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# Rethinking age heaping again for understanding its possibilities and limitations

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## Abstract

A'Hearn, Delfino, and Nuvolari recently argued in this journal that the indicator function of age heaping for education, and numeracy in particular, is quite limited. In contrast, we show empirically that by applying the methodological elements that were developed over the past decade, age-heaping-based numeracy research can be an important tool for economic history.

## KEYWORDS

age-heaping, capital Italy, gender equality, human, numeracy

A'Hearn, Delfino, and Nuvolari (hereafter A'Hearn et al.) recently argued in this journal that evidence on age heaping should not be interpreted as indicating numeracy alone.<sup>1</sup> Rather, cultural behaviour and the activities of the state administration should be taken into consideration when interpreting age heaping. We fully agree with their view that an analysis of age-heaping data requires a careful consideration of the sources and the cultural and administrative environment in which these were created. If we speak of 'numeracy' estimates in the following, we define this as the inverse of age-heaping ratios, taking into account the cultural and administrative environment and the usual assumptions (see section III). However, many arguments in their article aim at demonstrating that the indicator function of age heaping for education, and numeracy in particular, is quite limited. For example, they create the impression that female numeracy cannot be approximated with this technique. We argue that some of their arguments are strongly exaggerating an otherwise reasonable critical position. Moreover, we find that they do not apply many of the

<sup>1</sup> A'Hearn, Delfino, and Nuvolari, 'Rethinking age heaping'.



methodological elements that have been developed over the past decade. Lack of consideration of these insights can eventually lead to a biased view of this important tool for economic history.

First, we fully agree with A'Hearn et al. about the relevance of age-heaping-based numeracy research. Evidence on historical human capital is very scarce, and when literacy and other indicators become widely available from the late nineteenth century, they are 'fraught with gaps, inconsistent reporting and other shortcomings'.<sup>2</sup> Moreover, recent studies have found that numerical and scientific skills are among the most crucial determinants of economic growth.<sup>3</sup> Numerical skills are vital; for example, if labourers are able to work with numerical proportions and calendars, and plan working hours, they are far more productive, and this was certainly the case in nineteenth-century agricultural economies.<sup>4</sup>

Recently age heaping even featured in the *Global education monitoring* flagship report of the United Nations.<sup>5</sup> It is probably one of the very few research areas and methodologies that were developed mostly in economic history and that are nowadays applied to assess the global development of humankind.<sup>6</sup>

As a caveat, we should note that not all samples are equally useful for age-heaping analysis (and some are not useful at all). It is important to study carefully who asked the age question; who responded to it, and in which way; and whether there was counterchecking, social desirability, or other sources of biases. Such potential biases were often discussed in extensive appendices to earlier studies, but less often read.

However, A'Hearn et al. actually suggest a new variant of the age-heaping numeracy approach. Their calculation is not compatible with the methods mostly applied in the last decade. First, they do not aggregate all evidence by birth decade, as is now conventional practice in the vast majority of age-heaping studies, and age groups are not consistently considered. Second, they implicitly relax the basic assumption of the Whipple index that ages should be—at least approximately—uniformly distributed (for example, the migration data, which they analyse, are certainly not uniformly distributed).<sup>7</sup> The Ellis Island sources on Italian migrants might be one example of a source that is not useful for age-heaping analysis. Third, the age-heaping literature published over the previous decades considered counterchecking by census takers and other distortions by the person in charge of recording and reporting. In contrast, A'Hearn et al. discuss obviously counterchecked samples of the twentieth century (for example, China). Fourth, they suggest a new method of comparing the preference for heaping on the end-digit 0 compared to the heaping on 5, and call this very different indicator simply 'age heaping', as if it were identical to the Whipple index. Before this indicator could sensibly be used, it would require a systematic assessment.

<sup>2</sup> Ibid., p. 111.

<sup>3</sup> Hanushek and Woessmann, 'Do better schools lead to more growth?'; Baten and Juif, 'Story of large land-owners'.

<sup>4</sup> Tollnek and Baten, 'Farmers'.

<sup>5</sup> UNESCO, *Global education monitoring report 2021*.

<sup>6</sup> Baten, 'Indirect survey estimates'; Ferber and Baten, 'Age-heaping and numerical abilities'.

