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## **Social and Intertemporal Differences of Basic Numeracy in Pannonia (1<sup>st</sup> Century BCE-3<sup>rd</sup> Century CE)**

*Please note: This is not the final version of this paper. A later version has been published in the Scandinavian Economic History Review.*

### **Abstract**

In this study, we assess the human capital of Roman legionaries, officers, and the civilian population born between the first century BCE and the third century CE in Pannonia (today's West Hungary). Age-heaping techniques allow the measurement of human capital for this early period, although we need to discuss intensively potential selectivity. We find that the Roman military benefitted strongly from occupational choice selectivity: those social groups who decided for a military career had better numeracy values than the remainder of the population. This applied especially to the first centuries BCE and CE. Over time, however, the civilian population converged to the military occupational groups.

**Keywords:** Human Capital, Ancient Roman, Military, Occupational choice, Numeracy

**JEL:** N33, J24,

### **Introduction**

How can human capital of Roman soldiers, officers, and civilians be measured? Obviously, no school enrollment rates are available for this early period of human history. However, a considerable number of studies have recently used a measure of basic numerical skills, which takes the share of people who report an exact age as an indicator. In historical populations (as well as in the poorest countries today) a substantial share of the people was not able to state their exact age and hence reported a rounded age, such as "I am 40", when they were in fact e.g. 39 or 41. In hundreds of samples and dozens of studies, it has been proven that there is a

significant correlation between the share of exact reported ages and other human capital indicators (see section 2 and Appendix A for longer methodological treatment). Duncan-Jones pioneered this approach for ancient history. He decided to put the main focus on the phenomenon in general, because it was not well known in the ancient history literature before.<sup>1</sup>

The main body of evidence consists here of age statements on Roman tombstones in the upper and lower Pannonian provinces (mainly today's West Hungary and smaller parts of Eastern Austria). Upper and Lower Pannonia were Roman frontier zone provinces<sup>2</sup> with a number of legions allocated to the province<sup>3</sup> and probably with an educational standard below the Roman Imperial average (Duncan-Jones 1990). Upper and lower Pannonia were probably more representative for the Empire than, for example, Rome itself, although the present stage of research does not allow us to judge representativeness for the Empire exactly. Mihailescu-Bîrliba, Piftor and Cozma compiled a substantial number of tombstones in order to study life expectancies and other demographic issues on the Roman provinces (Mihailescu-Bîrliba 2007)<sup>4</sup>. Close relatives and friends normally remarked the age of the deceased on these tombstones, as they were the donors of the tombstones. Sometimes the deceased himself or herself was able to inform relatives about the own age a few days or weeks before her or his death. It is a great advantage that we know about the donor, because we can test systematically whether different characteristics of donors make a substantial difference#. It can make a substantial difference, whether age is self-reported or whether

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<sup>1</sup> R. Duncan-Jones's now classical article on 'Age-Rounding, Illiteracy and Social Differentiation in the Roman Empire' (Duncan-Jones 1977) was the first detailed analysis (cf. idem, Duncan-Jones 1990, chapters 5 & 6). Before Duncan-Jones only W. Levison (1898), A. R. Burn (1952/53), A. Mócsy (1966), and M. Clauss (1973) pointed out the fact of age-rounding.

<sup>2</sup> On the Pannonian Provinces cf. Alföldy (2011), Wilkes (1999), Bechert (1999), Fitz (1993-95), Mócsy (1974), and Mócsy (1959).

<sup>3</sup> Under Traian (98-117 A.D.) there were 4 legiones garrisoned : *XIV Gemina* (Carnuntum), *X Gemina* (Vindobona), *I Adiutrix* (Brigetio) and *II Adiutrix* (Aquincum). The Marcomannic Wars under Marcus Aurelius (169-180 A.D.) caused severe strains.

<sup>4</sup> The lists compiled by J. Szilágyi (*Acta antiqua Academiae Scientiarum Hungaricae* [1961;1962; 1963; 1965; 1966; 1967]) date the inscriptions only in two great groups (1st – 2nd century and 3rd – 6th, or sometimes 7th century).

close relatives and friends reported the age of the deceased, especially if these came from different social strata. Fortunately, in most cases the assumption holds that friends and relatives come from similar social groups as the deceased.

Comparing social strata, we find that social groups who decided for a military career had better numeracy values than the remainder of the population. This applied especially to the last centuries BCE and the first one CE. Over time, however, the civilian population converged to the military occupational groups. The military lost some of its unusual attractiveness during the later periods of the Empire when fewer additional provinces were conquered and less prey was to be gained. The process can be interpreted as a catching up of the civilian population. The underlying forces of this process towards less military bias might have contributed to the decline of the Roman Empire.

### **Method: Age Heaping as an Indicator of Basic Numeracy**

We study numerical abilities in this article, which are an important component of overall human capital. In order to provide estimates of very basic components of numeracy, we will apply the age-heaping methodology.<sup>5</sup> Duncan-Jones has been the pioneer of its use in the study of ancient history, but recently a large wave of studies has developed on the last centuries before present, which we will briefly review in the following. The idea is that in less developed countries of the past, only a certain share of the population was able to report their own age exactly when census-takers, army recruitment officers, or prison officials asked for it. The remaining population reported a rounded age, for example, 40, when they were in fact 39 or 41. The typical result is an age distribution with spikes at ages ending in a five or a zero and an underrepresentation of other ages, which does not reflect the true age distribution. There was also some heaping on multiples of two, which was quite widespread among

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<sup>5</sup> For more detailed surveys on the age-heaping methodology see B. A'Hearn, J. Baten and D. Crayen (2009).

children and teenagers and to a lesser extent among young adults in their twenties. This shows that most individuals actually knew their age as teenagers, but only in well-educated societies were they able to remember or calculate their exact age again later in life.<sup>6</sup>

We will exclude those below age 18 and above 82 since a number of possible distortions affect those specific age groups, leading to age reporting behavior different from that of the adult group in between. Many young males and females married in their early twenties or mid to late teens, when they also had to register as voters, military conscripts, etc.<sup>7</sup> On such occasions, they were sometimes subject to minimum age requirements, a condition which gave rise to increased age awareness.<sup>8</sup> Moreover, individuals in this age group were physically growing, which makes it easier to determine their age with a relatively high accuracy. All of these factors tend to deflate age-heaping levels for children and young adults, compared with the age reporting of the same individuals at higher ages.

To give an example of rounding on multiples of five, the census of Mexico City 1790 reports 410 people aged 40, but only 42 aged 41.<sup>9</sup> This is a case of age-heaping. The same indication can be found in the Imperium Romanum, such as Scheidel demonstrated for Noricum (mainly today's Austria), i.e. the western neighbour of Pannonia, the province which we will study below (Scheidel 1991/92). Demographers see this age misreporting as a problem when calculating life expectancies and other population statistics. However, exactly this misreporting enables us to approximate numerical abilities of historical populations. The ratio between the preferred ages and the others can be calculated by using several indices, one

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<sup>6</sup> At higher ages, this heaping pattern is mostly negligible, but interestingly somewhat stronger among populations who are numerate enough not to round on multiples of five.

<sup>7</sup> While Saller (1987) and Shaw (1987) assumed late 20s for men and late teens for women as usual age of first marriage in the Roman Empire (while the members of the senatorial class married younger), Lelis et al. (2003) proposed recently an earlier marriage-age for both men and women. On both opinions cf. Scheidel (2007).

<sup>8</sup> For legal minimum age for marriage of girls (12 years) and boys (14 years) cf. Codex Iustinianus 5,4,24.

<sup>9</sup> The evidence on Mexico City 1790 comes from the Census of Revillagigedo 1790: Instituto Nacional de Estadística, Geografía e Informática (2003), see Manzel, Baten and Stolz (2012) for an analysis and data description.

of them being the Whipple index.<sup>10</sup> To calculate the Whipple index of age-heaping, the number of persons reporting a rounded age ending in 0 or 5 is divided by the total number of people, and this is subsequently multiplied by 500. Thus, the index measures the proportion of people who state an age ending in a five or zero, assuming that each terminal digit should appear with the same frequency in the “true” age distribution.<sup>11</sup>

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

In the longer working paper version, A’Hearn et al. also studied the Myers index, which has the advantage that all rounding patterns are reflected, and typical age distributions can be considered, as Scheidel (1996) did. However, the Myers index is unfortunately scale-dependent (i.e., higher numbers of cases yield a different age heaping estimate than smaller numbers). In simulation studies, the Whipple index clearly outperformed the Myers index. For an easier interpretation, A’Hearn, Baten, and Crayen suggested another index, which we call the ABCC index.<sup>12</sup> It is a simple linear transformation of the Whipple index and yields an estimate of the share of individuals who correctly report their age:

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

The share of persons able to report an exact age turns out to be highly correlated with other measures of human capital, like literacy and schooling, both across countries, individuals, and over time (Bachi 1951, Myers 1954, Mokyr 1983, A’Hearn et al. 2009). The possibly widest geographical sample studied so far has been created by Crayen and Baten,

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<sup>10</sup> A’Hearn, Baten and Crayen (2009) found that this index is the only one that fulfils the desired properties of scale independence (a linear response to the degree of heaping), and that it ranks samples with different degrees of heaping reliably.

<sup>11</sup> 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.

<sup>12</sup> The name results from the initials of the authors’ last names plus Greg Clark’s, who suggested this in a comment on their paper. Whipple indexes below 100 are normally caused by random variation of birth rates in the 20<sup>th</sup> century rich countries. They are not carrying important information, hence normally set to 100 in the ABCC index.

who were able to include 70 countries for which both age-heaping and schooling data (as well as other explanatory variables) were available (Crayen and Baten 2010). They found in a series of cross-sections between the 1880s and 1940s that primary schooling and age-heaping were closely correlated, with R-squares between 0.55 and 0.76 (including other control variables, see below). Again, the coefficients were shown to be relatively stable over time. This large sample also allowed for the examination of various other potential determinants of age-heaping. To assess whether the degree of bureaucracy, birth registration, and government interaction with citizens is likely to influence the knowledge of one's exact age, independent of personal education, Crayen and Baten used the number of censuses performed for each individual country up to the period under study as an explanatory variable for their age-heaping measure. Except for countries with a very long history of census taking, in all specifications this variable turned out to be insignificant, which would suggest that such an independent bureaucracy effect was rather weak. It should be clarified here that the independent bureaucracy effect is weak if census data is studied that does not underlie institutionally determined sample selectivity. If such sample selectivity is present, institutional effects play a role, of course. In other words, it appears to be the case that societies with a high number of censuses and an early introduction of birth registers had a high degree of age awareness. But those societies also introduced schooling early, and this was the variable that clearly had more explanatory power than the independent bureaucracy effect.

