (UNDYB); France 1851, 1856, 1861, 1866, 1936 (Rothenbacher), 1990 (UNDYB); Georgia 1959, 1970 (Demoskop Weekly); Ghana 1960, 1970 (UNDYB); Gambia 1973 (UNDYB); Greece 1951 (UNDYB); Guatemala 1950 (UNDYB); Guinea-Bissau 1950 (UNDYB); Guyana 1946 (UNDYB); Hong Kong 1961, 1976, 1986, 1991 (UNDYB); Honduras 1974 (UNDYB); Haiti 1950, 1971 (UNDYB); Hungary 1949 (Rothenbacher); Indonesia 1980 (UNDYB); Ireland 1926 (Rothenbacher), 1979, 1991 (UNDYB); Israel - Jewish population 1948 (UNDYB); India 1971 (UNDYB); Iraq 1965 (UNDYB); Iran 1966 (UNDYB); Italy 1871, 1931, 1936 (Rothenbacher); Japan 1947, 1985, 1990 (UNDYB); Kenya 1979, 1989 (UNDYB); Kyrgyzstan 1959, 1970 (Demoskop Weekly), 1989 (UNDYB); Korea (South) 1955, 1960, 1975, 1980, 1985, 1990 (UNDYB); Kazakhstan 1959, 1970 (Demoskop Weekly), 1989 (UNDYB); Sri Lanka 1981 (UNDYB); Liberia 1962, 1974 (UNDYB); Lithuania 1959, 1970 (Demoskop Weekly), 1989 (UNDYB); Latvia 1959, 1970 (Demoskop Weekly); Morocco 1960 (UNDYB); Moldova 1959 (Demoskop Weekly), 1989 (UNDYB); Madagascar 1975 (UNDYB); Mali 1976 (UNDYB): Mexico 1950, 1960, 1970, 1990 (UNDYB); Malaysia – Sarawak 1960 (UNDYB); Nigeria 1963 (UNDYB); Nicaragua 1971 (UNDYB); Netherlands 1849, 1859, 1869, 1879, 1889, 1899, 1909 (Rothenbacher); Norway 1980, 1990 (UNDYB); Nepal 1981 (UNDYB); New Zealand 1986, 1991 (UNDYB); Panama 1980, 1990 (UNDYB); Philippines 1948, 1960 (UNDYB); Poland 1921 (Rothenbacher), 1978 (UNDYB); Puerto Rico 1990 (UNDYB); Portugal 1940 (Rothenbacher); Paraguay 1962 (UNDYB); Qatar 1986 (UNDYB); Romania 1992 (UNDYB); Russia 1959, 1970 (Demoskop Weekly), 1989 (UNDYB); Sweden 1880, 1900, 1910, 1920, 1930 (Rothenbacher), 1990 (UNDYB); Slovenia 1991 (UNDYB); Syria 1970 (UNDYB); Togo 1958, 1970 (UNDYB); Thailand 1947, 1960 (UNDYB); Tajikistan 1959, 1970 (Demoskop Weekly); Turkmenistan 1959, 1970 (Demoskop Weekly); Tunisia 1966 (UNDYB); Turkey 1985, 1990 (UNDYB); Ukraine 1959, 1970 (Demoskop Weekly); Uganda 1991 (UNDYB); United Kingdom 1911, 1921, 1926, 1931, 1937 (Rothenbacher), 1851 (see Crayen & Baten 2010), 1991 (UNDYB); United States 1850, 1860, 1870, 1880, 1900 (Ruggles et al. 2010), 1950, 1970, 1980, 1990 (UNDYB); Uruguay 1975, 1985 (UNDYB); Uzbekistan 1959, 1970 (Demoskop Weekly); Vietnam 1989 (UNDYB); South Africa 1970, 1980, 1985 (UNDYB); Zambia 1974 (UNDYB).

6. Summary

This thesis made use of the phenomenon of age-heaping to assess human capital in today's developing regions mainly for the time period from 1880 to 1960. Although the age-heaping methodology is still quite new in the field of economic history and it captures only a very basic aspect of human capital, many studies have demonstrated now its usefulness as a proxy for basic numerical skills. This thesis contributed to this strand of literature and presented new empirical evidence for assessing the historical roots and determinants of today's educational situation in Africa, Asia, and the Americas. The focus in these studies was always on the aggregated level of countries. For further research, it would be most interesting to exploit additional sources and examine the mechanisms that drive human capital accumulation on the micro data level.

