Determinants of Human Capital Formation, Fertility, and Height in European and Latin American Countries From the Early Modern Period to the 20th Century

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Despite of the support of several people, it is me alone who is responsible for the contents of this thesis.

Table of Contents

List of Figures

List of Tables

List of Figures in Appendices

List of Tables in Appendices

Abbreviations

ABCC	Index that yields an estimate of the share of people who state a non-rounded age; it ranges from 0 to 100 and can be interpreted as percentages; the label results from the initial letters of the last names of the three scholars who invented it and another who commented on their paper (**A**'Hearn, Brian, **B**aten, Joerg, **C**rayen, Dorothee and **C**lark, Gregory)
GEnum	Gender Equality Index in numeracy
INEGI	Instituto Nacional de Estadística y Geografía (National Institute of Statistics and Geography, Mexico)
IPUMS	Integrated Public Use Microdata Series
MNRR	Male Net Reproduction Rate
MRR	Male Reproduction Rate
OLS	Ordinary Least Squares Estimation
PISA	Program for International Student Assessment
RE	Random Effects Estimation
US	United States of America
Wh	Whipple Index that yields an estimate of age heaping; it ranges from 0 to 500
WLS	Weighted Least Squares Regression
ZTP	Zero Truncated Poisson Estimation

Country Abbreviations (According to DIN ISO 3166)

At	Austria
Ch	Switzerland
De	Germany
Dk	Denmark
Es	Spain
It	Italy
Mx	Mexico
Uy	Uruguay

1 Introduction

What determines the wellbeing of individuals? There is no trivial answer to this question because numerous factors influence the personal perception of the wellbeing of people. While one person perceives the amount of leisure and time spent with her or his family as wellbeing or happiness (which would be the "highest" form of individually perceived wellbeing), another person enjoys the luxury that comes along with a high income from working long hours in a demanding job. However, there is consensus about some measurable determinants of wellbeing, such as the access to (formal) education and health services. While the vast majority of people living in developed countries are provided with these benefits, there are numerous people in developing regions all over the world without the possibility to cover even their very basic needs. This high level of inequality between world regions has detrimental effects on those who are suffering from it. However, even within the high income countries, there exist considerable inequalities between rich and poor, immigrant and non-immigrant groups, and among men and women. Moreover, inequality is not only an inconvenient condition for the individual suffering from it, but it has strong negative effects on economic growth. Hence, the question arises: what favors economic growth, and how can inequality be reduced significantly?

One of the main driving factors of economic growth is the formation of human capital. In many developing regions, there are a large number of people who do not even have very basic education; thus, many of these regions have still great tasks ahead of them. Efforts will be needed to reinforce the advancement of industrialization, and broad-based education for the masses will have to be provided.

In this doctoral thesis, I focus on several countries in two world regions that have undergone the essential phases of development, industrialization, and a significant rise in human capital in different time periods reaching from the early modern period to the 20th century. The aim of this doctoral thesis is to shed more light on human capital development, fertility, and health status during that long time period.

For the purpose of analyzing core issues of the underlying processes, I created two large databases.[1] One of the datasets includes information on seven countries from

[1] The data stem from different sources, among them several archives and the Internet. The sources are

Europe and one from Latin America: Austria, Italy, Germany, Denmark, Switzerland, Spain, and Uruguay.[2] The data contain information about approximately 325,000 individuals and cover the time span from the mid-17th century (Austria) to the early 19th century (Uruguay). This large database allows assessing the underlying processes of two important issues that helped shaping society as it is today: human capital formation and fertility patterns.

The period covered by this database is a particularly interesting one because it includes three core events that were at the heart of development of the European society: the French Revolution that brought along a new way of thinking and provided the basis for an increasing equality among social groups; the Industrial Revolution that laid the cornerstone for continuous economic growth; and, last but not least, the fertility transition that led to a significant decline in birth rates and reinforced the "quantity-quality trade-off"[3] in children (see, for example, Clark 2007; Cummins 2013). The development of human capital skills is at the very heart of all these achievements. Only on the basis of a skilled society can the necessary technological processes evolve that promote industrialization and subsequent economic growth. But how can we measure human capital or basic education in a time in which formal education in terms of schooling was not available for the vast majority of society?

To approximate human capital during the period under consideration, I use information on two indicators: literacy and numeracy. The first indicator, literacy, can be derived by testing the skill of reading and writing texts via the demonstration in front of census personnel, for example. Numeracy, on the other hand, is a proxy for basic numerical skills of people, hence, the skill of dealing with numbers and processing simple mathematical tasks. For the calculation of numeracy indicators, we consider age statements that people reported in a census, for example. The age distribution of nearly all past societies (until the 19th or 20th century, depending on the period, world region, and country) contains considerable "heaps" at numbers divisible by five indicating that a large amount of people reported rounded numbers. For example, when a person was asked for his or her age and did not know it, he or she might state a "popular" number

described in detail in the respective chapters. While one of the great challenges was the collection of all these data, the merging and standardizing processes to prepare the data for the analyses required a lot of effort.

[2] The other large database contains observations from Mexico.

[3] The "quantity-quality trade-off" in children refers to the decision of couples to reduce their fertility and invest more in every single child in terms of financial means and parental time, for example. In doing so, they increased the outcome of their offspring.

such as 35, when the person was in reality 34 years old. This "age-heaping" pattern can be converted into an index such as the so-called "ABCC"[4] that represents the share of people that are able to state their ages exactly (A'Hearn, Baten, and Crayen 2009, p. 788). Consequently, the interpretation is similar as in the case of literacy that measures the share of people able to read and write. These indicators are highly correlated with other measures of human capital such as schooling and math skills and provide us with the possibility to study human capital development in the very long run.

To understand the process of human capital formation and fertility patterns during the early modern period, we have to consider the particular underlying mechanisms of this time. Early modern society was trapped in what scholars call the "Malthusian equilibrium". During most of this phase, which according to some scholars lasted hundreds or even thousands of years, living standards were low for the majority of people and both population and the economy grew on very low levels (Clark 2007; Galor and Weil 1999). Death rates were dramatically high, which created incentives for the parents to "replace" deceased children. A large number of children were considered a good provision for older ages and thus fertility remained nearly "uncontrolled" within marriage (see, for example, Cummins 2013). Only in times of exogenous shocks, such as the Black Death that led to a dramatic decline of the population, could living standards increase: because workforce was scarce immediately after such catastrophes, the real wages increased, which led to a higher income of people, accompanied by rising living standards. It was only during such periods that the population could grow steadily (Galor and Weil 1999).

In the Malthusian world, inequality was high and the structures of society rigid. Intergenerational (upward) mobility was rarely an option and access to broad-based formal education was not given (Clark 2007; Cummins 2013). However, A'Hearn, Baten, and Crayen (2009, Table 4) showed that there was indeed an enormous increase in human capital from the beginning of the early modern period to the beginning of the 19th century in Europe. ABCC levels increased from approximately 55% in 1450 to nearly 90% in some of the European regions. But how was such a large increase possible given the circumstances of that period?

To answer this question, we analyze human capital and fertility patterns among socioeconomic groups. One might assume that in a society suffering from large

[4] The ABCC is labeled after the three initial letters of the authors' last names (A'Hearn, Baten, and Crayen 2009) including Gregory Clark's who commented on their paper.

inequalities and rigid structures, people with higher incomes have an advantage over other, poorer groups in terms of their human capital and their number of offspring.[5] While we can confirm this assumption, we find that the large group of farmers was also provided with favorable human capital skills. Furthermore, the analysis of the "reproductive success"[6] among socioeconomic groups reveals that farmers also had a large number of children compared to other socioeconomic groups. It seems likely that farmers passed on their favorable human capital skills to their children and reinforced the human capital increase during the early modern period. This is an important and rather unexpected finding because the role of farmers in the process of human capital formation has not received much attention so far. Because innovation and advancement of technology was attributed mainly to urban centers, most of the previous studies focused on the development of the highly skilled (urban) groups (see, for example, Clark 2007).

Given the scarcity of resources in the Malthusian period, we might wonder whether the high fertility of couples, aiming at a high quantity in offspring, caused a rivalry among siblings that led to a lower "quality" in every single child. But how can we measure the "quality" of children? If we assume that quality is closely related to health and the access to nutrition, we can implement the anthropometric history method which uses the measurement of height growth as an indicator of wellbeing. The height of people reflects not only the sheer access to nutrition (that might be of low quality, for example), but it delivers information on the "net nutritional status" of individuals that is influenced by the procurement of protein, the disease environment, and food prices (see, for example, A'Hearn 2003; Baten and Blum 2014). If a person faces poor living standards or a large amount of labor during childhood, this will also result in a shorter height (Baten 1999). Of course, a large share of the maximum height a person can reach is determined by genetic variation. However, there remain still significant differences across populations or population groups that are due to their living conditions and the supply of protein in the region they live (A'Hearn 2003).