Crayen and Baten also tested whether the general standard of living had an influence on age-heaping tendencies (using height as well as GDP per capita as welfare indicators), and found a varying influence: in some decades, there was a statistically significant correlation, while in others there was none. Cultural determinants of age-heaping are a potential source to explain the exceptionally high numeracy in East Asia – compared to her low schooling

investment during the early 20<sup>th</sup> century. However, a recent study on China, Korea and East Asia argued that the background of this East Asian phenomenon is in fact that East Asian educational tradition emphasized the component “numeracy” more than literacy as other components. In fact, Hanushek and Woessmann (2012) identified much higher numerical abilities among East Asians (relative to schooling inputs) even for the 1960s-2000. They identified this numeracy component as the most relevant: it explains much more of economic growth than schooling enrolment rates.<sup>13</sup>

Of course, we cannot a-priori exclude the possibility that in Pannonia a different cultural attitude towards numbers existed. Too little is known about education and culture during Roman antiquity. The evidence about regional correlations presented in the selectivity section suggests that for this period numeracy and literacy (and orthographical knowledge) tended to be related, not strongly “distorted” by cultural preferences for, as against, numbers. However, we would not exclude alternative interpretations of age-heaping for the period of the Roman Empire at this point, because more evidence is needed to determine the degree to which age-heaping represents human capital rather than other factors, such as cultural or institutional ones. In addition, when we speak of “human capital”, we do not only have in mind the human capital of individuals. If an individual lives in a group that is innumerate, she might also report a rounded age even if her individual numeracy would allow her to state an exact one. Our interpretation is rather related to groups (“the citizens”, “the soldiers”), even if our econometric model is based on individual units, but this we do to be able to control for multiple characteristics.

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<sup>13</sup> Baten, Ma, Morgan and Wang assessed the cultural factor of dragon year heaping among the Chinese, but found that it did not play a large role (Baten et al. 2010).



## Data set

The Roman Empire was a world of inscriptions. Ramsay MacMullen (1982) coined the phrase epigraphic habit for this fact. The breakthrough of stone as popular medium for inscriptions in the imperial period led to the availability of about 300.000 items for modern research – and every year digs unearth many more. Of these approximately two-thirds to three-quarters are grave inscriptions. The main body of evidence consists of age statements on Roman tombstones, on which normally close relatives or comrades of the deceased remarked his or her age.<sup>14</sup> Other information items on tombstones are the name, sometimes occupation, social status, whether the donor was the wife or somebody else, and the military rank, if the deceased served in the army.

The data set based on the compilation of Mihailescu-Bîrliba et al. (2007) yielded 1,239 observations.<sup>15</sup> We excluded children and teenagers younger than 18, because their age is normally stated by parents, or it is rounded on multiples of two rather than five. We also excluded very old persons (above 83), because those stating “I am 100 years old” tended to exaggerate and brag with their age. After excluding those and the cases for which not even an approximate year of burial could be estimated, we could use 928 cases in the analysis (Table 2).

The decision to set the maximum age at 82, rather than 72 as in most studies, needs to be discussed<sup>16</sup>. The advantage is that the sample is slightly larger. The potential disadvantage is survivor bias. To assess this possibility we performed a robustness test: do the results change if the maximum is chosen at 72? Fortunately, the differences are very small (see Appendix C).

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<sup>14</sup> Sometimes the deceased him- or herself was able to inform relatives about the own age, before dying. One might wonder whether death in the battlefield might influence the age statement. Scheidel (2011, 428) states: “All we can say is that on average an in long term, battle mortality was by no means negligible”. However, given the fact that tombstone evidence often relies on the age statements done by relatives and friends, this should not bias our results.

<sup>15</sup> The revision of all inscriptions revealed several distorting read errors and new datings.

<sup>16</sup> Duncan-Jones (1990) has chosen 62 for the upper limit.

In Pannonia, roughly three quarters of age statements were rounded on multiples of five (Table 2)<sup>17</sup>. This is a quite substantial heaping, even by Roman standards. Duncan-Jones reports age-heaping by province and finds that the two Pannonian provinces were among those, which had quite high age heaping.<sup>18</sup> However, a part of this fact might be explained by the timing: In Pannonia, a number of tombstones of already the first century CE were included, whereas North Africa and also Pompeji before the volcano catastrophe had almost no tombstones with age statements during the early centuries. When their age statements started, the population had already acquired better basic numeracy.

The social composition of the sample consists of one third of civilian citizens, one quarter of civilian non-citizens and one quarter of soldiers (which of course could be citizens or foreigners, too). The remaining sixth consists of officers (including non-commissioned officers), slaves and liberated slaves, and occupations, which were otherwise skill-intensive (scribes<sup>19</sup> etc.) or of higher social status (such as members of city councils). A large part of the “citizens” were probably colonizing persons born in other provinces (especially in Italy), at least until the Caracalla edict of 212 which expanded citizenship to almost all male persons of the Empire.<sup>20</sup> In contrast, the “non-citizens” were mostly persons who were descendants of the pre-imperial local population of this region. The majority of military personnel probably immigrated during the first century of the province and was supplemented with auxiliary troops of the region later on. The service in auxiliary troops was rewarded at the end with the Roman citizenship. It is a quite typical situation in the Roman provinces that we find a composite population of soldiers and civilians (many of them having immigrated from

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<sup>17</sup> The inversely formulated variable ‘numerate’ understates numeracy by 20%, because also every fifth of those stating a rounded age had really a rounded age.

<sup>18</sup> Duncan-Jones (1990)

<sup>19</sup> However, there is the ‘famous’ Petaus, the scribe who could not write, see Hanson (1991), 171–175. Single exceptions are not biasing larger samples, of course.

<sup>20</sup> Crook (1967); Sherwin-White (<sup>2</sup>1973); Because the new citizens needed a Roman family name (*nomen gentile*), the family name of Caracalla, Aurelius, became the most widespread in the Imperium Romanum and thereby an important evidence for dating inscription at least with a terminus post quem.

neighboring or other provinces) mixed with descendants of the autochthonic local population.<sup>21</sup>

The temporal distribution of our data set consists of 8.5 percent of our individuals being born before the year 0 CE, substantial shares (46.6 and 35.6 percent) in the first and second century CE, and the remaining 9 percent in the third century. As the statements about birth period are sometimes quite imprecise, the identification of different centuries are often only rough approximations.

In order to assess regional composition, we separated out the four largest places, which account for roughly 40 percent of the total population, including Carnuntum, which was the capital of Pannonia (Figure 1). Roughly one third of the observations relates to the eastern part of Pannonia inferior, the rest to the Western part.

We also included dummy variables for the age groups of 18-22 and 23-32, because those age groups tend to round less on multiples of five, and rather round more on multiples of two. 13 and 25 percent fell into this category. 33 percent of the deceased were female, as well as 17 percent of the donors.

In our evaluation of gravestones, we should pay attention to the donors and their possible influence on the age statement. As the age of the deceased is not self-reported, it is interesting to consider who might have reported it: was it the husband or wife? Or perhaps military comrades in the case of soldiers and officers? Among the military, we would have a priori imagined that military comrades were most active among donating tombstones and hence in many cases reporting the age of the deceased. Actually, in the majority of cases this was not true. Richard Saller and Brent Shaw detected that military gravestones (with and without age statement) in certain regions, amongst others Pannonia, are erected predominantly by members of the nuclear family (73 % in Pannonia) – despite an official marriage ban for

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<sup>21</sup> Cf. Móscy (1959); Barkóczy (1964). On the methodical problems in the work of Móscy cf. Swoboda (1962).

Roman soldiers in the first two centuries CE! (Saller – Shaw 1984). Within the nuclear family, it is quite likely that before the death of the person who would be dying soon, the age would be mentioned.

For the remaining part of the military, there might be a bias from the fact that the comrades might know the enlistment age, and hence could calculate the age. If they were able to perform this numerical procedure, however, we would conclude that the numeracy in this social group was quite remarkable.

### **Selectivity Issues**

Before we move to the results, we want to assess carefully selectivity issues. One big potential caveat of comparing different social groups with the tombstone evidence is clearly, who could afford tombstones? Which selectivities can perhaps bias the results? Three potential selectivities of this category could occur as follows: First, one could imagine that only rich soldiers could afford tombstones, i.e. that there would be positive bias especially among soldiers. Second, our sample in general might be unrepresentative for the Pannonian population. And third, it could be that tombstone data is always positively biased. We approach this question using various strategies: We first compare the military share of tombstones with the overall population. We then compare tombstone evidence with numeracy data from other sources. Does this imply that tombstones were a highly selective source? Finally, we compare regional estimates of education based on Latin inscription spelling mistakes and inscription density with tombstone-based numeracy estimates.

First, one could imagine that only rich soldiers could afford tombstones. As we focus on the social composition mainly, an obvious question is who was able to finance a tombstone at all. Setting a gravestone was not an unaffordable luxury, especially for members

of the Roman army.<sup>22</sup> Sometime the gravestone's cost is stated in the inscription, which could be sometimes less than 100 sesterces. Duncan-Jones (1982, 79s, cf. 127–131) has shown that more common costs between 1000 and 2000 sesterces represent a manageable part of several year's salary, because the necessary expenses for food and other items allowed substantial savings. The annual salary of a soldier was 900, since the end of the first century 1200 sesterces – and he often (especially during the later principate) received substantial special payments. It was relatively easy to save enough money for a tombstone.<sup>23</sup> Furthermore, funerary colleges were founded as a kind of insurance for the cost of burial.<sup>24</sup>

Second, our sample in general might be unrepresentative for the Pannonian population. Obviously the military – with a share of 23% soldiers and 8% officers – was overrepresented in our sample; but how much? The question about the size of the empire's military and total population is difficult to answer. Beloch (1886) estimated a total population of 54 million<sup>25</sup>, in a later essay<sup>26</sup> between 70 and 80 million in CE 14, which increased – in his opinion – to 100 million at the beginning of the third century.<sup>27</sup> Even modern researchers assume that the population size was between 60 and 70 million ('low count') and 100 million ('high count') (Scheidel 2009). During the first three centuries CE between 25 and 33 legions (Roman citizens), each composed of about 5000 men, were active in the Roman Empire. Taking legions, auxiliary troops, special units in Rome and the fleet together, we arrive between 300 and 400 thousand military persons.<sup>28</sup> Scheidel (1995; 2011) proposes to reckon

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<sup>22</sup> Hope (2000), 161.