<sup>7</sup> Migrants are typically in their 20s; the share of older ages is very small among migrants, as people often do not migrate when they have reached older ages. This results in an age distribution in which, for example, the end-digit 3 is much more strongly represented in the age group 23–32 than most other end-digits. However, an important requirement of the Whipple index is an approximately uniform distribution of end-digits, except for the end-digits on which the 'heaping' takes place; A'Hearn et al., 'Quantifying quantitative literacy'. In the age-heaping literature of the last decade, samples with a clearly non-uniform age distribution (this also applies to marriage records) are mostly avoided.

**TABLE 1** Regressions: correlates of female literacy, and the female literacy gap

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dependent variable	Literacy	Literacy	Literacy	Literacy	Literacy	Literacy	Literacy gap
Age group	23–32	33–42	43–52	53–62	63–72	23–72	23–72
Female numeracy	9.91*** (0.000)	7.19*** (0.000)	5.48*** (0.000)	4.72*** (0.000)	4.61*** (0.000)	5.58*** (0.000)	0.88*** (0.001)
Number gap (female)							
Time fixed effects	No	No	No	No	No	Yes	Yes
Constant	–6.05*** (0.000)	–3.50*** (0.000)	–1.96*** (0.002)	–1.29** (0.013)	–1.39** (0.013)	–2.12*** (0.000)	0.42*** (0.000)
Observations	69	69	69	69	69	345	345
R <sup>2</sup>	0.516	0.489	0.435	0.458	0.445	0.466	0.107

Notes: Literacy is in logs. Robust  $p$ -values in parentheses: \*\*\* $p < 0.01$ ; \*\* $p < 0.05$ ; \* $p < 0.1$ . Dependent variable in cols. 1–6 is female literacy, for cross-sections of the 69 Italian provinces in cols. 1–5, and a panel of the 69 provinces times the five age groups that correspond with the five birth decades in cols. 6 and 7. In Col. 7, the dependent variable is the gap between male literacy and female literacy (male literacy minus female literacy). The main right-hand-side variable is female numeracy in cols. 1–6, and male numeracy minus female numeracy in col. 7. It is calculated following A’Hearn et al.’s (‘Quantifying quantitative literacy’)  $w$ -index, later called the ‘ABCC-index’ (Tollnek and Baten, ‘Age-heaping-based human capital estimates’). The  $R^2$  in col. 7 is smaller, as there are other variables that could play a role, such as cattle farming, large urban effects, and other variables. The measurement error of all four variables adds up. Moreover, Italian numeracy was already quite high in this census, resulting in a modest amount of variation overall. The correlation between the literacy gender gap and the numeracy gender gap in Turkey is much closer, for example, probably because numeracy was substantially lower, allowing more variation of the numeracy gap; Alexopoulos and Baten, ‘Gender (in)equality’.

For comparison: if the gap in literacy between males and females and the gap in school enrolment is regressed, the  $R^2$  is similarly ‘only’ 0.10. This was calculated based on enrolment rates of children being enrolled in schools divided by the total number of eligible children; we thank Gabriele Cappelli for providing the evidence for 1861 on the birth cohort mostly born in the 1850s. We compare this with the corresponding cohort from the Italian census of 1871.

Sources: Calculated on the basis of MAIC, *Censimento generale al 31 dicembre 1871*; Cappelli and Quiroga, ‘Female teachers’.

## I | AGE HEAPING AND INSIGHTS INTO FEMALE EDUCATION

A’Hearn et al. argue that for women, cultural factors play a particularly strong role for their age responses (if they were asked their age at all). Readers of the article by A’Hearn et al. might get the impression that age heaping is not a good indicator of female educational levels. If this were true, it would be a great disadvantage for economic historians, because very little information on the education of women in earlier periods is available. However, looking at evidence from the Italian census of 1871, the indicator function of age heaping for Italian female education is quite strong. The correlation coefficient between the Italian provinces of female literacy and female numeracy is close to 0.7 for all age groups and always highly significant (tables 1 and 2).

The correlation for males is even higher, but not by a large amount. Moreover, the deviations between female literacy and female numeracy follow the patterns established for other countries (figure 1). For example, a tradition of cattle farming was identified as being beneficial for female numeracy, more than for males.<sup>8</sup> Women in the province of Udine, which has a strong cattle farming tradition, are relatively more numerate than literate.<sup>9</sup> Moreover, large urban places such as Rome and Naples have been identified as being relatively beneficial for female (and male)

<sup>8</sup> Baten and de Pleijt, ‘Girl power generates superstars’.