By analyzing a dataset on heights of Bavarian conscripts, I am able to assess the question of a potential rivalry among siblings. While focusing on the impact of family size on height, I also control for the birth order of the siblings. Although one might

[5] In the early modern period a large number of children were considered a good provision for older ages.
[6] The reproductive success refers to the surviving number of children as a result from birth and death rates (see, for example, Clark 2007).

assume a great "struggle" for the resources among siblings in times of the Malthusian period, surprisingly, the results suggest that the conscripts of large families are also significantly taller than those with a lower number of siblings.

In the following, I will address the question of how the population managed to liberate itself from the Malthusian trap. While the aforementioned contribution of farmers might be one determinant that paved the way out of the "Malthusian trap" to sustained economic growth, Unified Growth Theory identifies the technological progress in urban centers as the main driving force behind the emancipation of the Malthusian period. Galor and Weil (1999, 2000) argue that once technological progress advances, the need for highly skilled labor force increases dramatically, which leads to a rise in the "returns to human capital", i.e., wages. The higher expected return to the human capital of their children, together with a dramatic decrease of mortality rates due to advances in health technology, induces parents to lower their fertility and invest more in every single child leading to the "quantity-quality trade-off" in children. This is the phase in which society finally reduces fertility rates and enters modernity with continuous economic growth. At the same time, the increasing demand for education leads to the establishment of mass education.

By compiling and analyzing a very large database that includs more than half a million Mexican observations and covers the period from 1870 to 1940, I am able to assess the important time period of advancing industrialization in this country. It is exactly this period, in which technological progress advances and the need for a large number of skilled workers increases. An important theory concerning the labor force participation of women relative to that of men has been developed by Goldin (1995). Goldin found that in societies with low levels of income, inequality between women and men is relatively low. In times of increasing incomes and industrialization, it is the labor force participation of males that increases strongly. This is the phase when the gender gap opens: men benefit to a large extent from new opportunities in the labor market and increasing education, while women lag behind. Women manage to raise their labor force participation and benefit from the new opportunities only in the last phase of this process, when incomes have reached a high level and the demand for "white-collar"[7] labor force increases. Adapting the theory developed by Goldin based on the relative labor force participation of women to relative differences in basic

[7] "White-collar" determines higher skilled employment opportunities in firms (offices) in contrast to "blue-collar" which is related to work in factories.

education, enables me to assess the educational gender gap in Mexico in the important phase of the industrialization.

As two of the chapters in this doctoral thesis are already published, and the others are intended for publication, I refer to the chapters as “papers” or “studies”. This doctoral thesis is structured as follows: chapter two provides a comprehensive overview over the implementation of the age-heaping technique, its advantages, and potential biases. In chapter three, I analyze the human capital formation of different socioeconomic groups across a number of European countries and Uruguay during the early modern period, using the ABCC index. In chapter four, I assess the “reproductive success” of different socioeconomic groups during the early modern period until the beginning of the 19th century. By implementing the anthropometric history method in chapter five, I use heights to analyze the hypothesis of a “rivalry” among siblings in the Malthusian period. In chapter six, I discuss educational gender inequality in the time of increasing industrialization in Mexico by using the age-heaping method. Chapter seven concludes.

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2 Age-Heaping-Based Human Capital Estimates

Abstract:

In this article, we provide comprehensive insights into the implementation and the use of the age-heaping method. Age heaping can be applied to approximate basic numerical skills and hence basic education. We discuss the advantages and potential issues of different indicators and we show the relationship of those indicators with literacy and schooling. The application of age-heaping-based indicators enables us to explore various topics on basic education such as the gender gap and the divergence of countries in the very long run. This well-established technique has been used by a great variety of authors who also show that numeracy has a large impact on growth.

This chapter is based on an article by Tollnek and Baten (2016), which is published in Diebolt, Claude and Haupert, Mike (eds.), *Handbook of Cliometrics*, 131–154. Berlin/Heidelberg: Springer-Verlag, Available Online at: http://www.springer.com/de/book/9783642404054. The version of the article included in this doctoral thesis is equal in contents, but includes minor deviations in the text. The concept of the paper and the writing were to 80% on my behalf, to 20% on behalf of Joerg Baten.

2.1 Introduction

Education is one of the driving factors for the development and long-term economic growth of countries. Many projects in development aid are set up to increase school enrollment rates or years of schooling to improve education and thus the prospects of future generations. Nowadays, there are plenty of measures and indexes at hand to quantify different levels of education among children, adolescents and adults. Through various tests and methods, the levels of education or human capital are comparable on an international basis. In the famous Program for International Student Assessment (PISA), scholars compare cognitive skills of students from various countries around the world. On the one hand, the impact of such a program is enormous: countries with lower scores invest financial means or restructure their schedules to push forward in the range. On the other hand, the results build one of the largest databases on students' education worldwide with which scholars are able to conduct analyses and draw conclusions for the future.

However, if we go some decades further back in time, we have to rely on other measures of human capital such as years of schooling, enrollment rates or literacy because we simply lack other indicators. The differentiation between different years of schooling, for example, is slightly less exact than that of the cognitive skills tests of the PISA study. Moreover, there are other issues that might occur with these indicators. If a child is enrolled in school it does not necessarily mean that he or she acquires a certain level of reading or mathematical skills before potentially dropping out. Literacy rates are often self-reported or even have to be constructed from people's ability to append their signatures to documents, such as marriage registers or wills, which does not necessarily imply that the person is able to read and write. Reis (2005) reports such estimated literacy rates for a number of European countries around 1800. The English database implemented by Schofield (1973) reaches back to the middle of the 18th century. By analyzing wills, Gregory Clark (2007) constructed another large database on English literacy that even dates back to 1585.

The construction of databases on literacy reaching back to the 16th century is, of course, an exceptional case and only possible for a country such as England where the availability of sources is much better than in most of the other countries in the world. In most countries, data sources are scarce and do not provide literacy or enrollment rates until after the Industrial Revolution. For some less developed countries or world regions, we do not even find comprehensive enrollment rates for the past 50 years because schooling was not obligatory or there were no schools nearby for children to attend. But how can we measure human capital in times in which education was only available for the rich or in regions where data sources are very scarce?

In numerous surveys, church registers or census lists, people reported information from which scholars are able to derive a basic indicator of human capital: their age. The underlying concept for calculating such an indicator is the so-called “age heaping”: in earlier times, when people did not have birth certificates or passports, they were often not aware of their true age or they simply did not know it because no one kept record of their exact date of birth. As a consequence, when people were asked for their age and they did not know it exactly, they tended to state a “popular” number. For instance, they claimed to be 35 when they were in reality 34 or 36. Hence, the age distribution shows “heaps” or “spikes” at these popular digits that are mainly multiples of five (see, for example, Myers 1954). Why does this clearly not reflect the true distribution of ages? We can explore that with a small example: if in the year 1935, for example, one hundred people stated to be 35 years old but only fifty people reported being 34 or 36 years of age, this would mean that twice as many children were born in 1900 compared to the years 1901 and 1899. This is a very unlikely scenario and most probably due to age non-awareness. This phenomenon causes problems for demographers because they have difficulties estimating the true distribution of males and females in certain age groups or the life expectancy of a population (see, for example, A’Hearn, Baten, and Crayen 2009, p. 786). But, while being a disadvantage to the accuracy of demographic research, this pattern is actually a benefit for the research on basic education: by implementing an indicator such as the Whipple, we can calculate the ratio of the individuals who were able to report their own ages exactly in contrast to those who stated rounded numbers. Consequently, an indicator based on age heaping enables us to conduct studies on basic numeracy or human capital for a great variety of countries and in the very long run.

Many authors used the now well-established age-heaping method on various topics related to basic education: Myers (1954), Mokyr (1983), Zelnik (1961), Duncan-Jones (1990), Budd and Guinnane (1991), Ó Gráda (2006), Manzel, Baten, and Stolz (2012) as well as Crayen and Baten (2010a, 2010b), among others, studied differences in numeracy of various countries, world regions and time periods. A’Hearn, Baten, and Crayen (2009) demonstrated the strong relationship between age-heaping-based indicators and literacy. De Moor and Van Zanden (2010), Manzel and Baten (2009), and

Friesen, Baten, and Prayon (2013) assessed gender inequalities in numeracy in different world regions, whereas Juif and Baten (2013) compared the numeracy levels of Inca Indios before and after the Spanish conquest. Stolz and Baten (2012) analyzed the effects of migration on human capital selectivity – hence, they measured the extent of "brain drain" or "brain gain" of countries through migration.[8] Charette and Meng (1998), for instance, assessed the impact of literacy and numeracy on labor market outcomes.