<sup>23</sup> On soldiers' wills cf. Champlin (1991), 56-58.

<sup>24</sup> Vegetius, *Epitoma rei militaris* II, 20, 6: "An eleventh sack was also added, into which the whole legion made a small contribution for burial expenses. If any of the soldiers died, the cost of his burial might thus be defrayed from this eleventh sack / Addebatur etiam saccus undecimus, in quem tota legio perticulum aliquam conferebat, sepulturae scilicet causa, ut, si quis ex contubernibus defecisset, de illo undecimo sacco ad sepulturam ipsius promeretur expensa." Cf. van Nijf (1997), 31–69; Oliver (2000), 10; Lindsay (2001).

<sup>25</sup> Beloch (1886) 507.

<sup>26</sup> Beloch (1899) 618.

<sup>27</sup> Beloch (1899) 620.

<sup>28</sup> Some scholars (e.g. Le Bohec (1993) 36s.) suppose an equilibrium between legions and auxiliaries, some (e.g. Birley) that the auxiliaries overbalanced the legions (c. 220.000 compared to c. 140-168.000 (c. 150 BCE) and c. 150-180.000 (from 160 BCE) respectively (data based on required strength)).

on 120 discharges (veterans) per legion and year and an annual intake of 250-260 recruits per legion. Altogether legions, auxiliary troops, special units, the fleet (300 to 400 000) required a total of about 15.000 recruits every year and dismissed about 7.500 veterans. Adding these persons who had left the military after their service, but would still like to see their military service mentioned on the tombstone, might perhaps increase the figure by one-third, i.e. to 400 – 530,000. Relative to circa 40 million males of adult age<sup>29</sup> this would be around 1-2 percent military share if the retired soldiers are included (with substantial regional deviation because of the recruitment's procedure, see Scheidel 2011). But when we consider the Danubian provinces at the end of the second century the military's proportion of the population increase considerably: The 12 legions and the auxiliaries (one third of the Roman forces) stationed in the Danubian provinces comprised c. 150.000 men.<sup>30</sup> Including retired soldiers (i.e. 200.000 military persons) relative to c.1.5 million adults<sup>31</sup> the military share would be around 13 percent. Hence, the soldiers were significantly overrepresented in the tombstone evidence, as they amount to 23 percent (Table 2), not to speak of the officers. However, this does not automatically imply that we have a highly selective group, at least not a positively selected one. We could rather expect that the soldiers were slightly less positively selected than the civilian majority of our sample, because for them the funeral colleges often paid the tombstones.

Third, it could be that tombstone data is always positively biased. Of course, a potential bias always exists if the person whose education we measure could underlie a

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<sup>29</sup> During the Roman republic men had to do military service aged 17 to 46. We considered modern populations with low life expectancies (similar to life expectancies in Roman antiquity) and their life tables and arrived at an estimate of one half of the population being in adult age (i.e. older than 20). We omit children and teenagers from the denominator.

<sup>30</sup> Wilkes (2001) 275.

<sup>31</sup> Beloch reckoned the population of the Danubian provinces in BCE 14 c. 2 million (Beloch (1886) 460-465; 507) or at the most c. 3 million (Beloch (1899) 617). If we gather that the population increased as Beloch assumed (from 54 (1886) or 80 (1899) million in BCE 14 to 100 million in around BCE 200 in toto), the Danubian provinces maybe reached c. 3,7 million in around BCE 200. There are no numbers for the single provinces. Alföldy (1965) 24, reckoned the population of Dalmatia c. 600-700.000 at the beginning of the first century BCE. Because there were no legions in Dalmatia in the second century, we may subtract the at least 700.000 Dalmatians from c. 3,7 million.

selective process. For example, if literacy is measured – for 17<sup>th</sup> century England, for example – by analyzing the share of signatures in marriage contracts, and there was only a share of people who was in the position to marry. One strategy to assess the importance of this selectivity is to compare tombstone-based numeracy estimates to various sources of different institutions. If the tombstone data would be highly selective, we could expect a seemingly higher numeracy of this evidence, compared to other evidence.

Scheidel recently studied a number of different sources on age-heaping in Roman Egypt.<sup>32</sup> His special focus was on the widely differing degrees of age-heaping in census and tax lists on the one side, and tombstones and other evidence on the other side. His article serves as a critical re-assessment of the Duncan-Jones methodology on this issue. Scheidel makes a very important point, namely that the institutional context of age statements has to be carefully taken into account. We used his information that he reports on potential counter-checking in census and tax lists, and compare these sources with tombstone and other data. Our result is that tombstone is only modestly upwardly biased. This result we would have expected, given the higher numeracy of military persons and the over-representation of military persons in tombstone evidence (see Appendix B).

Scheidel considers in his study also other sources for which no counter-checking seems likely or possible. Those sources include contracts, mummy labels, tombstones, and lists of local officials for liturgical purposes. The contract papyri also contained age statements, namely those of both contract partners and a number of witnesses. For Egypt, this source yields a relatively large number of cases: The papyri on 275 age statements could be mobilized, all coming from the city of Tebtunis, and yielding a numeracy estimate of 62 percent.

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<sup>32</sup> Scheidel (1996).

In addition to this source, Scheidel also employs samples of mummy labels both for males (N=188) and females (N=91, total N=279), which were tagged on top of the mummified corpses. The numeracy estimate is quite similar to the contract source, with 65 and 68 percent basic numeracy, respectively. Those numeracy estimates are slightly below estimates for tombstone-based numeracy, which amounts to 70 and 73 percent ABCC for males and females respectively (total N=281).<sup>33</sup> Compared to numeracy estimates of 62-68 percent of the non-tombstone sources -- for which also counter-checking is not documented -- this suggests a modest upward bias of around 6-7 percent for tombstones. Of course, we cannot be sure of this number, as regional and social biases can work in both directions. But it seems reconfirming that several sources are roughly in the same range of the numeracy distribution.<sup>34</sup>

In sum, Scheidel's exercise in source criticism is very important, as it shows that different institutional contexts may generate different degrees of counter-checking and selectivity. This is most obvious in the case of the census and tax lists: if the result was particularly important for the ruling bureaucracy and if the officials had the possibility to counter-check ages, they sometimes did so and the resulting source is useless for age-heaping based numeracy estimation. This was not only done in Roman Egypt, but we have similar examples from Korea (Baten and Sohn 2013), and Russia (Baten and Szoltysek 2012), in which previous censuses were used for counter-checking, and the resulting data could not be used for age-heaping analysis. Unfortunately, this detailed comparison of different types of sources is only possible for the Egyptian province with its abundance of papyrus sources,

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<sup>33</sup> The tombstone evidence comes from four different places in different regions of Egypt.

<sup>34</sup> A final source used by Scheidel might display a strong downward bias, as the ABCC value was only 50 percent: this source was taken from liturgical lists compiled by village officials about other local public officials such as "village elders, guards, policemen, night-watchmen and overseers of irrigation".- This source is by far the smallest (N=115), and Scheidel discusses that for this kind of liturgical source, officials often paid very little attention to the age information (lists of this type survived which did not contain any age statement). It might have even been the case that the recording official did not even ask the people described for their age, but just estimated their age crudely himself. However, given the very small sample size of this source, also random variation might have been the reason of the seemingly strong age heaping.



whereas for Pannonia we have to rely on tombstones, which might be slightly upwardly biased in levels. The results based on Scheidel's data for Egypt are very important for our study, because the low amount of selectivity of tombstone-based numeracy estimates suggest that our results are very likely not severely affected by this issue, at least if we can assume that selectivities worked in a similar way in Egypt and Pannonia.

Harper recently presented additional evidence for a small sample of slaves in Greece (Thera), and their numeracy can be estimated as being 42 percent for those aged 30 and higher (Harper 2008). The numeracy value of Pannonian slaves would be 29 percent for all ages (see Table 4; on the number of underlying cases see Table 5)<sup>35</sup>. Although the two samples cannot directly be compared, the similarity of magnitude of slave numeracy might tentatively support the notion that tombstone-based numeracy cannot be widely off the mark.

A second method to assess the validity and representativeness of tombstone-based numeracy is to compare it with other proxies for education. If tombstone evidence was highly selective in some places, we would not expect a substantial interregional correlation with these other indicators.

In fact, the regional differences of age-heaping are similar to the regional differences in illiteracy. Churchin (1995) could validate this correlation for Central Spain<sup>36</sup> during Roman antiquity. He considered six chiefdoms in the Spanish interior (Arevaci, Carpetani, Celtiberi, Pelendones, Turmogi, Vaccaeii). He argued that he should not include more coastal and urban regions, as those might be characterized by higher literacy. In contrast, his landlocked, interior regions would be relatively homogenous. Frequent spelling errors<sup>37</sup> were, for

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<sup>35</sup> In the Pannonian case restricting the slave sample to age 30 and higher is not possible due to a small number of cases.

<sup>36</sup> There are no analyses in detail on spelling errors in inscriptions in Pannonia (cf. e.g. Herman (1961) and (1990); Mihăescu (1978); a list with errors in inscriptions in Lőrincz, Marton, Redö (1991), 103–121). Mócsy (1962) 767 and (1974) 259–263, is too pessimistic on the Latinity in Pannonia (cf. on school education Bilkei (1983)).

<sup>37</sup> On the problem to distinguish between spelling errors and regional or local characteristics of linguistic and grammar cf. e.g. Adamik (2005).

example, using “e” instead of “ae” (for example, in haeredes) or omitting “c” as in “Quin(c)tio”. He admits that he partly measured the literacy of the stonecutter, and only partly the one of the donor – obviously, the donors did not detect the spelling errors, otherwise they had not accepted the gravestone.<sup>38</sup> Curchin considered the age heaping of both females and males, and the spelling errors of both urban and rural people. Age heaping is highest among the Pelendones with a value of 89.6. Spelling errors are also most frequent for this chiefdom, with around 34 and 35 for urban and rural locations, respectively. The lowest age heaping (66 for males) and spelling error rate (around 24 and 21 for urban and rural) was found for the Carpetani. The urban and rural Arevaci, rural Celtiberi, urban and rural Turmogi, urban and rural Vaccaei were lying in between, very close to an imagined regression line. Only the urban Celtiberi were deviating slightly.