<sup>9</sup> US Consular Reports, *Cattle and Dairy Farming*.

**TABLE 2** The correlation between literacy and numeracy in Italy (1871 census)**A. Female literacy and numeracy**

Age group	Correlation coefficient	Significance
23–32	0.718	0.000
33–42	0.700	0.000
43–52	0.659	0.000
53–62	0.677	0.000
63–72	0.667	0.000

**B. Male literacy and numeracy**

Age group	Correlation coefficient	Significance
23–32	0.806	0.000
33–42	0.803	0.000
43–52	0.791	0.000
53–62	0.786	0.000
63–72	0.735	0.000

*Notes:* Literacy is in logs. We show Pearson's correlation coefficients between the ABCC score of age heaping and gender-specific literacy levels. ABCC: see notes to tab. 1. All analysed age groups are included. For comparison with enrolment: If we include only the 38 provinces for which female literacy is below 25% (that is, below the average), the correlation between female literacy and female numeracy is still 0.620 ( $p = 0.000$ , 23–32 age group), while, for example, the correlation between female literacy and female enrolment rates is similar (0.636,  $p = 0.000$ , 23–32 age group, 1861 enrolment).

*Source:* See notes to tab. 1.

literacy.<sup>10</sup> In figure 1 Rome and Naples deviate to the upper left, and Udine and similar provinces to the lower right (figure 1). In other words, much of the remaining variation could be explained by findings for other countries. Finally, even the gender inequality of numeracy and the gender inequality of literacy are significantly correlated in Italy, as in other countries (column 7, table 1).<sup>11</sup>

It should be noted that the south of Italy had lower levels of literacy and numeracy than the north, but southern values, at around 85, are high by international comparison.<sup>12</sup> In the last descriptive section of their article, A'Hearn et al. show that some individuals in the south had substantial numeracy. We would expect these numeracy values at this literacy level.<sup>13</sup>

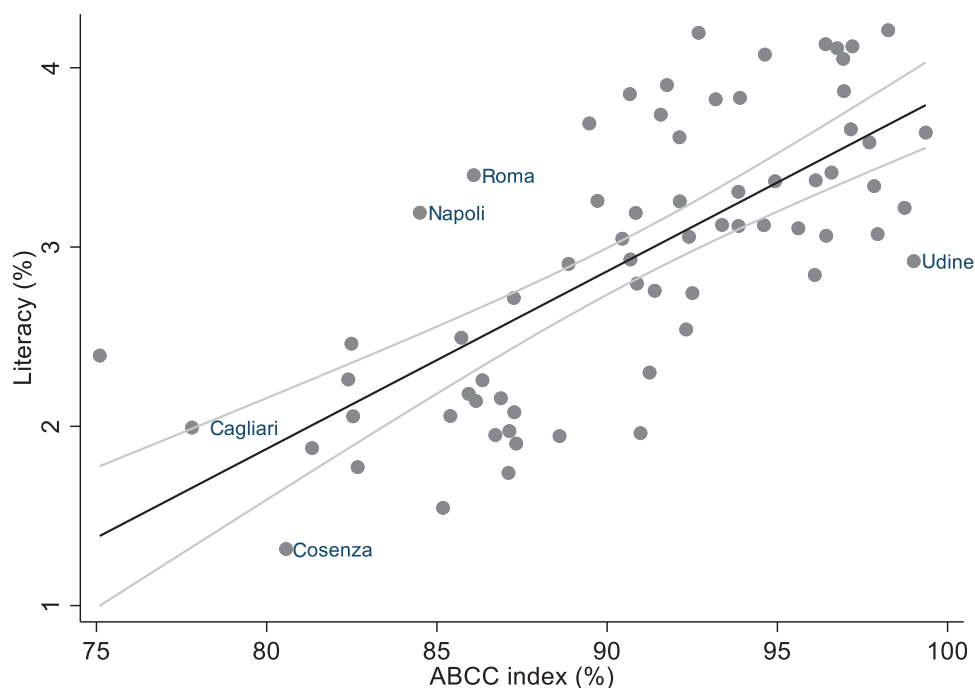
To support the limited numeracy information content of female age heaping, A'Hearn et al. follow Földvari et al. in speculating that married women tended to adjust their own age

<sup>10</sup> Hippe, 'Human capital formation', p. 181.