In the following section we will explain in greater detail the advantages and potential caveats of the age-heaping method. We also discuss the indicators that are commonly used to approximate basic numeracy and we describe in which way they are calculated. Furthermore, we explore the relationship between age-heaping-based indicators and other measures such as literacy and schooling. In section three we describe different research topics that have been assessed by implementing the age-heaping method, while in section four we discuss studies that explore differences in numeracy levels across various world regions. In section five we present the development of women's numeracy and the gender gap. Section six provides concluding remarks concerning the impact of basic numeracy.

2.2 Age-Heaping-Based Indicators: Advantages, Potential Biases, and Indexes

2.2.1 Advantages, Potential Biases, and Heaping Patterns

The requirement for employing numeracy as an indicator for human capital is that a certain share of people in earlier times – especially before the Industrial Revolution – were not aware of their actual age because they did not know their date of birth or they were not able to calculate the number of years from their date of birth to the actual year.[9] Consequently, when individuals were asked for their age and could not state it exactly, they did not report a random number, but they typically tended to report a number divisible by five such as 35, 40, 45, and so on (Duncan-Jones 1990, pp. 79–81, A'Hearn et al. 2009, p. 785).

[8] Brain drain means that highly educated people emigrate from their country of origin to another. Brain gain means the opposite effect.
[9] However, we have to keep in mind that there are individuals still living today, predominantly in the least developed countries, who are not aware of their true age when they are asked for it (Juif and Baten 2013).

While the afore-mentioned is the most commonly detected heaping pattern, there is also some heaping on multiples of two – hence, even numbers.[10] In some special cases such as the Chinese culture, one might think of a different heaping pattern, for example the avoidance of the number four, which when pronounced sounds similar to the word for "death" or the preference of the number eight, which can be associated with fortune (Crayen and Baten 2010a, p. 87). However, Baten, Ma, Morgan, and Wang (2010, p. 353) found that Chinese migrants to the United States (US) heaped considerably more on multiples of five than on the birth year of the dragon, for instance, which is a very popular animal sign in China.

One great advantage of an age-heaping-based indicator is that it enables us to assess basic numeracy for a large number of countries over a very long period of time because this phenomenon presumably appeared in most societies until a certain point in time (Duncan-Jones 1990). The second advantage is that there exist a large number of sources that can be employed to calculate numeracy indexes. In principle, we can use any list for which people had to report their age including census lists, ecclesiastical surveys, tax lists, marriage registers, death registers and shipping lists, just to name a few (see also A'Hearn et al. 2009, p. 786). Of course, selection biases need to be studied. One very early census in the history of mankind that we are aware of is the population census decreed by Emperor Augustus, around the birth of Christ, for which Maria and Joseph were heading to their place of birth to be enumerated. Duncan-Jones (1990, p. 79), however, reveals another way to measure age awareness in ancient times:

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[10] De Moor and Van Zanden (2010, p. 184) even report a preference for multiples of 12 in different medieval and early modern sources, among them a census from Tuscany in 1427 and another from Reims in 1422. This phenomenon could be the result of religious orientations and the underlying usage of the number twelve as a holy number. Interestingly, this heaping pattern was more often adopted by women than by men, especially during early modern times in the South Netherlands. This could be due to a stricter adherence of religious practices or beliefs by women than by men, though this is not scientifically proven so far.
Another pattern might also occur if a certain share of the population was surveyed and the results were written down in year t, whereas the rest of the data collection was performed in the following year t+1. After the census was finished, the census official compiled the results in a clean and comprehensive list in year t+1. Because he was aware of the age statements that had been reported in year t, he added 1 year to those ages. As a result, we find heaping on the terminal digits one and six in these lists. If this pattern can be identified without reasonable doubt, the additional year should be subtracted from all of the affected age statements.
In a similar way, the authors of some studies have found that numeracy estimates based on age statements of marriage lists tend to be upwardly biased (which is partly due to the fact that marriage was restricted to those who earned a living and could nourish a family in many historical societies). Death registers on the other hand tend to yield downwardly biased estimates. This type of bias could happen if the deceased person did not have any relatives or close friends whom the recorder could ask for an age statement. Consequently, he estimated the age by himself. Adjustment factors for these types of sources are available from the authors.

the inscriptions on tombstones in the Roman world. Age heaping on multiples of five was very common in the first centuries after Christ, with levels of age-misreporting of up to approximately 81% (Duncan-Jones 1990, p. 82).

The most important factor when calculating age-heaping levels derived from the afore-mentioned lists is that the ages of the individuals are self-reported and not counterchecked.[11] In some cases, particularly church survey data, such as marriage registers, it is possible that an ambitious priest counterchecked the ages of the bride and groom by their respective birth dates in a birth or baptism register. In the case that ages are counterchecked, we usually cannot detect any age heaping at all. Hence, if numeracy levels are extremely high, particularly in the case of very early samples of rural parishes, we should either eliminate the sample from the data set or check the possibility of high numeracy levels. We could, for example, compare the numeracy levels to the corresponding literacy rates of the parish or to the numeracy levels of regions or villages with a similar infrastructure, education system, and so on (A'Hearn et al 2009, p. 795). Generally, we can say that the further back in time the period of interest lies, and the higher the age heaping is, the more likely it is that ages are not counterchecked. In censuses executed by governmental authorities and in times in which obligatory identification did not exist, we can assume that ages are not counterchecked.

Another possible objection could be the question: whose age heaping do we measure after all? Do the statements truly reflect the pattern of the respondents or is the observed age heaping actually caused by the census taker? Critics could argue that the census taker might have estimated the ages of the people by himself or corrected those that seemed implausible to him. This potential issue has to be examined carefully for each data source. However, there are various hints that this is not the case in the studies under discussion. According to Manzel and Baten (2009, p. 48), some of the executive authorities explicitly instructed the census takers to interrogate the people individually.[12] Moreover, if the age-heaping results were influenced by the individual numeracy level of the census taker, the results of different censuses should vary within one region or country for the same birth cohorts. The authors, however, find that the

[11] Self-reporting is, of course, not an option if we consider tombstones or death registers. The ages provided in these sources reflect the heaping pattern of the individual who reported the age in place of the respective person. But even in such cases, there are gender- or social group-specific differences observable (Duncan-Jones 1990, p. 83). It is most likely that the persons providing the ages for the tombstones were related to the deceased person or at least of similar social or educational status.

[12] They found information on censuses from which it becomes clear that the authorities asked the census takers to survey each person individually.

results of different censuses display very similar levels of age heaping for the respective birth decades.

Another strong argument in favor of the self-reporting of surveyed individuals is the difference in numeracy levels that we find between occupational or social groups. Baten and Mumme (2010) as well as Tollnek and Baten (2013) reveal that better educated groups of professionals, such as merchants, show significantly higher levels of basic numeracy than unskilled or partly skilled individuals. Furthermore, A'Hearn et al (2009) show that the correlation between literacy and numeracy rates is very strong on a regional or country-wide basis. Clearly, we are only able to detect such considerable region or occupation specific differences if people stated their ages by themselves.

Related to information about households or married couples, there is a further possible question to discuss: did women report their ages themselves or did their husband help them – or even answer for them? How reliable are comparisons between male and female numeracy originating from the same source? In various studies, scholars suggest that we can rely on the age statements made by or assigned to women: according to De Moor and Van Zanden (2010, p. 202), the indexes of women and men in a Belgian census, for example, were actually not that different. Hence, it seems plausible that the individuals responded by themselves. Furthermore, they find that women sometimes displayed preferences for different numbers than men – such as multiples of the number twelve – which can only occur if the women stated their ages by themselves.

Manzel, Baten, and Stolz (2012, p. 939) also find evidence in favor of the self-reporting of household members, which is based on results from the 1744 census of Buenos Aires: if it was the case that the head of household stated the ages in place of the other family members, there should be substantial differences in the numeracy levels, because one might assume that the heads were better educated than the other members, given that he or she provided the family income and in most of the cases reported an occupation. However, the difference is almost negligible. Moreover, the authors report sources in which the interviewer made complementary remarks. Related to a certain person who reported to be 30 years old, he noted, "[…] but looked considerably older" (Manzel et al. 2012, p. 940, citing Cook 1985, p. 34). Such statements strengthen the assumption that census takers asked the people individually for their ages and did not accept someone else answering in their place. With all the results of the afore-mentioned studies and the information provided on the procedure of various censuses, we can assume that the studies discussed in this paper deliver reliable information on the basic education of the respective population.