We calculated correlations coefficients based on Curchin’s evidence. No matter which classification we use, the correlation between age heaping and spelling errors is always quite substantial, even if the samples are small. The correlation between spelling errors of urban and rural places of chiefdoms and age heaping by chiefdom is 0.54 ( $p=0.068$ ). If the urban Celtiberi are removed as an outlier, the correlation coefficient increases to 0.66 ( $p=0.028$ ). This is also justified by the fact that the Celtiberi were the least documented for age heaping, with the smallest N). The corresponding correlation between spelling errors of chiefdoms and age heaping of both males and females is 0.60 ( $p=0.086$ ), even if the samples are also here very small due to the small number of chiefdom units studied (and the underlying number of age statements is also not large,  $N=232$ ). Even if this evidence on spelling errors is limited in several dimensions, it is one important piece of evidence that confirms the hypothesis that age heaping measures human capital between regions of the Roman Empire. It also supports

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<sup>38</sup> Kubitschek (1926) 95s.

the view that selectivity of tombstone sources cannot have been very crucial, because otherwise the correlation might have disappeared for this reason.

András Mócsy (1970) studied whether the simple number of inscriptions found in a given territory correlates negatively with the percentage of spelling irregularities. He studied the province of Moesia superior. The number of inscriptions ranged from a minimum of 10 (in Horreum Margi) to a maximum of 165 (in Viminacium). The highest share of spelling mistakes (30%) was found in the former, the lowest error rate in the latter (11%). We computed the correlation coefficient between these two variables, and found it to be as high as 0.95 ( $p=0.000$ ), again with a quite small sample unfortunately ( $N=9$ ). The evidence might suggest that both the share of orthographic mistakes as well as the total number of inscriptions might serve as a rough literacy indicator (in the Latin language). Harris (1989) considered the relationship between the number of inscriptions per area in various Roman provinces and the age-heaping levels. Again, there is a correlation between the two: The province Africa Proconsularis was intensively covered with inscriptions, and had the lowest level of age heaping. Numidia and Dalmatia follow in both indicators. On the other side of the spectrum, Noricum had the lowest density of inscriptions and the highest age-heaping (i.e. the lowest numeracy). The results of Mócsy, Curchin and Harris, even if all plagued with small numbers of cases, indicate that tombstone-based numeracy in a particular places cannot be heavily distorted by very strong selectivity bias. This is remarkable that in all these different places lived different shares of military and migrant persons. In addition, it can be concluded that the method of age-heaping is a useful and innovative tool for assessing human capital in the ancient world.

In Scheidel's careful comparison of different sources for Roman Egypt, the result in the discussion above was a modest bias of some 6-7 percent higher numeracy for tombstone donors, compared to other sources (which might also already contain an upward bias).

Were selectivities comparable in Egypt and Pannonia? We cannot be sure, that cultural traditions in Egypt were similar to Pannonia, which had different levels of numeracy and also different funeral traditions. We need to make a strong cautious remark. We still think that the comparison is useful. Only from Egyptian evidence we can obtain non-tombstone numeracy available for the ancient world, apart from the Greek slave lists.<sup>39</sup> Unfortunately, bureaucratic documents to compare with tombstone evidence are only available for Egypt and Greece, but it seems likely that the basic result can be generalized: using tombstone evidence, we have a slightly higher share of middle- and upper-class people than in regular sources. Especially tombstones of civilians might be slightly positively selective, because they could afford such a monument, but this even reinforces our argument.<sup>40</sup>

### **Results: military bias?**

We ran linear probability model and logit regressions (Table 3). The dependent variable is 1 if the age statement does not end with 5 or 0, and 0 otherwise. In column 1, all available cases are included. In the second column, we included the variable “female donor” as a robustness check. In a third regression model, we restricted the sample to ages 23 – 82. In column 4, we report a logit regression.

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<sup>39</sup> We performed additional research with modern data at high and low levels of numeracy that comes from different institutional backgrounds such as marriage registers and local population registers for modern Hungary and Italy. We find that marriage registers of the same age group indicated slightly higher numeracy but differences between a high and a low numeracy region were broadly comparable.

<sup>40</sup> This fact also explains why tombstones cannot to provide sufficient data to estimate average life expectancy. Other arguments are e.g. gaps in the material (urban bias), the underrepresentation of children (age bias), bias in commemorative practice, implausible discrepancies in different regions cf. Burn (1952/53) ; Hopkins (1966; 1987) ; Salmon (1987); Parkin (1992); Scheidel (2001); Revell (2005). Hope (2007) examines inter alia soldiers’ tombstones from Carnuntum and interprets the age statements as a mode of definition of a soldier’s identity within the army, with which she wants to explain change from first to second and third century BCE.

More positively concerning tombstone records Storey and Paine (1999), who analysed only inscriptions with age at death completely expressed in years, months, and days.

Frier (1982, 2000) selected a suitable tombstone data set (another weak point is the comparison with modern life tables) to ‘prove’ the validity of Ulpian’s life table.

In both the logit and the linear probability regressions, we find a substantial military bias. The constant represents the social group of “non-citizens” – people without Roman citizenship, mostly of indigenous origin from Pannonia or neighboring regions (Column 1 and 2). Relative to this constant, the soldiers had a numeracy advantage of 20 percent in the first, most comprehensive regression. We assessed the group of officers (e.g. *centurio*) including ‘non-commissioned officers’ (*principales*)<sup>41</sup>. Officers had even an advantage of 34 percent over the non-citizens (foreigners). This is higher than the advantage of citizens. Only the local elites had an even higher ABCC value than the soldiers and officers.<sup>42</sup> Slaves or liberated former slaves had also a significant advantage over the reference category. The other regression models demonstrate that this result is quite robust.<sup>43</sup>

Differences in the centuries of birth were modestly negative relative to the reference category, which is the third century CE. But statistically significant is only the first century CE. The insignificance of the last century BCE might be a result of the small number of cases. Individuals born in the territory before Pannonia became part of a Roman province in 9/10 CE were less numerate than the later-born (although only partly significant).

We singled out the four best-documented towns of the sample, notably Aquincum (today’s Budapest), Brigetio (Komárom-Szöny), Carnuntum (Petronell), and Intercisa. Intercisa was a relatively unimportant settlement, but also having lived in Aquincum did not have a positive effect, but rather a negative one. Only in the cases of Brigetio and Carnuntum (the largest settlement of the province) there was clearly an urban numeracy advantage (or

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<sup>41</sup> Breeze (1974) estimates a number of about 1100 special post below the centurionate, i.e. over one-fifth of a legion. On the *principales* cf. Breeze (1971, 1974, <sup>2</sup>1974), Clauss (1973), Rankov (1986; 1999), and Stoll (1997).

<sup>42</sup> Including priests. Beard (1990) emphasized rightly that the Roman paganism was not ‘text free’ (in contrast to the Christianity, a ‘religion of the book’ [‘Buchreligion’]). Nevertheless not every priest was literate, for examples cf. Hanson (1991), 160, footnote 5.

<sup>43</sup> The size of the Logit coefficients are not directly comparable, because Logit does not include a constant.

selective migration into the larger towns). The eastern part (Pannonia inferior) was more numerate than the West.<sup>44</sup>

Finally, we assessed the gender of the donor. As most historical societies discriminated female children in access to education, one might have expected a negative and significant coefficient for this variable, but this was not the case. In other regressions, we also used gender variables for the buried person, and again there was no significant effect (not shown, available from authors).

The adjusted R-square of around 10 percent is not extremely large, but it is also not negligible for a regression that takes individuals as observation units (and between individuals, there is always a substantial amount of random variation).

In sum, for our core question about the “military bias” we find that soldiers had a strong advantage over the indigenous population – and we are speaking here about indigenous population that was rich enough to finance a tombstone. Officers had an even stronger numeracy advantage; hence this social group was probably very positively selected.

### **Trend estimation and social differences over time**

The dating of tombstones in the study of Mihailescu-Bîrliba et al. is relatively exact<sup>45</sup> and allows comparing centuries, although we should acknowledge a lot of measurement error in identifying the centuries of birth. The average numeracy values document a strong increase between the first century CE and the third one CE (Figure 2). We also assessed the robustness by comparing only those cases in which the donors came from the same generation as the deceased, and found the pattern confirmed. Secondly, we also assessed whether the same upward trend can be observed if we organize the time dimension by the century of death, and

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<sup>44</sup> We also included dummy variables for the younger age groups of those aged 18-22 and 23-32, because earlier studies found that teenagers and those in their 20s round often on multiples of two rather than multiples of five, which is confirmed here. These variables are included here as control variables, not as variables which are meant to indicate important numeracy differences.

<sup>45</sup> Aside from several corrections in detail.

again observe the upward trend: The tombstones that we dated to be erected in the first century CE displayed a numeracy of 18, the second century 20, and the third century 37.

Does this pattern correspond with other evidence on ancient Roman development? Jongman (2007) has marshalled a lot of evidence to document that there was a strong boom on most production activities during the Roman Imperial period: Metal production boomed (visible as pollution in Arctic ice kernels), and agriculture and animal-farming was strongly expanded – although it is not always easy to normalize by population size, and taphonomic biases (the probability of an ancient item to show up in archaeological reports) have to be taken into account. Koepke (2008) also demonstrated that the last century BCE was a low point of human development, as extremely poor anthropometric values point to a severe crisis period. The terrible civil wars and unrest of this century as well as the difficult climatic conditions might have had an impact both on the low anthropometric as well as the low numeracy values. Even if Rome expanded strongly during the century, this Empire-building phase does not necessarily imply higher standards of living and education for the Roman population. Given that the civil wars and famines meant uncertainty about the future, investments in one's children's education must have been very limited. In contrast to this century of catastrophes, even the modest height of the first to third century CE appears as a recovery period.<sup>46</sup>

However, it might seem astonishing that the second century displayed higher numeracy values than the first century CE, because the former saw a number of barbarian invasions and a plague epidemic. Nevertheless, in a frontier province like Pannonia, the first century CE might still have had low numeracy values, because the gradual transformation from the previous tribal organization to a relatively literate Roman culture might have not immediately led to high numeracy values. In contrast, in other provinces such as Egypt,

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<sup>46</sup> N. Koepke and J. Baten (2005; 2008)

which were characterized by a quite literate culture already before Roman times, we observe much higher numeracy values.