Chapter 2 presented a study that contributed new empirical evidence to the colonial legacy debate that discusses the role of institutions, geography and human capital for long-term economic development. The crucial question addressed was whether institutions are fundamentally more important to start the process of a positive economic development (as promoted by Acemoglu et al. 2001) or whether growth and human capital accumulation come first and lead then to institutional improvement (as brought forward by Glaeser et al. 2004). New empirical evidence to the role of human capital within this controversial debate was provided by using the age-heaping methodology. The chapter presented estimates of basic numeracy levels of 68 former colonies in Africa, Asia, and the Americas mainly for the 19th and 20th century, for a few countries even for the 18th century. To address the problem of endogeneity an instrumental variable approach was used. In contrast to Glaeser et al.'s (2004) human capital argument, this study assessed not only the human capital of the settler population, but focused on the whole population, i.e. also on the human capital of the indigenous populations. The new human capital estimates indicate that the educational level of the indigenous populations also varied a lot. Additionally, possible spill-over effects from (sometimes small) migrant communities on the indigenous population have to be taken into account. The empirical results indicate that colonial institutions did of course influence the long-term economic development of these countries. However, the results show that human capital played also an important role, and instrumental variable effects might have run through this causality chain.

Chapter 3 of my thesis examined the development and persistence of human capital in Africa since the late 19th century. It presented new estimates on basic numeracy for 34 African countries for the period 1880 to 1960. As data on human capital in Africa before 1960 are scarce, this new data set gives valuable insights into the state of the educational situation during the colonial period in Africa. The evidence reveals large differences between countries and regions: Numeracy levels were generally highest in the Southern region of Africa. Also the French settler colonies Algeria and Tunisia had high numeracy levels around 1900. In contrast, Egypt, Morocco, Nigeria, Ethiopia, and the Comoros were the countries with ABCC values less than 50 points during this period which ranks them very low not only in Africa but also worldwide. Regression results suggest that primary school enrolment ratios and the presence of European settlers in the colonies played the most important roles in determining basic numerical skills.

The second part of Chapter 3 addressed the question of the persistence of human capital. Using the new human capital estimates from the colonial period and comparing them to current literacy levels in Africa, a strong path-dependency was observable. Additionally, even after controlling for factors like school enrolment and public expenditure on education, regression results indicate that the numeracy level 100 years ago still has a significant influence on literacy rates today in Africa. Thus, at least partially, the roots for educational underdevelopment in Africa can be traced back to the colonial period. However, I found also strong support for the possibility of escaping this "trap of early human capital underdevelopment" through consequent investment in schooling.

In Chapter 4 the focus was on gender inequality in education. Here as well, the age-heaping approach is used to trace the human capital development in 14 Asian countries during the first half of the 20th century. The numeracy estimates revealed high variation of educational levels among the countries in the Asian region: while most Southeast Asian countries had already high numeracy levels during the first half of the 20th century, most South and West Asian countries are characterised by low numerical skills. Regression results identified enrolment rates, GDP per capita and female voting rights as important determinants of numeracy. Female voting rights can be interpreted as a proxy for the attitude of a society towards women's role in that society. Additionally, the regression results indicate that cultural factors (religion) impacted the accumulation of human capital.

The development of the gender gap over time revealed a U-shaped path: At low numeracy levels gender equality is high. As numeracy increases, gender equality decreases initially before rising to high levels again, declines and increases again with higher numeracy levels. This observation was further tested by performing a panel analysis. Its results confirm the U-hypothesis for Asia during the first half of the 20th century. The results indicate that the attitude of a society towards women's role in social life as well as the level of economic development of a country is particularly important for an equal distribution of education between the genders.

Chapter 5 contributed to the age-heaping methodology itself. The traditional Whipple index captures the heaping behaviour of adults, which is based on multiples of five. In this chapter a reformulated Whipple index, respectively ABCC index, for the age group 17 to 22 is introduced. This new index, the ABCC2 index, captures the special heaping behaviour of young adolescents. In contrast to adults, this age group tends to round its age to even numbers, which are 16, 18, 20, and 22. The study presented graphical and analytical analyses that show the high reliability of this new index. Furthermore, when data sources provide only information on young adults (as is often the case for data on military recruits or from marriage registers) and not on older age groups, it is possible to estimate the average heaping behaviour of the older population on the basis of the heaping level of adolescents. The analyses show that this new index is a valuable and reliable tool for extending age-heaping analysis to the adolescents and young adult group and that it could spur further research in this field.

6.1. References

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