2.2.2 Whipple, ABCC, and Other Indexes

There are various indexes we can adopt for measuring age heaping. In some cases the employed scheme varies from one study to another, depending on the author. What many of the indexes have in common, though, is the assumption that ages, stated as integers, follow a discrete uniform distribution. For example, 10% of the people in the ten-year age group from 30 to 39 are expected to report their age as 31, i.e., with “1” as the terminal digit since it is the only number ending with this digit in this ten-number interval. Applied to heaping on multiples of five, this implies that 1/5 (two out of ten) or 20% of the ages in this age group end in the digit “0” or “5”. Ó Gráda (2006, p. 129), for example, implements a simple index by observing the frequency of the numbers divisible by ten in the age groups 30–34, 40–44 etc. Observing five ages in each group should, in the simplest case, deliver the same frequency for each digit. A value greater than 0.2 (which equals 1/5) indicates a rounding pattern of the respondents. As a consequence, we expect each age to be reported by about the same number of individuals. However, we have to be careful concerning the assumptions of age distributions in general. Especially in older age groups, it is most likely that a higher share of people is alive at age 60 in contrast to those aged 69 (Crayen and Baten 2010a, p. 84).

When it comes to measuring the actual degree of age heaping, there are some desired properties that can improve the results of the indicator, as described by A’Hearn et al. (2009, p. 788). First, the index should be mathematically scale independent, which means that it delivers comparable results for two samples with the same heaping patterns but different sample sizes. The second valuable feature is the linear response to the degree of heaping, which implies that the indicator increases linearly when heaping rises. Finally, the coefficient of variation should be as small as possible across different random samples.[13]

There are several established measures with at least some of the desired properties such as the indexes suggested by Mokyr, Bachi, and Myers (Mokyr 1983;

[13] Please see A’Hearn et al. (2006, pp. 11–21) for a more detailed discussion on the properties.

Bachi 1951; Myers 1954).[14] A'Hearn et al. (2006, p. 12) state that the indicators proposed by Mokyr and Bachi are not calculated on the basis of specific expected frequencies. Hence, they do not rely on a particular assumption about which terminal digit appears with a certain frequency. However, there is a common procedure also discussed by Myers (1954, p. 826) that implies the expected proportion of each terminal digit to be 10%. For this procedure it is necessary to sum up all of the ages ending in zero, then those ending in one and so on, starting at age 20, for example. In the next step, the share of the population stating the respective terminal digit (zero to nine) relative to the whole population is calculated.[15] Consequently, each percentage share greater than ten means an overrepresentation of the ages with the respective digit. The "blended" index proposed by Myers (1954) works in a similar way as this procedure but with some adjustments: instead of starting the aggregation at age 20, he uses the terminal digits at each age between 23 and 32, for example, as the starting point. He then proceeds with the aggregation of the ages with each terminal digit (zero to nine), but instead of counting each unit digit once, it is counted several times, according to the respective "leading" digit.[16] The result of this procedure represents the relative share of the people that reported ages with the respective last digit. If there is no age heaping in the data, the percentage share of each figure should not differ largely from 10% (Myers 1954, p. 827).[17]

While the Bachi and Myers indexes are scale independent at least in the mathematical sense, none of the indexes turns out to be scale independent in the statistical sense, meaning that the mathematical scale independency does not hold in random sample settings, as A'Hearn et al. (2006, p. 18) show.[18] Each of the three indexes discussed in this section can be adopted to reveal any kind of heaping, be it rounding on multiples of five or the preference for any other of the ten digits. This might be a small advantage in contrast to indicators that can only detect a preference for multiples of five. However, there is an indicator that exceeds all of the others in terms of

[14] The Mokyr index we refer to in this section is also called the Lambda index (A'Hearn et al. 2006, p. 12).

[15] The digit "0" includes all ages ending in zero, hence, 30, 40, 50, etc. The digit "1" includes all ages ending in one, hence, 31, 41, 51, and so on.

[16] Myers criticizes that starting the aggregation at a certain age, for example 20, increases the share of people with a digit ending in zero because "[...] the 'leading' digits naturally occur more frequently among the persons counted than the 'following' ones" (Myers 1954, p. 826).

[17] For a more detailed description of the "blended" method, see Myers (1954).

[18] Statistical scale dependency means that the assumed mathematical scale independency can change when applying an indicator to random samples of different size. For more information on this topic, see A'Hearn et al. (2006, pp. 17–18).

its properties: the Whipple index. The Whipple is statistically scale independent, its expected value rises linearly with the degree of heaping, and its coefficient of variation is lower than that for the other indicators discussed (A'Hearn et al. 2009, p. 788). The Whipple index is calculated as presented in the following formula (1):[19]

$$(1)\ Wh = \frac{\sum(n_{25}+n_{30}+\cdots+n_{65}+n_{70})}{\frac{1}{5}\sum_{i=23}^{72} n_i} \times 100$$

In the enumerator, the number of individuals reporting ages ending in zero or five is aggregated. This is divided by all of the reported ages in the age range 23 to 72. Subsequently, we multiply the sum of the reported ages by 1/5 in the denominator. This is based on the assumption that 20% of all the people correctly report an age ending with zero or five. In the next step, the whole term is multiplied by 100 for a convenient interpretation. Hence, the Whipple can take on values usually ranging between 100 and 500. If exactly 1/5 of all the individuals state an age ending in a multiple of five, the Whipple takes on the value 100. In the case that all of the people state a multiple of five, the Whipple increases to 500. However, we have to be careful when interpreting this figure: a value of 500 would still mean that 1/5 of the individuals who state a heaped age, were doing so correctly. Admittedly, with an age-heaping effect of this size, we might as well assume that these individuals did not report their correct age because of age awareness. In theory, the Whipple can also take on the value zero, if no person reports a multiple of five – this would be the case of perfect "anti-heaping" (A'Hearn et al. 2009, p. 787). The Whipple increases linearly, which means that it rises by 50% whenever the proportion of people reporting a multiple of five increases by 50% (Crayen and Baten 2010a, p. 84).

Crayen and Baten (2010a, p. 84) state that because of its design, the Whipple index obviously does not account for the fact that a lower number of people are alive at higher ages. Thus, there are naturally a higher number of people reporting the age of 60 than the age of 69, even if there was no age heaping in the population otherwise. The authors suggest reducing this potential bias by calculating the Whipple for age groups of ten-year steps. Additionally, the age groups can be arranged such that the multiples of five, and especially the numbers ending with zero, are more evenly distributed within

[19] On the description and the use of the Whipple and ABCC indices see also, for example, Manzel and Baten (2009, pp. 45–46), Crayen and Baten (2010b, p. 457), Baten and Mumme (2010, Appendix, p. 35), Manzel et al. (2012, Appendix, p. 59), Juif and Baten (2013, pp. 231–233 and Appendix B, pp. 47–48), and Friesen et al. (2013, pp. 10–11).

the age groups: the first age group starts at age 23 and ends with age 32. The other age groups are arranged accordingly: 33 to 42, 53 to 62, and so on. It is more reliable to exclude individuals older than 72 years because they tend to exaggerate their age. In principle, the survivor bias effect could also play a role because people with a higher basic education might have a higher life expectancy due to a higher expected income, for example. However, Crayen and Baten (2010a, Appendix A, p. 94) showed that it did not have a large empirical impact.

It is also common to exclude the individuals younger than 23 years of age from the analysis for two reasons: First, young people often married around the age of 20 or entered military service at that time. As they often had to report their ages at such events, their age awareness is expected to be better than that of older individuals. Second, younger people tended to round their ages to a much greater degree on multiples of two than of five. Additionally, for children still living with their parents, we do not know if they reported their ages themselves or if their parents answered for them (Manzel and Baten 2009, p. 46). To account for a higher degree of heaping on multiples of two among this group, which is not captured directly by the Whipple, Crayen and Baten (2010a, Appendix A) propose an upward adjustment of the Whipple index. With this adjustment, the value of the youngest age group increases and, hence, the estimated numeracy decreases.[20]

The Whipple index combines a number of desired properties and is – after making some adjustments – a reliable measure for the degree of age heaping. However, the adopted scale and the interpretation of its outcomes are not particularly intuitive. A'Hearn, Baten, and Crayen (2009, p. 788) solved this issue by introducing another indicator which they called the "ABCC".[21] The calculation works as shown in the following formula (2):

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

[20] If the Whipple indicator is larger than 100, they suggest adding 0.2 units to the value of the age group 33 to 42 "for every Whipple unit above 100". The resulting value is aggregated to the value of the age group 23 to 32, which delivers the new estimate for this group. For example, if the value of the age group 23 to 32 is 150 and that of the age group 33 to 42 is 160, then the digit above 100 has to be multiplied by 0.2 (60*0.2=12). The result is added to the original value of those aged 23 to 32 (150+12). Consequently, the new estimate for the youngest age group is 162 (Crayen and Baten 2010a, Appendix A, pp. 95–96).