Do we also observe a change of social differences of numeracy between the early and the late period in our sample? The number of cases per social group do not allow a resolution of single centuries; hence we distinguish two periods (Table 4): The last century BCE and first one CE as the “early period”, and the second and third century – the “late period”. At least the soldier, citizen and non-citizen group is sufficiently documented, and we might dare some tentative conclusions about the officers during the latter period. A main result is the very low numeracy of citizens and non-citizens in the first centuries: only 7 and 18 percent, whereas the soldiers had a strong advantage with 32 percent numeracy during this period. In contrast, the differences were much smaller during the last two centuries: citizens, officers and soldiers are now on a relatively similar level, only the “non-citizens”, the descendants of the indigenous population, are still lagging behind. Among the soldiers, there has not been much progress in numeracy, whereas the citizens and non-citizens have made substantial progress. In other words, the positive selectivity into the military in this Roman province has declined.

Now, some part of this effect might be caused by immigration of officers and soldiers into Pannonia, who might have grown up in the Italian heartland or other, more educated provinces. In contrast, the indigenous “non-citizens” might have always been slightly less educated. But it is notable that the selectivity effect into the military is also pronounced when we compare soldiers and officers with the citizens, who have also mostly immigrated into Pannonia during the first centuries of the province. The decline of military bias over the centuries is most visible in the comparison of citizens and military personnel.

In addition, we have performed a separate analysis on the composition of legions (Appendix D). The result is that most military immigration took place before 100 CE. Hence,



we excluded in a robustness test of table 4 all those recruited before 100 CE, and the results are that soldiers still had higher numeracy. Hence, while it might explain a certain amount of the advantage of soldiers as we admit explicitly now in the text, it does not invalidate the story.

Moreover, on the general existence of a military selectivity bias in the Roman economy, it might be mentioned that Duncan-Jones (1990) finds that also soldiers in Rome were more numerate than civilian citizens. This confirms our argument of a ‘military bias’ in the empire. A migration effect did most likely not distort this result for the capital of the Roman Empire.

### **Discussion: is a slightly higher level of education of soldiers plausible?**

Is it plausible that the Roman Army attracted the brightest minds into its ranks? The extremely high recognition of military success in the ancient Roman Society could have provided motivation for this. Soldiers and officers could obtain slaves and other prey as well as during the Roman Empire *stipendium* (pay)<sup>47</sup>, *donativum* (gift of money, e.g. on the occasion of the accession of a new emperor)<sup>48</sup>, and *praemium* (gratification at demobilisation; the non-citizen members of the *auxilia* were rewarded with Roman citizenship).<sup>49</sup> Military success was also a precondition for power in civil and political life, and prestige in the social environment. It would be plausible if the military would have been able to attract the best-educated persons.

The so-called third century crisis existed, over 60 emperors and usurpers (“Soldatenkaiser”) speak for itself. However, there is a broad discussion about the impacts of

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<sup>47</sup> In the first two centuries a not generous, but fixed pay, in addition, a safe food supply even in times of shortage and a comparatively good health care made the army an attractive employer. On the development of the military pay see below.

<sup>48</sup> The examples in the sources are incomplete and inexact. For an overview cf. Kainz (2009), 63–65; Campbell (1984), 165–171; 186–198.

<sup>49</sup> Cf. in general Speidel (2000); Campbell (2002), 32; 34.

this crisis<sup>50</sup>, because the sources are hard to interpret. Hekster gets to the heart of it: “In short, it is extremely difficult to make statements about the economic situation in the Roman Empire as a whole.”<sup>51</sup> There are hints of a demographic decline, possibly worsened by the Antonine plague (a kind of smallpox?).<sup>52</sup> If we assume a decrease in population of 10% of the entire population (probably 20% in cities and in the army),<sup>53</sup> the Roman army didn’t have the choice among the recruits as before – even if the decrease in population did not cause a shortage in population, but only reduced a overspill, which arose during the 150 years after Augustus. One fact could be a prove for this ‘fight’ for the best mind – an inconsistent prove prima facie: At the end of the second and the beginning of the third century the military pay was increased extremely three times.<sup>54</sup> In CE 197, the pay was increased by 50%<sup>55</sup> or even doubled, but this was the first increase for over 110 years. In CE 212 Caracalla increased the pay by 50%, in CE 235 Maximinus doubled the pay again.<sup>56</sup> Prima facie, this sharp increase (in CE 235 a soldier got three times the amount of the pay in CE 197) should attract many men to join the army.<sup>57</sup> But we can turn over the argument: The emperors had to increase the pay dramatically to attract recruits ever.<sup>58</sup> The expenses for the army could be financed only by the reduction of the precious metal’s content and the weight reduction respectively of the silver coins<sup>59</sup>, a flirtation with the people’s trust in solidity of money. Although the worsening of the coins did not lead to a distinctive general inflation until the seventies of the third

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<sup>50</sup> Cf. Ruffing (2008).

<sup>51</sup> Hekster (2008) 34.

<sup>52</sup> Hekster (2008) 33s.

<sup>53</sup> Ruffing (2008) 827.

<sup>54</sup> The aim to tie the soldiers close to the paying emperor may not be underestimated.

<sup>55</sup> Alston (1994).

<sup>56</sup> Speidel (2000).

<sup>57</sup> De Blois (2002) 98s.; Speidel (2000), 92s.

<sup>58</sup> De Blois (2002). In addition some scholars (e.g. Phang (2001)) advocated (with reference to Herodian III, 8, 5) the end of the marriage ban under Septimius Severus; which could be interpreted as a concession to the soldiers, but Eck (2011) proved, that there was only still the toleration of living together between soldiers and women.

<sup>59</sup> Langenegger (2010); De Blois (2002), 96; 103.

century<sup>60</sup>, the financial attractiveness of the army obviously diminish.<sup>61</sup> The edict of Diocletian on maximum prices CE 301 complains:

“[...] and finally that sometimes in a single purchase a soldier is deprived of his bonus and salary, and that the contribution of the whole world to support the armies falls to the abominable profits of thieves, so that our soldiers seem with their own hands to offer the hopes of their service and the completed labors to the profiteers, with the result that the pillagers of the nation constantly seize more than they know how to hold.”<sup>62</sup>

Even if we bear propagandistic exaggeration in mind, the passage does not reflect – at least in campaigns – a soldier’s life free of care. At the same time, we can detect a partly development to more and more pressure in regard to recruitment (e.g. insisting that the sons of veterans join the army or responsibility of city governments and individual landowners for finding recruits).<sup>63</sup> There are some additional points, which could have made military service less attractive. As we mentioned above fewer additional provinces were conquered and less prey was to be gained. With the third century a century of civil wars started, too. The risk of death was probably higher in a battle against an equal opponent, and a surviving defeated only could hope for *clementia* (clemency) by the new emperor, against whom the defeated had fought. At the same time, there were more and more opportunities in the administration of the huge empire for the smarter minds. E.g., not least for the financing of the army, the internal revenue office was extended. In the fourth century the size of the administration is estimated at around 30.000-35.000 officials.<sup>64</sup> From today’s point of view, an absolutely

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<sup>60</sup> Ruffing (2008) 820–825.

<sup>61</sup> Hekster (2008) 38s. De Blois (2002) 103s and 105, emphasizes probable heavily fluctuated prices in army or war zones.

<sup>62</sup> Lauffer (1971) (Translation E.R. Graser).

<sup>63</sup> Campbell (2002) 31s.

<sup>64</sup> Jones (1964) 1057.

ridiculous number in the face of the empire's size, but it was likely more than the double of the size in the second century.<sup>65</sup>

Understanding selectivities of economic choices of military careers will be helpful to understand ancient Rome. A number of recent studies in military history of different periods have generated substantial doubts about soldiers and officers being an uneducated and brutal subspecies of human beings. It is clear that killing and violence are main aims on the battlefield, but especially the Roman army is often described as a quite educated military institution which was able to fight against enemies even if those outnumbered the Roman forces (Gilliver 2007). Already the ancient writers like Vegetius, author of a military compendium, were aware of this tactical supremacy:

“In every battle it is not numbers and untaught bravery so much as skill and training that generally produce the victory. For we see no other explanation of the conquest of the world by the Roman People than their drill-at-arms, camp-discipline and military expertise. How else could small Roman forces have availed against hordes of Gaul? How could small stature have ventured to confront Germanic tallness? [...] A small force which is highly trained in the conflicts of war is more apt to victory: a raw and untrained horde is always to slaughter.”<sup>66</sup>

For ancient Roman soldiers their education to understand signals of relatively complex nature was decisive to win battles against enemies far larger in number, but lacking training and education. Creating the “shock” effects, which were often decisive in battles, depends on the trained performance of educated soldiers. This training is more important than cruelty and savagery of, for example, the “Barbarian” enemies of the Roman legions. The

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<sup>65</sup> Ausbüttel (1998) 159ss.

<sup>66</sup> Vegetius, *Epitoma rei militaris* I, 1: in omni autem proelio non tam multitudo et virtus indocta quam ars et exercitium solent praestare victoriam. Nulla enim alia re vidimus populum Romanum orbem subegisse terrarum nisi armorum exercitio, disciplina castrorum usuque militia. Quid enim adversus Gallorum multitudinem paucitas Romana valisset? Quid adversus germanorum proceritatem brevitudo potuisset audere? [...] Etenim in certamine bellorum exercitata paucitas ad victoriam promptior est, rudis et indocta multitudo exposita semper ad caedem. (Translation: M.P. Milner).

literature about the “Western Culture of War” has argued that a special motivation<sup>67</sup> and education of each soldier was decisive to explain why sometimes armies with smaller number of fighters win (Hanson 2005).

How literate were the Romans in general, and soldiers in particular? William Harris argued for a quite pessimistic view: he estimated that the literacy rate in the western Roman provinces was not higher than 10 percent (Harris 1989). However, Harris’s opinion is controversial. Apart from methodological difficulties, numerous studies could differentiate Harris’s general view.<sup>68</sup> The role of literacy and numeracy especially in the Roman army<sup>69</sup> should not be underestimated, as even Harris noted a higher rate of literacy (compared to the civilian population) and suggested that soldiers often came from propertied and educated families (Harris 1989, 254). Vegetius suggested basic calculation and writing skills at least of a part of the soldiers due to the complex administration of the Roman army:

“Since there are several administrative departments in the legions which require literate soldiers, it is advisable that those approving recruits should test for tall stature, physical strength and alertness in everyone indeed, but in some the knowledge of “symbols” [short-hand writing] and expertise in calculation and reckoning is selected. For the administration of the entire legion, including special services, military services, and money, is recorded daily in the Acts with one might say greater exactitude than records of military and civil taxation are noted down in official files.”<sup>70</sup>

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<sup>67</sup> MacMullen (1984) accentuates the importance of human relationships in small networks, whereas Flaig (1992) stresses the rigid code of honour.