<sup>11</sup> Turkey: Alexopoulou and Baten, 'Gender (in)equality'.

<sup>12</sup> Crayen and Baten, 'Global trends in numeracy'.

<sup>13</sup> We would expect the South to have lower numeracy than the North, as land inequality was high (Baten and Hippe, 'Geography, land inequality and regional numeracy') and Catholicism was often practiced very conservatively. Name days were partly a policy instrument of the Counter-Reformation; Kacane, 'Celebrations of name day'. We could expect it to reflect extreme forms of Catholicism, and following Becker and Woessmann, 'Was Weber wrong?', this would lead us to expect lower numeracy in such an environment.



**FIGURE 1** Female age-heaping and female literacy, by Italian province. ABCC: see notes to tab. 1. Literacy is in logs. Age group is 23–32. All other age groups look very similar. For other countries, a similarly strong correlation of female age heaping and female literacy could be observed (for example, Alexopoulos and Baten, ‘Gender (in)equality’). This evidence plausibly supports the educational proxy function of age heaping. *Source:* Calculation based on MAIC, *Censimento generale al 31 dicembre 1871* [Colour figure can be viewed at [wileyonlinelibrary.com](http://wileyonlinelibrary.com)]

relative to their husband (reporting, for example, an age of 26 or 27, if the husband reported 30, and the ‘socially desirable’ age difference was three or four).<sup>14</sup> There is only indirect and not fully convincing evidence for this. Földvari et al. calculated the age of the husband minus the age of the spouse and observed age heaping on multiples of two.<sup>15</sup> They speculated that this might be supporting evidence for adjusting the spouse’s age to the husband’s age. However, there is substantial heaping not only on five but also on multiples of two in all age statements, which could easily cause this pattern. A second argument put forward by Földvari et al. is that married women sometimes seem to have higher numeracy than single women.<sup>16</sup> Selectivity into marriage might play a role here, as Friesen et al. countered, and A’Hearn et al. also mention this argument.<sup>17</sup>

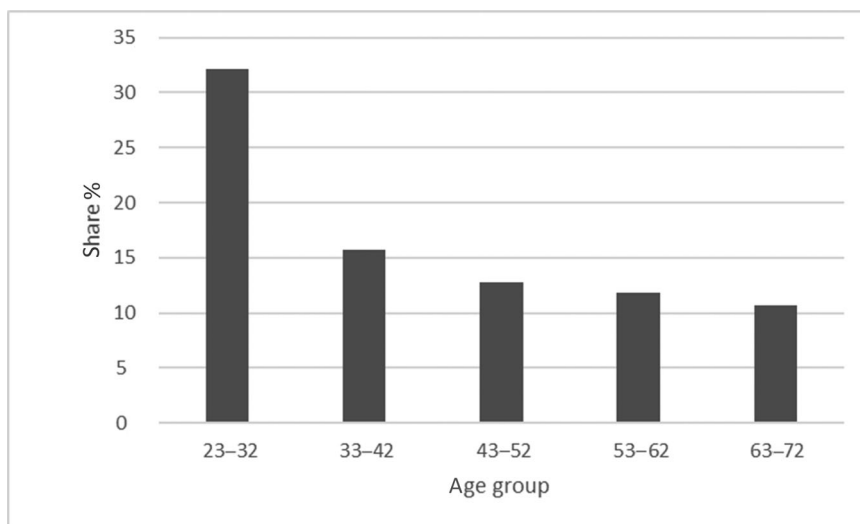
How numerate were single and married women in the case of the 1871 Italian census? First of all, this analysis only makes sense for the youngest age groups, especially 23–32 (and, to a lesser extent, 33–43). Single women at higher ages were a small minority, around 10 per cent at age 50 and

<sup>14</sup> Földvari, van Leeuwen, and van Leeuwen-Li, ‘How did women count?’.

<sup>15</sup> Ibid.

<sup>16</sup> Ibid.

<sup>17</sup> Friesen, Baten, and Prayon, ‘Women count’.