[21] The name of the index is constructed by the initial letters of the last names of the three authors including Gregory Clark's.

The ABCC is based on a linear transformation of the original Whipple index and reaches from 0 to 100. For the case of "perfect" heaping and thus a Whipple of 500, the ABCC takes on the value 0. If every person states his or her age correctly, the ABCC value increases to 100. Hence, the ABCC can intuitively be interpreted as the share of people stating their age correctly. This measure has been successfully used in a variety of studies so far (see, for example, Manzel and Baten 2009; Baten and Mumme 2010; Manzel et al. 2012; Stolz and Baten 2012; Juif and Baten 2013; Baten and Juif 2014).

Because age-heaping indicators such as the Whipple and the ABCC Index are employed to approximate basic education if other indicators are not available, it is very important that these indexes correlate with other measures. It turns out that there is a strong correlation between the share of people reporting their correct age and indicators such as literacy or schooling. Myers (1954, p. 830) finds a correlation of high literacy rates and low levels of age misreporting for Australia, Canada, and Great Britain. Duncan-Jones (1990) also reports a significant correlation between age heaping and illiteracy in a number of developing countries in the 20th century, among them Egypt (1947), Morocco (1960), and Mexico (1970). Furthermore, A'Hearn et al. (2006, p. 21) perform analyses on the relationship between age heaping and illiteracy in various countries. They detect a very strong, significant, and robust correlation between the two indicators for almost all of the 52 countries in their data set. In the very detailed analysis for the United States (US), the correlation is particularly strong, even when controlling for birthplace, ethnic group, and gender balance, and it is evident for both pooled and regional fixed effects regressions (A'Hearn et al. 2009, p. 789).

Moreover, Crayen, and Baten (2010a, pp. 90–91) tested the impact of several factors such as primary schooling, height, and state antiquity on age heaping.[22] For a global dataset, they found that school enrollment is one of the driving factors for the development of numerical abilities among societies. In all of the modifications and independent of the factors controlled for, it is always highly and significantly correlated with age heaping. Consequently, we assume that age-heaping-based indicators are valid estimators for basic education.

[22] Height is employed as a proxy indicator for infant malnutrition because the smaller a person is, the more likely it is that he or she did not have access to protein-rich nutrition which also hinders the development of numerical skills. State antiquity approximates the quality of institutions.

2.3 Applied Age-Heaping Indicators in Various Research Topics

2.3.1 Reconstructing Very Early Numeracy Differences: The Example of Inca Indios

Acemoglu, Johnson and Robinson (2001, 2002) studied the differences between former European colonies. They compare the former colonies that are rich today to those that are poor. Acemoglu et al. argue that the Europeans created exploitative institutions in the colonies that had an adverse disease environment for Europeans. In contrast, they implemented growth-promoting types of institutions in those colonies in which Europeans settled. Examples for the latter would be the US, Australia, Argentina, and South Africa, in part, whereas a classical example for the former would be West Africa. The more or less growth-promoting nature of colonial institutions translated into better or worse institutions during the late 20th century. This had an impact on today's difference in real income per capita because institutions tend to remain similar for a longer period. Applying the age-heaping technique to this topic is particularly useful because alternative views suggest a strong role of human capital channels (Glaeser et al. 2004). A related question is, for example, whether there were "pre-colonial legacies": how much did the ancient economies and societies invest before the colonialists arrived?

A paper by Juif and Baten (2013) employs an early Spanish census that was taken directly after the invasion of the Incan Empire. It makes use of the fact that basic numeracy is usually attained during the first decade of life. Clearly, the question needs to be considered whether such a birth cohort-specific analysis could be distorted by later learning processes. However, the numeracy values of the cohort born before the invasion are close to zero and thus cannot be upwardly biased. The numeracy levels of the cohorts born after the invasion, in contrast, were slowly rising. Consequently, the most important result of this study was that in fact some pre-colonial legacy – or burden – existed in Andean America. This legacy has not been reduced during colonial times, as colonial institutions such as the Peruvian *Mita* reinforced educational inequality (Dell 2010, p. 1891). During the early period, it is interesting that some Indio groups that were allied with the Spanish during the invasion (and received tax exemptions and a slightly less terrible standard of living after the invasion in return) also displayed a better numeracy. A likely interpretation is that their slightly higher net income allowed more investments in the basic numeracy of their children. This observation also stands in contrast to the suspicion that cultural attitudes could have implied a different number rounding behavior (Juif and Baten 2013, p. 235). Another problem considered by Juif and Baten (2013, p. 237) is whether colonial officials did not ask the Indio people for their age, but tended to estimate it without asking (if they estimated after asking, this would not be a problem for the age-heaping procedure because in this case the respondent did most likely not know his age either). Juif and Baten rejected these doubts in their study with arguments based on the effect that the social difference of numeracy within the Indio groups was substantial. In addition, the colonial officials sometimes explicitly noted thoughts about the appearance of a person if the self-reported age and the official's impression differed. This clearly indicates that the Indio people were in fact asked for their age. As a result, this earliest numeracy study for a non-European country revealed that a negative pre-colonial legacy was in fact very likely (Juif and Baten 2013, p. 239).

2.3.2 Religion and Numeracy

A number of scholars have recently studied potential religious determinants of human capital formation (see Becker and Woessmann 2009 for a widely cited study and a good overview). The relative exogenous character of religious rules has been stressed by this literature because beliefs about the necessity to read religious texts are considered to be less influenced by economic factors and profit-maximizing educational investment decisions. Botticini and Eckstein (2007) explained how religious rules for the provision of education of one's (male) offspring appeared in the Jewish faith. In the first century BCE, a conflict between two influential religious factions of Judaism took place. One of these factions, the Pharisees, stressed the religious duty to educate, and they gained stronger influence on Judaism than the other group (Botticini and Eckstein 2007, p. 891). Botticini and Eckstein emphasize that the "education rule" was not economically motivated because the large majority of the Jewish were farmers and rural day laborers, for whom a substantial educational investment would not yield sufficient returns during this period. Only with the substantial urban growth in Mesopotamia during the 8th and 9th centuries CE could the Jewish population living there use their religiously determined education to achieve profitable positions as merchants and, later on, as bankers (Botticini and Eckstein 2007, pp. 908–909). Medieval Western Europe actually first tried to attract this religious and occupational group because the kings of England and France assumed correctly that government revenues might increase. The famous restriction of Jewish population groups to being exclusively merchants, bankers, and other traders – occupations that were forbidden to the Christian population – was only created later, during the High Middle Ages. Botticini and Eckstein (2007) therefore reject the hypothesis that this restriction caused high Jewish educational levels.

The debate over religious differences of education and numeracy in particular has important implications for history and for our understanding of human capital formation. For that reason, Juif and Baten (2014) studied the differences between the average population and the persons who were accused by the inquisition of practicing Jewish beliefs in Iberia and Latin America. The period under study runs from the 15th to the 18th centuries. The sources that are available for this early period were primarily created by the inquisition. A question about the age of the accused was included for identification purposes. Besides the evidence from the inquisition lists, they also included census-based numeracy evidence to compare the average population in the same regional units. The authors studied potential selectivities and biases intensively and dismissed them ultimately. The most important result of this study of religion and numeracy is that persons who were accused of being Jewish had a substantially higher numeracy than the average population. If we accept the working hypothesis that most of the persons accused of Judaism came from families of a different educational behavior (and a different educational self-selection), the religious factor appears to be of important influence. However, the authors also find that the catholic elites (such as priests) had a substantially higher numeracy compared to the average Iberian and Latin American population.

2.3.3 Path Dependency of Early Numeracy and Land Inequality as Determinants of Modern Math and Science Skills?

Within the framework of Unified Growth Theory, Galor, Moav, and Vollrath (2009) have focused on land inequality as one of the crucial obstacles to human capital formation. They describe the political economy of regions and countries with higher and lower land inequality, assuming an influential role of two different elite groups: large landowners and industrial capitalists. In regions with lower land inequality, industrialists wielded larger relative power in the decision making process concerning educational investments. In contrast, in regions with high land inequality large landowners remained in power and were not particularly interested in spending their taxed income for primary schooling: First of all, their agricultural day laborers did not have to be educated to fulfill their manual tasks (at least that is the traditional view).

Secondly, additional primary schooling would have increased their burden of taxation. Thirdly, educated workers might have moved to cities or may even have initiated land reforms. In a study of this land inequality effect on modern math and science skills, Baten and Juif (2014) also include early numeracy (around 1820) as the second main determinant. They find that early numeracy has a large explanatory share, even after controlling for land inequality and a number of other factors. It seems that this path dependency worked via economic specialization: if an economy specialized early on the production of human-capital-intensive products, the relatively high income allowed investing in education for the next generation. In addition, such human-capital-intensive production methods probably resulted in substantial switching costs – hence, the countries specialized in this type of production and developed a branding and reputation for their products. As a consequence, they were most likely entering a high degree of path-dependency.