<sup>68</sup> Cf. the collection of essays in Humphrey (1991); Woolf (2000)

<sup>69</sup> On the military organization and literacy cf. Phang (2007); Speidel (1996); Speidel (1995), 200s.; Daris (1964). On the problem of defining ancient illiteracy cf. A. E. Hanson (1991). On the question if ancient literacy should be divided in separate specific literacies as e.g. military literacy cf. Woolf (2009).

<sup>70</sup> Vegetius, *Epitoma rei militaris* II, 19: Sed quoniam in legionibus plures scholae sunt, quae litteratos milites quaerunt, ab his, qui tirones probant, in omnibus quidem staturae magnitudinem, corporis robur, alacritatem animi convenit explorari, sed in quibusdam notarum peritia, calculandi computandique usus eligitur. Totius enim legionis ratio, sive obsequiorum sive militarium munerum sive pecuniae, cottidie adscribitur actis maiore prope diligentia quam res annonaria vel civilis polyptychis adnotatur. (Translation: M.P. Milner)

Cf. Vegetius, *Epitoma rei militaris* II, 20: These accounts were preserved in a wicker coffer, “with the standard-bearers”, as they now say. For this reason, standard-bearers were chosen not just for their

Wooden writing-tablets with ink texts were discovered at Vindolanda, a fort south of Hadrian's Wall (close to the modern Bardon Mill, Northumberland, England) as supporting documents for an extensive 'paperwork' in the Roman army (Bowman and Thomas 1994&2003, Bowman 1994, Birley 2002).<sup>71</sup> Alan K. Bowman comments the Vindolanda tablets as follows:

"In the army, we might see a microcosmos, where élite literacy in the officer class regulated the lives of the rest. In fact, there is strong evidence for literacy among centurions, decurions and principales and some evidence for its presence at lower levels, but it is certainly impossible to claim *mass* literacy in the army (which must, in any case, be envisaged as a more literate world than the civilian)." (Bowman 1994; italics in original text)

Another very instructive example of literacy in the Roman army are 146 written *ostraca*, found in Bu Njem (Libya) and presenting lists, daily reports and similar notes (Marichal 1992).<sup>72</sup> Especially the use of letters, which represent Latin transliterations of Punic phonemes, and the variety of the handwriting proves that the soldiers with native Punic language had learnt writing *before* their recruitment, maybe in (very) elementary schools or at home and not in the fort during her service. Vössing supposed that their writing competence was the reason for their recruiting and deployment in this brigade (Vössing 1997, 81-82). In Bu Njem we can also understand, that within the same status group the level of literacy could differ considerably: E.g. the centurionate contained educated and uneducated native speakers of Latin, as well as those who learned Latin as a second language.<sup>73</sup>

On the other hand we have to admit that, even if we have documents providing information that almost a third of 86 auxiliary cavalry soldiers could write (Fink 1971, Nr.

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trustworthiness but for being literate too, who would know how to look after deposits and render account to each man. / Haec ratio apud signiferos, ut nunc dicunt, in cofino seruabatur. Et ideo signiferi non solum fideles sed etiam litterati homines eligebantur, qui et seruare deposita scirent et singulis reddere rationem.

<sup>71</sup> Another case study in Dura Europos (Syria) cf. Perkins (1959).

<sup>72</sup> More cautious in with regard to literacy Adams (1994).

<sup>73</sup> Adams (1999).

34; see also Harris 1989, 254; Hopkins 1991), this means that two third of them probably could *not* (even if we assume that auxiliary soldiers on a smaller scale than legionary soldiers belonged to the propertied and educated class).<sup>74</sup>

## **Conclusion**

In this study, we assessed the human capital of Roman legionaries, officers, and the civilian population born between the first century BCE and the third century CE. Innovative age-heaping techniques allowed the measurement of human capital for this early period. We have carefully studied potential selectivities of our sources by comparing the tombstone-based evidence with age statements from other institutional contexts, and by comparing regional numeracy with other indicators of ancient education.

We found that the Roman military benefitted strongly from occupational choice selectivity: those social groups who decided for a military career had better numeracy values than the remainder of the population. Hence we confirm with quantitative methods ancient writers like Vegetius, author of a military compendium, who were aware of this tactical supremacy. He had stressed that skill, expertise and training even of the ordinary soldiers were the prime forces of the Roman legions that enabled them to win over much larger numbers of barbaric armies who were also taller in stature than the Roman soldiers.

This ‘military bias’ applied especially to the first centuries BCE and CE. Over time, however, the civilian population converged to the military occupational groups. Although the available evidence might not be sufficient to assess this problem, it might be productive to think in the future about further implications of our findings: could the high initial ‘military bias’ and its decline during the later centuries also imply that the Roman military lost a part

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<sup>74</sup> Campbell (2002), 32s., and Hope (2007) 121, are critical on a developed soldiers’ literacy, too. Hence, any educational advantage of soldiers was modest and on a low level in general. This is not inconsistent with the relatively high ABVCC value we observed in the army. Basic numeracy is per definition really a basic skill. (see also Reis, 2008: p.19).

of its strength? If this was the case, the underlying forces of this process might have also contributed to the fall of the Roman Empire.



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Table 1: Numeracy estimates for Egypt, based on biased and relatively unbiased sources

Source type	Numeracy (ABCC)	N	Bias?
Contracts from Tebtunis	62	275	Small?
Mummy labels Female	65	91	Small?
Mummy labels Male	68	188	Small?
Public officials	50	115	Downward
Tombstones Female	73	125	Modest upward
Tombstones Male	70	156	Modest upward
Census and tax lists	93	885	Strong upward (counter-checking)

Note: Calculated from the data reported in Scheidel (1996), and Bagnall and Frier, 1994. Details available from the authors under the keyword `g:\a\ro\egypt_scheideldata.do`

Table 2: Descriptive statistics of the data set

Variable	Obs.	Mean
numerate	242	0.261
skill_elite	33	0.036
citizen	306	0.330
non-citizen	213	0.230
officer	75	0.081
slave_freed	49	0.053
soldier	215	0.232
unknown	37	0.040
bcent1BCE	79	0.085
bcent1CE	432	0.466
bcent2CE	330	0.356
bcent3CE	87	0.094
Aquincum	97	0.105
Brigetio	78	0.084
Carnuntum	121	0.130
Intercisa	87	0.094
panno_inf	326	0.351
age18	118	0.127
age23	233	0.252
female	308	0.334
donor_female	157	0.169

Total number of observations for each variable: 928

Table 3: Regression of “Being Numerate” (Linear Prob. and Logit Models)

Donor generation	All	All	All	All
Age	All	All	Only 23-82	
Estimation	Linear prob.	Linear prob.	Linear prob.	Logit
skill_elite	46.3*** (0.000)	46.4*** (0.000)	47.4*** (0.000)	62.3*** (0.000)
citizen	13.5*** (0.007)	13.6*** (0.006)	15.0*** (0.005)	21.6*** (0.002)
officer	33.5*** (0.000)	33.8*** (0.000)	34.1*** (0.000)	49.0*** (0.000)
slave_freed	14.0* (0.095)	14.0* (0.094)	9.1 (0.314)	24.3** (0.050)
soldier	20.3*** (0.000)	20.4*** (0.000)	20.1*** (0.000)	31.1*** (0.000)
unknown	2.2 (0.816)	2.1 (0.820)	0.2 (0.981)	7.6 (0.563)
bcent1BCE	-8.7 (0.371)	-8.8 (0.363)	-10.4 (0.313)	-5.6 (0.539)
bcent1CE	-14.6** (0.044)	-14.7** (0.044)	-15.9* (0.051)	-10.8 (0.110)
bcent2CE	-8.0 (0.227)	-8.0 (0.230)	-8.7 (0.249)	-3.7 (0.534)
Aquincum	-13.8** (0.045)	-13.8** (0.046)	-9.7 (0.177)	-11.8** (0.018)
Brigetio	23.1*** (0.001)	23.1*** (0.001)	21.9*** (0.004)	27.8*** (0.003)
Carnuntum	19.5*** (0.001)	19.3*** (0.001)	15.9*** (0.008)	23.7*** (0.002)
Intercisa	-5.8 (0.414)	-5.9 (0.408)	-5.4 (0.468)	-5.6 (0.345)
panno_inf	20.1*** (0.000)	20.0*** (0.000)	14.9*** (0.008)	23.4*** (0.000)
age18	31.7*** (0.000)	31.6*** (0.000)		37.5*** (0.000)
age23	9.5** (0.024)	9.4** (0.025)	9.4** (0.022)	11.2** (0.020)
donor_female		-1.3 (0.787)	-3.6 (0.462)	-1.5 (0.752)
Constant	12.7 (0.150)	12.9 (0.145)	16.0* (0.094)	
Observations	928	928	810	928
Adj. R-sq.	0.133	0.133	0.111	5.359

Note: P-Values in parentheses. \*\*\* p<0.01, \*\* p<0.05, \* p<0.1.

The dependent variable is 1 if the age statement does not end with 5 or 0, and 0 otherwise.

Constant refers to non-citizens born in the 3<sup>rd</sup> century CE, age 33 to 82, male or unknown donor, Pannonia superior, other places than those mentioned above. We scaled the coefficients of all independent variables up by

125, for a more convenient interpretation of changes in numeracy: Assume that  $\frac{1}{m}$  of the population are numerate and that age is uniformly distributed.

$1 - \frac{1m}{m} = \frac{m-1}{m}$  is not numerate and will state a multiple of five as their age anyway.

$\frac{1}{5} \cdot \frac{1}{m}$  of the population will correctly and non-accidentally report a multiple of five.

In total,  $\frac{1}{5m} + \frac{m-1}{m} = \frac{1-5m-5}{5m} = \frac{5m-4}{5m} = 1 - \frac{4}{5m}$  will claim to be a multiple of five years old.

Conversely,  $1 - \left(1 - \frac{4}{5m}\right) = \frac{4}{5m}$  will answer with an age that is not a multiple of five.