**FIGURE 2** Share of unmarried females by age group in Italy, 1871 census. Shares of women being single, related to their age groups. *Source:* MAIC, *Censimento generale al 31 dicembre 1871*

70 (figure 2). During the mid-nineteenth century, marriage typically required a sufficient income, and the minority who never married was most likely a selected group.<sup>18</sup>

If we compare the numeracy of married and single females in Italy, as well as in three provinces of the north, centre, and south, we do not see much of a marriage premium (table 3). In the 23–32 age group, single women were 4.3 per cent more numerate than married women in Italy. In light of these results, it is hard to imagine that women adjusted their ages relative to their husbands to a substantial extent.

## II | THE CORRELATION BETWEEN LITERACY AND NUMERACY, AND THE INFORMATIVENESS OF AGE HEAPING FOR NUMERICAL SKILLS

Almost all of the age-heaping studies of the last decade compared the evidence with other educational indicators for sub-periods in which both indicators are available. All these studies found a close correlation between age heaping and other educational indicators.<sup>19</sup> Even in the case of the ancient Roman economy, such plausibility tests turned out to be possible and confirmed the information content of age heaping for educational analysis.

There is a large literature in social history about the problematic assumption that literacy can be equated to education.<sup>20</sup> In sum, literacy also contains a substantial amount of measurement error. However, A'Hearn et al. seem to assume that literacy is a perfect yardstick for education. They simply call it 'education'.<sup>21</sup> They argue that if there is variation in age heaping even within

<sup>18</sup> Manfredini, Breschi, Fornasin, and Seghieri, 'Height, socioeconomic status and marriage'.

<sup>19</sup> For an overview, see Tollnek and Baten, 'Age-heaping-based human capital estimates'.

<sup>20</sup> Tóth, *Literacy and written culture*.

<sup>21</sup> A'Hearn et al., 'Rethinking age heaping', p. 121.

**TABLE 3** Numeracy of single and married women in Italy (ages 23–42, 1871 census)

Geographical unit	Age group	Single	Married	Marriage premium
Italy	Age 33–42	85.9	87.6	1.7
	Age 23–32	93.5	89.2	−4.3
	All (23–42)	89.7	88.4	−1.3
Ancona, province (centre)	Age 33–42	85.9	87.6	1.7
	Age 23–32	93.3	88.6	−4.7
	All (23–42)	89.6	88.1	−1.5
Catanzaro, province (south)	Age 33–42	81.8	80.5	−1.3
	Age 23–32	87.0	81.4	−5.6
	All (23–42)	84.4	81.0	−3.4
Reggio Emilia, province (north)	Age 33–42	95.9	94.4	−1.5
	Age 23–32	96.7	95.0	−1.7
	All 23–42	96.3	94.7	−1.6

*Notes:* We compare numeracy levels of single and married females in three provinces and in all of Italy. The provinces were chosen based on their numeracy value, always taking the one closest to the average of the centre, south, and north regions. We focus on young age groups (23–32 and 33–42) that had a substantial share of single women. The ‘marriage premium’ displays the numeracy of married women minus the numeracy of single women.

*Source:* MAIC, *Censimento generale al 31 dicembre 1871*.

literate (or illiterate) groups, this is an argument against the informativeness of age heaping for measuring educational levels.

We would argue that any single indicator of empirical research has a degree of measurement error. Age-heaping-based estimators offer the large advantage of a differently constructed indicator that we can compare to other educational estimates and find out what the differences in education really looked like. Furthermore, A’Hearn et al. note that age heaping is mostly an ‘unintended’ indicator because age rounding did not matter much to the individuals studied.<sup>22</sup> Age heaping was less affected by social desirability than literacy or school enrolment. Being literate was very desirable for certain groups; for example, in the large cities of Italy in the nineteenth century. On the other hand, literacy is reported to be undesirable for women in some societies, especially if their husbands were not literate. For example, rural and fundamentally Catholic societies in southern Spain have such a reputation.<sup>23</sup>

Recently, it became possible to study regional, intrafamilial, and even individual correlations between mathematics tests and age heaping. For example, Baten studied the persistence of age heaping and children’s mathematics tests in the regions of West and Central Africa.<sup>24</sup> The PASEC dataset allows comparisons between the numerical abilities of children and age heaping of the parent generation. For example, in Burkina Faso the correlation coefficient by region is 0.78 ( $p = 0.023$ ), and in Niger 0.95 ( $p = 0.000$ ). For all countries in West and West-Central Africa included in PASEC, the correlation was as high as 0.8 ( $p = 0.000$ ).<sup>25</sup> Ferber and Baten studied this for

<sup>22</sup> A’Hearn et al., ‘Quantifying quantitative literacy’.