2.4 The Development of Numerical Skills in Different World Regions and Time Periods

2.4.1 A Human Capital Revolution in Europe

A'Hearn et al. (2009) discuss the development of numeracy all over Europe from the late middle ages to the early modern period. The European countries experienced a striking increase in numeracy during this time period, which can be identified as a "human capital revolution". While the numeracy values rose in all of the European countries, there was variation between the different parts of Europe. The Western European countries showed an exceptional development. As early as around 1450, the Netherlands represented numeracy values (approximated by the ABCC index) of roughly 70% (A'Hearn et al. 2009, pp. 801, 804).[23] Britain and France surpassed this value at around 1600 and 1650, respectively. Britain and Denmark, on the other hand, already experienced numeracy rates of 90% or more in the period of 1700. While Denmark's rates grew continuously until the end of the period at around 1800, Britain's values remained at the same level.

[23] The data are arranged in age groups and then transferred into birth half centuries. Hence, the value of the respective age group is subtracted from the census year. The resulting value is rounded to 50-year-intervals. For example, if the census year was 1740, then the age group 23 to 32 was born in the half century 1700.

The picture looks similar if we look at Central Europe (A'Hearn et al. 2009, pp. 801, 803). Austria and Protestant Germany already had high numeracy levels of between 78% and 87% around the period of 1600. Catholic Germany had lower values (68% in circa 1700), but increased its numeracy strongly thereafter. The Eastern European countries, in contrast to the rest of Europe, lagged slightly behind: around 1600, Bohemia represented numeracy values of only 44%. One period later, around 1650, Russia and Hungary showed levels of 43% and 32%, respectively. However, toward the end of the early modern era at approximately 1800, the overwhelming majority of the European countries managed to increase their human capital values significantly. Even the regions that lagged behind, such as Bohemia and Russia, reached numeracy levels well above 80% or close to 90% (A'Hearn et al. 2009, pp. 801, 805).

2.4.2 Numeracy Levels in Latin America

Manzel, Baten, and Stolz (2012) analyze long-term trends in numeracy for a number of Latin American countries from the 17th to the beginning of the 20th century. Some of the countries, such as Argentina and Uruguay, experienced strong increases of human capital throughout the whole time period that are comparable to those of some European countries. While Argentina started with an ABCC value of less than 20% in the birth decade 1680, it reached values of almost 70% around 1800 (Manzel et al. 2012, p. 954).[24] With an exceptional increase during the 19th century, Argentina reached almost full numeracy at the beginning of the 20th century. The development of Uruguay is similar, showing even higher numeracy levels than Argentina in parts of the 19th century. Despite such great examples of convergence, some of the Latin American countries underwent a process of divergence during the 19th century: in Colombia, Mexico and Ecuador the ABCC levels stagnated. While Mexico started off well with continuously growing numeracy levels from 1680 to 1790, there was almost no improvement throughout the 19th century. Ecuador's levels even worsened slightly during the 19th century. Brazil was a particular case because it began with increasing levels of numeracy during the 18th century, then experienced a short period of stagnation at the first half of the 19th century and managed to increase human capital

[24] The values for Argentina and Mexico are estimates based on regression results. They are controlled for capital effects and male share. For further information, please see Manzel et al. (2012). The data of all of the countries are arranged in birth decades. Hence, the value of the age group is subtracted from the census year and the resulting value is rounded to 10-year-intervals. For example, if the census year was 1940, then the age group 23 to 32 was born in the decade 1910.

again in the following decades (Manzel et al. 2012, p. 954). Toward the beginning of the 20th century, numeracy levels rose considerably in all of the observed countries.

2.4.3 Industrialized Countries vs. the Rest of the World?

Crayen and Baten (2010a) assess long-term trends of numeracy in 165 countries all over the world. The development of some industrialized countries not discussed so far is of interest: the US started with ABCC values below 87% at the beginning of the 19th century, which are among the lowest numbers compared to the other industrialized countries in the same period (Crayen and Baten 2010a, p. 85).[25] Toward the middle of the 19th century, the values of the country increased significantly to around 94%. The US converged continuously in the following decades and reached values of circa 98% at the end of the 19th century. Spain had values of about 88% around 1830. The increase of Spain's numeracy developed more slowly than that of the US, but it also reached levels close to 100% at the beginning of the 20th century. Exceptional cases are also Greece and Cyprus, which had values below 75% and 78%, respectively, at the end of the 19th century. However, their rates increased dramatically throughout the 20th century. Ireland is one of the few industrialized countries in which the ABCC index decreased slightly in the 1870s, which is likely due to the behavior after the Great Famine that took place two decades earlier (Crayen and Baten 2010a, p. 85).

The comparison of world regional numeracy trends reveals some crucial differences. South Asian countries had the highest age-heaping levels with ABCC values of less than 13% around 1840 (Crayen and Baten 2010a, p. 87). The numbers increased steadily throughout the following decades, reaching an ABCC index of above 55% toward the 1940s. The Middle East and North Africa had the second lowest levels of numeracy with values lower than 25% in the 1820s. Egypt most likely had the highest age-heaping level in this region with an ABCC of almost 0 (the case of "perfect" heaping) (Crayen and Baten 2010a, p. 86). But similar to South Asia, the Middle Eastern and North African countries managed to increase their numeracy levels continuously (Crayen and Baten 2010a, p. 87). The industrialized countries were on the upper range of the strata with the highest numeracy levels. East Asia still had ABCC levels of below 88% at the beginning and toward the middle of the 19th century.[26] In

[25] Crayen and Baten (2010a) use the Whipple index for all of their calculations. We translated all of the numbers into ABCC values for convenience.
[26] East Asia is dominated by Chinese data, since Japan is considered part of the industrialized countries.

only a few decades, though, age heaping in China decreased strongly and vanished around 1880. South East Asia and Latin America ranged between the regions with fairly high and relatively low levels of age heaping.

2.5 Numeracy Trends of Women and the Gender Gap in Different World Regions

2.5.1 Numeracy Trends of Women in Some Industrialized Countries

Gender equality in education and wages is a controversial topic. Even in countries with relatively high levels of income and education, such as the European countries or the US, there is an ongoing debate about wage differentials between men and women. Women with the same degree of education and experience often receive considerably lower wages than their male counterparts working in the same field or position.

But what about educational differences between men and women before formal schooling became accessible for most people? When did the gender gap open and did it worsen or improve over time? Duncan-Jones's (1990, p. 86) analysis of inscriptions on tombstones reveals a numeracy difference between men and women in Roman times that is most likely the earliest measurable gender gap. Although the age reported on the tombstone supposedly reflects the numerical abilities of a relative, the ages of women show a higher heaping pattern than those of men. The indicator implemented by Duncan-Jones represents the percentage share of people who report a rounded age, relative to those who state their age correctly.[27] While in some regions, such as Moesia or Pannonia, the women had considerably higher heaping levels than the men (28.1 and 17.1 percentage points) the differences were relatively small in most of the other regions: in Mauretania, for instance, the women's index was only 4.8 percentage points higher than the men's index. In Rome, the difference was 6.8 percentage points. However, there were also regions in which women had lower heaping values, such as Italy outside Rome (-1.9 percentage points).

De Moor and Van Zanden (2010) assess human capital levels in the medieval and early modern Low Countries. The results of the numeracy levels of Bruges in Belgium (1474–1524) suggest that the differences between women and men were

[27] He subtracts the 20% of the people who report a multiple of five correctly from the total number of people who state a rounded age. Hence, the reported percentage share contains those who incorrectly state a rounded age.

relatively small in total: the men have an ABCC index of about 85% and the women 83% (De Moor and Van Zanden 2010, p. 194).[28] In the city of Bruges, the women even surpassed the men slightly.[29] The authors also found similar results for Holland during the 16th to 18th centuries. The gender gaps were small then and women sometimes had higher numeracy levels than men.

For the US, Myers (1954, p. 830) reports that women showed significantly higher levels of age heaping than men in the 1950s. For the other countries included in his study – Australia, Canada, and Great Britain – he detects only very slight differences in age misreporting between women and men in the late 1940s or early 1950s. In Great Britain, women reported their ages even more precisely than men in that time period.

2.5.2 The Gender Gap in Latin America

The previous examples suggest that in particular regions and time periods, women's access to basic education was not as limited as one might have expected. However, we have to keep in mind that the Low Countries, for example, are different from many other countries with respect to the position of women in the society. Men and women already seemed to have had a relatively equal standing in the household in early modern times (De Moor and Van Zanden 2010, p. 182). But what about the basic education of women in the rest of the world?