The fraction of the population assumed to be numerate is recovered by multiplication with  $\frac{5}{4}$ , since

$$\frac{4}{5m} \times \frac{5}{4} = \frac{1}{m}$$

Table 4: ABCC-values by occupational group in the early and late period

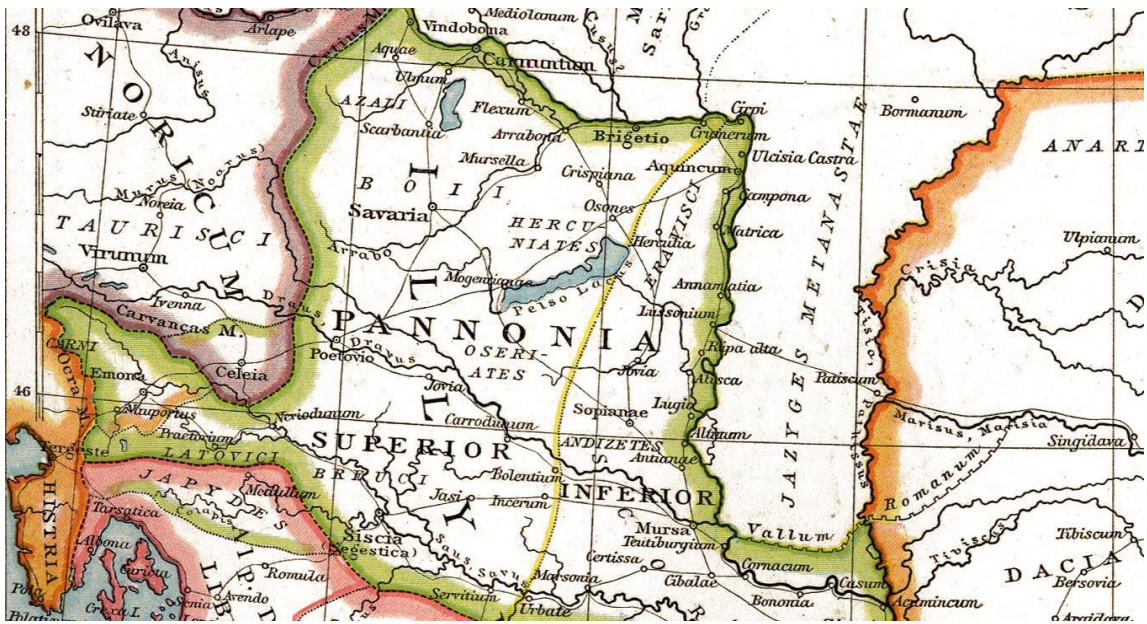
Occupational group	1st century BCE/1st CE	1st century BCE/1st CE	2nd/3 <sup>rd</sup> century CE	Total
Included military	All	Only recruited >100 CE	All	All
Citizen	17.9	18.5	40.5	31.7
Skill_elite			66.9	63.3
Non-citizen	6.8		15.3	8.9
Officer	37.7	(36)*	55.7	47.8
Slave_freed	23.2			29.3
Soldier	32.2	25.7*	37.1	34.0
Unknown			24.4	14.7

The number of cases of Soldiers born 1st century BCE/1st CE, but recruited after 100 CE is 74 (assuming an age of coming to Pannonia of around 20, which is the typical recruitment age), for the same demographic group of citizens, there are 59. The number of cases for officers is only 14.

Table 5: Number of cases by occupational group in the early and late period

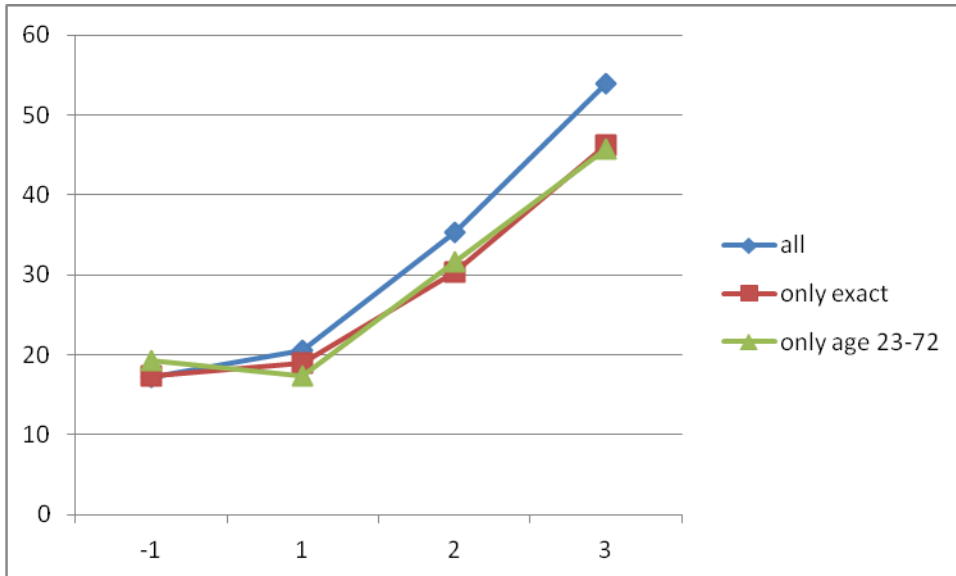
Occupational Group	1st century BCE/ 1st CE	2nd/3rd century CE	Total
Citizen	119	187	306
Elite	9	24	33
Noncitizen	160	53	213
Officer	33	42	75
Slave_freed	35	14	49
Soldier	139	76	215
Unknown	16	21	37

Figure 1: Map of Pannonia



Source: Allgemeiner historischer Handatlas in 96 Karten mit erläuterndem Text Bielefeld, Velhagen & Klasing 1886, p. 16.

Figure 2: Trends of numeracy over time



## **Appendix A: Additional discussion of age-heaping issues (meant for an internet appendix)**

A'Hearn, Baten, and Crayen (2009) found that the relationship between illiteracy and age-heaping for less developed countries (LDCs) after 1950 is very close. They calculated age-heaping and illiteracy for not less than 270,000 individuals who were organized by 416 regions, ranging from Latin America to Oceania. The correlation coefficient with illiteracy was as high as 0.7. The correlation with the PISA results for numerical skills was even as high as 0.85, hence the Whipple index is more strongly correlated with numerical skills. They also used a large U.S. census sample to perform a very detailed analysis of this relationship. They subdivided by race, gender, high and low educational status, and other criteria. In each case, they obtained a statistically significant relationship. Remarkable is also the fact that the coefficients are relatively stable between samples, i.e., a unit change in age-heaping is associated with similar changes in literacy across the various tests. The results are not only valid for the U.S.: In any country with substantial age-heaping that has been studied so far, the correlation was both statistically and economically significant.

To assess the robustness of those U.S. census results and the similar conclusions which could be drawn from the less developed countries of the late 20th century, as mentioned in the introduction to this study, A'Hearn et al. (2009) also assessed age-heaping and literacy in 16 different European countries between the middle ages and the early 19th century. Again, they found a positive correlation between age-heaping and literacy.

There remains some uncertainty about whether age-heaping in the sources contains information about the numeracy of the responding individual, or rather about the diligence of the reporting personnel who wrote down the statements. The age data of the relevant age groups were normally derived from statements from the person himself or herself. However, it is possible that a second party, especially the husband, may have made or influenced the

age statement, or even that the enumerator estimated the age without asking the individual. If the latter occurred, we would not be able to measure the numeracy of the person interviewed. In contrast, if the enumerator asked and obtained no response, a round age estimated by him would still measure basic numeracy correctly. A large body of literature has investigated the issue of other persons reporting. Földvári et al. speculated, for example, that wives may appear to have been more numerate than they actually were because they improved their age statement with the help of their husbands.<sup>75</sup> They compared the numeracy of married and unmarried women and found that the latter had significantly lower numeracy in some of their samples. However, de Moor and Zuijderduijn recently rejected this view with a number of good arguments.<sup>76</sup> Baten and Szoltysek compared male and female numeracy in their sample, and found that women were sometimes more numerate than men, which would support the hypothesis that they reported their age themselves.<sup>77</sup> On the other hand, there was a correlation between the male and female numeracy of different households. Recently, Friesen et al. compared systematically the evidence of a gender gap in numeracy and in literacy for the late 19<sup>th</sup> century and early 20<sup>th</sup> century, and found a strong correlation.<sup>78</sup> They argued that there is no reason why the misreporting of literacy and age should have yielded exactly the same gap between genders. A more likely explanation is that the well-known correlation between numeracy and literacy also applies to gender differences. For our study, the question

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<sup>75</sup> P. Földvári, B. van Leeuwen and J. van Leeuwen-Li, 'How did women count? A note on gender-specific age heaping differences in the sixteenth to nineteenth centuries', *Economic History Review* 65,1 (2012), 303–313.

<sup>76</sup> T. de Moor and J. Zuijderduijn, *The Art of Counting – Reconstructing Numeracy in the Middle and Upper Classes on the Basis of Portraits in the Early Modern Low Countries*, Working Papers 0016, Utrecht University, Centre for Global Economic History (2011) [<http://www.cgeh.nl/working-paper-series/>].

<sup>77</sup> J. Baten and M. Szoltysek, *The Human Capital of Central-Eastern and Eastern Europe in European Perspective*, Working Paper, University of Tuebingen / Max Planck Institute for Demographic Research (2012) [[http://www.demogr.mpg.de/en/projects\\_publications/publications\\_1904/mpidr\\_working\\_papers/the\\_human\\_capital\\_of\\_central\\_eastern\\_and\\_eastern\\_europe\\_in\\_european\\_perspective\\_4360.htm](http://www.demogr.mpg.de/en/projects_publications/publications_1904/mpidr_working_papers/the_human_capital_of_central_eastern_and_eastern_europe_in_european_perspective_4360.htm)]

<sup>78</sup> J. Friesen, J. Baten and V. Prayon, *Women count. Gender (In-)Equalities in the Human Capital Development in Asia, 1900-1960*, Working Papers in Economics and Finance No. 29, University of Tuebingen [[http://tobias-lib.uni-tuebingen.de/frontdoor.php?source\\_opus=6040&la=de](http://tobias-lib.uni-tuebingen.de/frontdoor.php?source_opus=6040&la=de)]

of whether the women answered themselves is slightly less important, because we mainly aim to estimate numeracy of different occupational groups.<sup>79</sup>

## **Appendix B: HEADING MISSING?!**

#8.c Scheidel's main observation is that in census returns from Roman Egypt, rounding on multiples of five is much less prominent than in most other sources. According to the census sources, Egypt in Roman time would have been – with an ABCC index of 93 -- almost as numerate as England around 1800 (Table 1) (Baten, Crayen and Voth 2013). While Egypt was certainly one of the most productive provinces of the Roman Empire – especially measured in grain output – it seems unlikely that this almost perfect numeracy was reached so early in human history.