<sup>23</sup> Pérez-Artés and Baten, ‘Land inequality and numeracy’.

<sup>24</sup> Baten, ‘Indirect survey estimates’.

<sup>25</sup> PASEC, ‘Education system performance’.





**TABLE 4** Regressions on the relationship between age heaping of the older generation and children's mathematics tests by region in 12 African countries, late twentieth/early twenty-first century

	(1)	(2)
ABCC index	0.293*** (0.027)	0.170*** (0.033)
Constant	-16.64*** (2.550)	-8.966** (3.175)
Country fixed effects	No	Yes
Observations	114	114
R <sup>2</sup>	0.404	0.715

*Notes:* Standard errors are robust: \*\*\*  $p < 0.01$ ; \*\*  $p < 0.05$ ; \*  $p < 0.1$ . In these regressions we assess the relationship between the numeracy of children and the ABCC index of caretakers. The regression was carried out with children's numeracy as the left-hand-side variable and the ABCC index as the right-hand-side variable. Included are all 114 regions in 12 countries in Sub-Saharan Africa (Central African Republic, Chad, Democratic Republic of the Congo, Gambia, Ghana, Guinea-Bissau, Lesotho, Madagascar, Sao Tomé and Príncipe, Sierra Leone, Togo, and Zimbabwe) for which MICS mathematics tests were available. Numeracy is measured using children's average score in mathematics tests consisting of four parts: number recognition, number discrimination, addition, and numerical patterns, with five or six questions for each. Col. 2 includes country fixed effects.

*Source:* Calculated based on UNICEF, *MICS*.

114 African regions for which *MICS* (Multiple Indicator Cluster Surveys) mathematics tests were available, and observed an R<sup>2</sup> between 0.40 and 0.71 in African regions in the twenty-first century (table 4).<sup>26</sup>

Ferber and Baten studied even correlations for parent-child dyads in Chad, Togo, and Sierra Leone (table 5).<sup>27</sup> If the parents reported a rounded age, the child would achieve a lower mathematics test score. This remained statistically significant even if the wealth of the family was entered as a control variable (for Togo and Chad). In contrast, the correlation between age heaping and literacy was much less obvious.

The Spanish Inquisition offers another insight, as the Inquisitors indirectly carried out a mathematics test with the accused.<sup>28</sup> Baten and Nalle analysed whether rounding individuals tended to perform worse in 'life course reckoning' tasks.<sup>29</sup> Life course reckoning tasks can be interpreted as mathematical tests, because it requires numerical skills to recount a life course in a correct and consistent way. In contrast, some individuals made statements such as (to report a hypothetical example): 'My age is 30. I married when I was 20, then worked for 15 years on a farm'; that is, an inconsistent life course reckoning. Comparing those who were five or more years out in their life course reckoning on the one side and age heaping on the other, age-heaping persons were twice as likely to fall into the 'problems with life reckoning' category (28.7 per cent versus 16.7 per cent). This was statistically significant even including occupational and other controls.

<sup>26</sup> UNICEF, *MICS*; Ferber and Baten, 'Age-heaping and numerical abilities'.

<sup>27</sup> Ibid.

<sup>28</sup> Nalle, 'Reckoning with one's life'.

<sup>29</sup> Baten and Nalle, 'Age-heaping and life course reckoning'.