Manzel and Baten (2009) assess the development of women's basic education for a large number of countries in Latin America via age-heaping-based indicators. They perform their analyses following a fundamental theory about labor force participation developed by Goldin (1995). Goldin finds that the labor force participation of women is described by a "U-shaped" pattern over time Goldin (1995, pp. 62–63). In societies with low income and low levels of education, women engage to a large degree in home production of agricultural goods and work on family farms. At this stage of the process, labor force participation shares are high for both men and women. With increasing levels of income and technological advancement, more women are tied to household activities and child care, while men work in factories, for example, where new production techniques overcome the traditional home production. Hence, women's

[28] De Moor and Van Zanden (2010) use the Whipple index. We translate the results from the Whipple index into ABCC levels for convenience.
[29] The women, however, represent higher values at the "Dozen Index" that detects rounding behavior on multiples of twelve. This is likely due to religious practices among Catholics (De Moor and Van Zanden 2010, p. 202).

level of labor market participation declines. According to Goldin (1995, pp. 67–68) one possible reason for that development could be that women's work in factories is socially stigmatized. The third stage of the process is observable in countries that have reached a high level of income and education. Women are able to achieve higher degrees of education and enter "white-collar" occupations that are less stigmatized than manufacturing work. In this last phase of the U-shape, women participate actively in the labor force again.

Manzel and Baten (2009) were able to confirm this pattern based on numeracy estimates for 28 countries in Latin America and the Caribbean from 1880 to 1949.[30] Instead of testing the relative labor force participation of women, they implement "the relationship between average education and the ratio between female and male education" as an indicator to demonstrate the U-shaped development (Manzel and Baten 2009, p. 40). As a general measure of educational equality between men and women, they subtract the Whipple index of men from that of women and divide the result by the Whipple of men. This is subsequently multiplied by -100 for convenient interpretation. If the outcome is positive, the women have a numeracy advantage over the men (and the other way round, if the index is negative). The positive index is defined as "gender equality" in basic education. It turns out that the equality index is negative for most of the countries. However, for some of the countries with high levels of basic numeracy throughout the time period, the equality is relatively high as well, indicating the last stage of the U-shape hypothesis. This is the case for Argentina and Uruguay as well as Guyana and Suriname, meaning that gender equality increases if basic education is well-established in the society in general (Manzel and Baten 2009, pp. 50–51). The ABCC values for Argentina, to state an example, reach from about 95% to 100% and the equality index is slightly above zero (Manzel and Baten 2009, p. 51 and Appendix p. 69). In Guatemala and the Dominican Republic, for example, the authors find the opposite effect, namely low basic numeracy and low equality indexes. Colombia, however, has ABCC levels between roughly 80% and 90%, while the equality index ranges between approximately -24 and -10, meaning that women have large educational disadvantages in Colombia at the beginning of the period, which decrease over time (Manzel and Baten 2009, pp. 50–51 and Appendix pp. 69–71). But there are also cases such as Haiti where numeracy is low, whereas gender inequality is not observable,

[30] The data are arranged in birth decades.

indicating the first stage of the U-shape hypothesis. In general, the non-Hispanic parts of the Caribbean represent considerably higher equality indexes as well as higher ABCC levels than the Latin American countries during the whole time period.[31] Toward the end of the period equality rises with increasing levels of basic numeracy in all of the countries. In Latin America, the ABCC values increase from roughly 78% in 1880 to about 93% in the 1940s and in the non-Hispanic Caribbean from about 90% to 99% (Manzel and Baten 2009, p. 52). The equality values increase from less than -12 to about -5 in Latin America and from roughly -3 to slightly above zero in the non-Hispanic Caribbean (Manzel and Baten 2009, p. 55). The ABCC and equality values of the Hispanic Caribbean are mainly lower compared to the values of Latin America.

To test the U-shaped hypothesis, Manzel and Baten perform a regression analysis with the equality index as the dependent variable, controlling for a number of other factors such as female voting rights and a democracy index (Manzel and Baten 2009, p. 58–59). The most important factors for the U-shape are the ABCC values to approximate basic education: they are included as a linear parameter to control for initial levels of education and they are added as squared values to test for higher levels of education. As a result, the linear (and hence lower) ABCC values have a significant and negative impact on equality, while higher levels of education (squared ABCCs) have a significant and positive impact on gender equality. The authors also plot the estimated values to illustrate the U-shape: the downward slope tends to be smooth, whereas the upward slope is strongly observable in the data. Hence, they demonstrated that Goldin's hypothesis also applies to basic education in Latin America and the Caribbean.

2.5.3 The Gender Gap in Asia

Friesen, Baten, and Prayon (2013) test the U-shape hypothesis for 14 countries in Asia from 1900 to the 1960s.[32] They use the ABCC index to approximate basic numeracy. Furthermore, they employ the educational gender equality index based on the Whipple index in the same way as Manzel and Baten (2009) did. Besides the age-heaping-based

[31] The low inequality of non-Hispanic countries might be due to the institutional framework created by slavery. As both men and women were torn away from their home countries and had to work equally, the "traditional" gender roles did not evolve as they did in other countries. Besides, Caribbean women tended to work outside their own household more often than their Latin American counterparts (Manzel and Baten 2009, p. 44).

[32] Included countries are: Afghanistan, Bangladesh, India, Iran, Sri Lanka, Nepal, Pakistan, Hong Kong, Indonesia, Cambodia, Federation of Malaya, Sarawak, the Philippines, and Thailand.

indicators, Friesen et al. (2013, p. 7) discuss literacy and school enrollment rates in the Asian countries in the dataset that clearly indicate high levels of inequality between men and women.

The analysis of the ABCC values provides further information on basic education between the sexes, especially when enrollment rates are not available for some of the regions. The authors find different results for the women's ABCC indexes among the observed regions: the vast majority of Southeast Asian women were already numerate around 1900, especially in Hong Kong and Thailand, while Indonesia lagged slightly behind (Friesen et al. 2013, pp. 18, 38). However, the picture looks different for women in South and West Asia: while Sri Lanka began with ABCC values of around 59% in 1900 and reached almost full numeracy in the 1950s, all of the other countries in this region reflected values far below. Women from Pakistan and Bangladesh had the lowest levels, not even reaching values of 50% toward the end of the period (Friesen et al. 2013, pp. 16, 20).

The equality index primarily reflects the different stages of the U-hypothesis. In the countries with very low human capital values for both women and men, such as Pakistan, Bangladesh, and India, equality values are only slightly below zero, indicating relative equality between women and men (Friesen et al. 2013, p. 23). This is also the case for the countries with high numeracy values, for example Hong Kong and Thailand, for which the equality values range slightly below or above the zero line (Friesen et al. 2013, p. 25). The equality indexes of most of the other countries lie considerably below zero (for example in Indonesia or Sri Lanka). Most of the countries with negative values experienced an increase toward the end of the period, which in some cases even turned the negative into a positive index, such as in the Philippines. The opposite effect takes place in Afghanistan, for instance. While the inequality is not as high around 1910 (about -12), it decreases continuously until reaching a value below -60 in the 1950s (Friesen et al. 2013, p. 23).

In the next step, the authors test the U-hypothesis in different regression models in which the equality index is the dependent variable. They control for factors such as female voting rights and religion. The most important determinant, the ABCC index, is included as a linear and a squared parameter (as in Manzel and Baten 2009). The results for the ABCCs are always highly significant and the correlation is negative for the linear ABCCs and positive for the squared ones. Furthermore, Friesen et al. (2013, p. 35) plot the regression results to illustrate the fitted values. The scatter plot shows an exact U-shaped pattern. Hence, the assumption of low gender inequality at low levels of human capital, rising inequality at increasing levels of education and, in the last phase, high levels of education and equality is fulfilled in the analysis of the 14 Asian countries under study.

2.6 Conclusion: The Impact of Numerical Abilities on Growth

In this article we showed that the age-heaping technique provides a unique opportunity to approximate basic education, especially in pre-industrial times. One might argue, though, that the mere knowledge of numeracy levels between different countries, for example, does not contribute to achieve a higher goal. However, although numeracy correlates strongly with literacy, number discipline might even have a larger impact on the development of market exchange (see, for example, De Moor and Van Zanden 2010). In many cases, we do not even know what literacy measures exactly: a broad range reaching from "is able to read and write" to "is only able to sign with his name" is possible. On the other hand, numeracy, or the ability to count, is the basis for participating actively in market mechanisms and for the emergence of capitalism. Crayen and Baten (2010a) show that numerical skills, in fact, have a strong impact on growth patterns across different world regions. In their analysis, the authors regress GDP growth rates on various factors, "growth capabilities", such as initial GDP levels and numeracy, approximated by the Whipple index, as well as a number of other control variables. It turns out that numeracy has not only a significant but also an economically meaningful impact on the growth rates of the included countries. Hence, the economy of those countries displaying higher levels of numeracy also grows at a faster pace than the economy of the countries with lower numeracy. All in all, we showed that age-heaping-based human capital estimates provide the opportunity to track potential reasons for the divergence of countries or world regions in the very long run.