Bagnall and Frier (1994) describe the census taking process in detail. Censuses were taken every 14 years over the first centuries of Roman dominance. From these censuses, tax lists were created that allowed to collect the resources which were crucial to provide the capital of the Empire with sufficient grain. Hence, an exceptional investment in accuracy of the census and tax lists seemed justified.

This is also supported by the description of Scheidel: As a similar source to census lists, Scheidel presents evidence on 496 male village men from official tax registers. All of this evidence is from the first century CE. Scheidel documents how these lists were directly compiled from the census returns; hence we aggregate those with the census returns. The

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<sup>79</sup> Moreover, there is sometimes direct evidence in the sources that the wives themselves were asked. K. Manzel, J. Baten and Y. Stolz, 'Convergence and Divergence of Numeracy: The Development of Age Heaping in Latin America, 17th to 20th Centuries', *Economic History Review* 65, 3 (2012), 932–960, reported finding sources on Latin American Indio women in which statements like this one were included: "She says that she is 30, but she looks more like 40." Even for black female and male slaves in the Cape Colony in South Africa who were accused of crimes, the legal personnel created a separate column that indicated whether the person was guessing her age, or whether she actually knew. It is possible that, if those Indio and African women, who probably were not shown much respect by colonial officers, were asked for their age, then European women might also have been asked for their age, as the level respect shown to them might have been somewhat greater.



disaggregated ABCC number would be similar in level and similarly overstated anyways: the biased ABCC would be 95 for the tax lists separately, and 93 for census returns and tax lists together. He documents clearly why those sources cannot be used to derive an unbiased numeracy estimate, as the census and tax officials used previous census lists to counter-check the sources: „Moreover, in the process of compiling these rosters, the officials could and did check the accuracy of the census reports for consistency with birth declarations and previous census returns.”- Of course, counter-checking always biases age-heaping downward and makes realistic numeracy estimates impossible. If this description of Scheidel is accurate -- and if the previous census taken 14 years earlier was used for counter-checking -- we might observe age-heaping on 44 or 54, for example, because those aged 30 or 40 in the previous census were now sometimes entered as ‘previous age plus 14’ by the census takers. In contrast, young taxpayers who entered for the first time might have been mostly asked for their age, hence we would expect rounding on 20. In fact, there were 10 persons in the census lists of age 44, but only 6 and 7 of age 42 and 43 (Bagnall and Frier, 1994, p. 335-336) and 10 of age 54, but only 4 and 3 of age 52 and 53. In contrast, age 20 is highly preferred with 28 persons (twice as much as surrounding ages. This suggests that Scheidel is right: counter-checking is very likely a strongly biasing factor in the Egyptian tax and census records. Besides, women in villages apparently avoided the terminal digit 7, which may be explained by regional beliefs of superstition, cf. Scheidel (1996), 65s. However, avoiding one number which is not adjacent to a multiple of five would not bias the results.

### **Appendix C: Robustness check applying the maximum age of 72 to the regressions**

The possibility exists that older people know their age less precisely. It has been found for some samples of the early modern period by A’Hearn et al.(2009); however, the hypothesis was rejected for 19th and 20th century evidence based on Crayen and Baten. Contrarily to

this effect, there could be survivor bias: More educated persons might survive to higher ages, whereas less skilled might have died at younger age. A third possibility is that the two effects cancel each other out. Hence it is important to check whether this effect exists, especially in populations with low life expectancy, in which higher ages might seldomly be reached. We restricted the sample to the age bracket 23 to 72 (Table C.1), the results are very similar to the results in table 3 which relates to ages 17 to 82 or 23 to 82.

In addition, we have also examined the potential age effect using a dummy variable of those aged 63 to 82 for the Roman period, and we find that the effect was actually insignificant and the coefficient small (only 3 percent, see Table C.2).

Table C1: Restricting the estimates of Table 3 to ages 23 to 72.

Donor generation	All	All	Only same g.	All
Age	All	All	All	
Estimation	Linear prob.	Linear prob.	Linear prob.	Logit
skill_elite	44.8*** (0.000)	45.2*** (0.000)		63.5*** (0.000)
citizen	16.6*** (0.002)	17.0*** (0.002)	17.4*** (0.009)	27.9*** (0.001)
officer	33.8*** (0.000)	34.7*** (0.000)	48.9*** (0.000)	52.4*** (0.000)
slave_freed	11.0 (0.251)	11.3 (0.237)	41829 (0.363)	24.0 (0.117)
soldier	20.1*** (0.001)	20.4*** (0.000)	21.0*** (0.004)	32.8*** (0.000)
unknown	1.3 (0.896)	1.2 (0.907)	-3.3 (0.771)	7.8 (0.606)
bcent1BCE	-6.7 (0.534)	-7.8 (0.475)	-4.1 (0.755)	-3.4 (0.725)
bcent1CE	-15.9* (0.055)	-16.4** (0.048)	-16.9* (0.090)	-12.9* (0.077)
bcent2CE	-8.4 (0.272)	-8.3 (0.278)	-8.7 (0.343)	-4.5 (0.479)
Aquincum	-9.0 (0.224)	-8.8 (0.235)	-9.0 (0.287)	-7.7 (0.175)
Brigetio	21.5***	21.4***	27.5**	23.9**

	(0.007)	(0.007)	(0.012)	(0.018)
Carnuntum	18.0***	17.3***	17.0**	19.9***
	(0.004)	(0.005)	(0.041)	(0.009)
Intercisa	-8.0	-8.3	-14.9	-7.4
	(0.315)	(0.294)	(0.117)	(0.220)
panno_inf	15.5***	14.9**	10.0	17.2***
	(0.008)	(0.011)	(0.141)	(0.008)
age23	9.4**	9.2**	12.3**	9.8**
	(0.025)	(0.028)	(0.023)	(0.028)
donor_female		-4.7	-7.5	-4.6
		(0.364)	(0.283)	(0.322)
Constant	14.5	15.6	16.6	
	(0.137)	(0.112)	(0.158)	
Observations	762	762	461	762
Adj. R-sq.	0.108	0.109	0.135	4628

Table C.2 Adding an age dummy “age 63-82” to the estimates of Table 3 to ages

Age	All	All
Estimation	Linear prob.	Linear prob.
skill_elite	49.3***	49.6***
	(0.000)	(0.000)
citizen	15.9***	16.2***
	(0.006)	(0.005)
officer	33.3***	34.0***
	(0.000)	(0.000)
slave_freed	8.4	8.5
	(0.399)	(0.396)
soldier	17.6***	17.8***
	(0.004)	(0.003)
unknown	1.4	1.3
	(0.898)	(0.906)
bcent1CE	-14.9*	-15.1*
	(0.074)	(0.069)
bcent2CE	-8.1	-8.0
	(0.292)	(0.298)
Aquincum	-8.6	-8.5
	(0.240)	(0.245)
Brigetio	22.7***	22.6***
	(0.003)	(0.003)
Carnuntum	20.7***	20.2***
	(0.001)	(0.002)
Intercisa	-4.0	-4.2
	(0.599)	(0.581)
panno_inf	15.4***	15.1***
	(0.007)	(0.009)
age23	8.8**	8.7**
	(0.040)	(0.043)
donor_female		-3.3

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		(0.516)
age6382	-3.1	-2.9
	(0.622)	(0.643)
Constant	14.3	15.0
Observations	(0.148)	(0.132)
Adj. R-sq.	0.112	0.113

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Note: as the first century BCE relies strongly on age group 63-82, there would be collinearity with the age dummy 63-82. Hence this century is excluded from this regression.

#### **Appendix D: The composition of legions in Pannonia**

There were several legions stationed in Pannonia in the course of time<sup>80</sup>, but legio I adiutrix<sup>81</sup>, legio II adiutrix<sup>82</sup>, legio X gemina<sup>83</sup> and legio XIV gemina<sup>84</sup> were long-term garrisons. The composition of these legions is quite difficult to categorize, because the soldier's origins are recorded rarely. But even the limited evidence shows the tendency, that after the beginning of the second century the area of recruitment was only seldomly Italy (and to some extent Narbonensis (today's Provence) and Spain) but recruitment mostly took place in the Danube provinces and Pannonia itself.<sup>85</sup> The newly enlisted legionaries were often only recent Roman citizens or had gained citizenship upon enlistment.<sup>86</sup>

The legio XV Apollinaris<sup>87</sup> was stationed in Pannonia in the first century. Up to the seventies the recruits came predominantly from Italy, afterwards the Pannonian recruits increased. At the beginning of the second century the legio was withdrawn to Cappadocia in the eastern part of the empire.

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<sup>80</sup> Móscy (1959) 81-85, and (1962) 612-624, give an overview for the legiones and auxilia.

<sup>81</sup> Lörincz (2000a).

<sup>82</sup> Lörincz (2000b).

<sup>83</sup> Gómez-Pantoja (2000).

<sup>84</sup> Franke (2000).

<sup>85</sup> Forni (1953); Forni (1974); Forni (1992a); Forni (1992b) 116–119, 131s., and 135 (typographical error: LEG. XIII GEMINA instead of LEG. XIII GEMINA); Mann (1983) 31-35 and 117-122 (table 17); Shochat (1983/84) presents few additional inscriptions, which maybe belong to Italian soldiers of the legio II adiutrix, but do not change the general picture. A quick overview on recruitment in the Roman Empire presents Campbell (2002), 25-32.

<sup>86</sup> Campbell (2002), 31.

<sup>87</sup> Wheeler (2000).

In great numbers auxilia-units (alae [riders] and cohortes [infantrymen]) are proven in Pannonia<sup>88</sup>, but evidence suggests that in general the auxilia increased the local recruitment after c. 100 CE, too.<sup>89</sup> Ethnic titles, which the auxilia (like the legions) sometimes bore (e.g. ala Hispanorum or legio Hispana/Hispaniensis), became only a reminiscence to the area, where the units originally were recruited, and not de facto place of birth.<sup>90</sup>

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<sup>88</sup> Lörincz (2001).

<sup>89</sup> Kraft (1951), 43-51; Le Bohec (1993), 106s; Cheesman (1914), 57-101; Móscy (1959), 120-122.

<sup>90</sup> As usual there are exceptions like the *cohors miliaria Hemesenorum*, which continued to draw their recruits from the area, where the *cohors* originally was raised, cf. Cheesman (1914), 83s (but with very small collection of evidenz).