**TABLE 5** Family-level regressions on the relationship between parental age heaping and children's mathematics tests in Togo, Sierra Leone, and Chad, late twentieth/early twenty-first century

	Togo		Sierra Leone		Chad	
	(1)	(2)	(3)	(4)	(5)	(6)
OLS						
Multiple of five	-0.683*	-0.627*	-0.587**	-0.321	-0.487**	-0.347*
	(0.285)	(0.272)	(0.196)	(0.190)	(0.158)	(0.152)
Regional fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Wealth index	No	Yes	No	Yes	No	Yes
Observations	2 781	2 781	5 909	5 909	8 100	8 100
R <sup>2</sup>	0.129	0.201	0.092	0.184	0.138	0.215
Tobit						
Multiple of five	-0.762*	-0.685*	-0.817**	-0.464	-1.933***	-1.531**
	(0.343)	(0.327)	(0.272)	(0.263)	(0.530)	(0.503)
Regional fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Wealth index	No	Yes	No	Yes	No	Yes
Observations	2 781	2 781	5 909	5 909	8 100	8 100

Notes: Standard errors are robust: \*\*\*  $p < 0.01$ ; \*\*  $p < 0.05$ ; \*  $p < 0.1$ . Numeracy is analysed as a multiple of five dummy and is used as the independent variable to explain the dependent variable of children's numeracy. Both an OLS and a Tobit regression are used, yielding similar results. Additional regional fixed effects are used to control for the average level of numeracy in the regions.

Source: Calculated based on UNICEF, *MICS*.

It should be noted that all the correlations reported thus far speak against the assumption that recording personnel or heads of households simply estimated ages for household members and others. This might have happened sometimes, but not for substantial shares.<sup>30</sup>

### III | COUNTERCHECKING, TRIANGULATION, AND STATE CAPACITY

A'Hearn et al. wonder about the degree to which state capacity causes age heaping. State capability is an underlying determinant of numeracy.<sup>31</sup> Clearly, counterchecking and triangulation techniques that were widely applied in the twentieth century reduced age heaping, and the age-heaping method was not designed for these cases. However, for the nineteenth century, Crayen and Baten have systematically studied the relationship in about 70 countries.<sup>32</sup> They found that when two widely used measures of state capacity, Bockstette et al.'s state antiquity index and the number of previous censuses, are included, as well as educational indicators, the latter are far more correlated with age heaping.<sup>33</sup> As a result, age heaping can be interpreted in most cases as a

<sup>30</sup> Qualitative evidence: Baten, Szoltysek, and Campestrini, "Girl power" in Eastern Europe?.

<sup>31</sup> Keyword and Baten, 'Elite violence'.

<sup>32</sup> Crayen and Baten, 'Global trends in numeracy'.

<sup>33</sup> Bockstette, Chanda, and Putterman, 'States and markets'.



proxy for educational differences for the nineteenth century and earlier (and for many developing countries even in the twentieth century).<sup>34</sup>

A'Hearn et al. cite Lee and Zhang, who hypothesize that age-heaping indices could serve as a proxy for 'legibility', the capacity of the state to obtain detailed information about their citizens.<sup>35</sup> However, in their regression results they actually find the opposite of their hypothesis. They find a very small  $R^2$  of 0.05 for their tax ratio indicator of state capability, whereas the age-heaping measure correlates strongly with literacy ( $R^2$  of 0.67).<sup>36</sup> In a footnote, they declared that 'lagging age-heaping by one year allows [us] to rule out the possibility of reverse causality'.<sup>37</sup> This sentence does not necessarily support the credibility of their statistical expertise. As a corollary of their article, Brambor et al. suggested a more sophisticated measure of legibility, very similar to that of Crayen and Baten, by using the number of previous censuses and similar administrative data collection efforts as a measure of 'legibility'.<sup>38</sup>

## IV | CONCLUSION

Since economic historians and social scientists generally aim to understand long-term development processes, they need indicators to monitor change. As any single indicator can be subject to biases or distortions in the data-generating process, it is quite helpful to have several indicators that can be compared. Statistical evidence indicates that age heaping is a reasonable indicator for numeracy. Although culture and state capacity specificities certainly need to be taken into account when employing age heaping, and counterexamples and outlying observations are to be expected, such biases do not invalidate the educational indicator function, if the empirical evidence is duly considered.

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<sup>34</sup> See Baten, 'Indirect survey estimates'.

<sup>35</sup> Lee and Zhang, 'Legibility'.

<sup>36</sup> Although the tax ratio is significant at the 10% level, the direction of causality might run from tax ratio and state capability to reduced age-heaping.

<sup>37</sup> Lee and Zhang, 'Legibility', p. 127.

<sup>38</sup> Brambor, Goenaga, Lindvall, and Teorell, 'Lay of the land'; Crayen and Baten, 'Global trends in numeracy'.



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