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3 Farmers at the Heart of the "Human Capital Revolution"? Decomposing the Numeracy Increase in Early Modern Europe

Abstract:

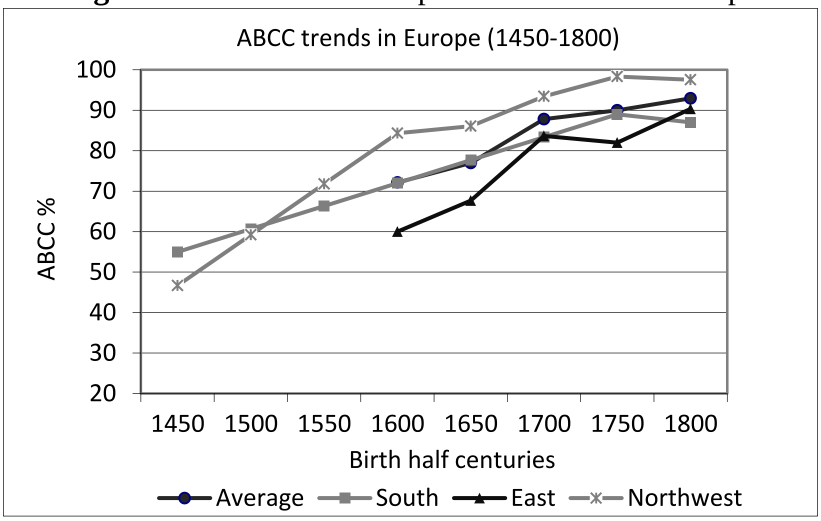
Did the early development of skills and numerical abilities occur primarily in urban centers and among the elite groups of society? In this study, we assess the human capital of different occupational groups in the early modern period and partially confirm this finding: the skilled and professional groups had higher skills than persons in unskilled occupations. However, there was another large group that developed substantial human capital and represented around one-third of the total population: farmers. By analyzing numeracy and literacy evidence from six countries in Europe and Latin America, we argue that farmers significantly contributed to the formation of human capital and, consequently, modern economic growth.

This chapter is based on an article by Tollnek and Baten (2017), which is published in the *Economic History Review*. Article First Published Online: 5 Mar 2017, DOI: 10.1111/ehr.12382. The version of the article included in this doctoral thesis is equal in contents, but includes minor deviations in the text. The concept of the paper was jointly developed, analyses and writing were equally shared.

3.1 Introduction

A'Hearn, Baten, and Crayen (2009) observed an enormous increase in numeracy in early modern Europe between the 15th and 18th centuries, which preceded the Industrial Revolution. They studied the numeracy development in a number of European countries using the ABCC index, which is based on the share of people able to report their ages exactly.[33] Modern evidence indicates that the age-heaping phenomenon can be implemented to develop an indicator of basic numeracy. The underlying method considers the share of individuals who are able to state their precise age on an annual basis, in contrast to those who report an age rounded to a multiple of five (stating, for example, "I am about 35" when they might be 34 in reality) (A'Hearn, Baten, and Crayen 2009, p. 788). European numeracy increased from below 50% before 1500 to more than 90% in the 19th century, describing the most rapid increase in human history observed so far (Figure 3.1). Hence, some authors termed it the "human capital revolution" (Baten 2016, pp. 74–75).[34]

Figure 3.1: The Human Capital Revolution in Europe



Note: Values refer to birth half centuries around the years noted. Evidence is based on A'Hearn, Baten, and Crayen (2009), Table 4. We included all countries for which longer series or at least early values

[33] The age-heaping technique to measure numeracy is explained in greater detail in section three of this chapter. The term "ABCC" results from the three initial letters of the authors' last names including Gregory Clark's who commented on their paper.

[34] This is a true revolution because the nearly 50 percentage-point-increase is comparable to the difference between the poorest and wealthiest economies of the early 20th century. Crayen and Baten (2010, p. 87): south Asia had a numeracy of 52% in the 1940s, whereas the wealthiest countries had achieved full numeracy. Thus, Europe was transformed from a half-numerate into a mainly numerate continent during this revolution. The differences between the European regions are also interesting: southern Europe evolved the fastest in the late Middle Ages, but the well-known overtaking of Northwestern Europe is also visible in the numeracy record. Africa and most of Asia did not experience strong increases in numeracy until approximately 1800. Thus far, we know little of the development in East Asia, but China's position declined around 1860.

were available: "Northwest" is Great Britain, Netherlands and protestant Germany, "South" is Italy (North). "East" is the average of Russia, Bohemia and Austria (from around 1600). "Average" is the average of those three regions. When values between benchmark dates were missing, they were interpolated. Weak estimates (in italic in Table 4 of A'Hearn et al.) were omitted. For Great Britain and Netherlands before 1600, the benchmark year of Great Britain 1600 was used, and the changes from Germany (protestant).

A similar substantial increase in numeracy did not occur as early in other world regions where evidence exists. We would like to understand this dramatic change, as it is arguably one of the core developments in human history.[35] One strategy to gain insights into the process of this educational revolution is to disaggregate the population by occupational groups and answer the following question: which occupational groups served as the basis for the early modern human capital revolution? Based on the emphasis that numerous studies place on urban skills, the most likely candidates would be urban occupational groups such as merchants or skilled craftsmen (Epstein 1998, pp. 684, 705–706; Van Zanden 2009, p. 143; Minns and Wallis 2012, p. 575). In a similar vein, Clark suggested that the wealthy and "capitalist" groups of society provided their offspring with favorable skills (Clark 2007, ch. 6). We expect that numeracy and in some occupations also literacy were crucial to the successful completion of an apprenticeship. Houston summarizes this stating a "generally superior literacy of towns and cities" (Houston 2002, p. 146). However, other scholars argued that also rural population groups experienced a strong increase in education (Graff 1987, pp. 154–155). A closer look at the human capital development of rural population groups provides substantial insights. Therefore, our initial hypothesis is the following:

(1) The early human capital revolution primarily occurred in urban centers. The relatively well-educated groups of craftsmen, traders, and professionals took the lead, whereas the farming (and unskilled) population groups followed after a long delay.[36]

While we partially confirm this hypothesis (skilled urban residents developed well), we propose a second hypothesis:

(2) Farmers had developed substantial human capital already by the 18th century, which contributed significantly to the early modern numeracy increase.

[35] For a cause-or-consequence discussion of education, institutions, trade and wages, see Allen (2003, pp. 404–405, 414, 418–427).

[36] We refer to "farmers" or the "farming group" here as those individuals whose livelihoods came from farming activities. These individuals had medium-sized or larger farms or lived at least self-sufficiently. Persons for whom the information indicated that they did not control land were not included in the farmer category. We did not include day laborers or servants who might have worked or lived on a farm. In section four of this chapter, we discuss the heterogeneity of the farmer group and construct subcategories.

The explanation behind this second hypothesis rests on two pillars: Firstly, the proximity to food production implied that farmers' offspring suffered less from malnutrition, which is an obstacle to cognitive development. Therefore, we present evidence on the relatively low level of protein malnutrition of farmers and their families. Secondly, the income position of farmers was favorable in the 18th century and might have improved over the early modern period. A part of this additional income was reinvested into education (for a detailed discussion, see section three of this chapter).

In our analysis, we include a number of countries in Europe and Latin America: Austria, Germany, Spain, Southern Italy, and Uruguay. We intentionally include a New World economy to which Europeans emigrated in substantial numbers, as emigration was an option available to many Europeans during this period. Considering only those who remained in Europe could be regarded as analyzing a biased sample. To assess the education of farmers using an additional human capital indicator, we also compare literacy evidence from Switzerland and Northern Germany.

To assess these hypotheses, we consider evidence from the early modern period – primarily the 18th century – which enables us to study the relative positions of farmers and other occupational groups. Focusing on the numeracy towards the end of the revolutionary process (but before it ended in the 19th century) has the advantage of allowing us to create a robust database with substantial variation. If we assume that initial levels were low for most of the occupational groups before the human capital revolution began, we can interpret a numeracy increase as a result of this process. In a final section, we present preliminary evidence on occupation-specific numeracy before the early modern human capital revolution – while also highlighting the limitations of these early sources.

How did we select the sources for the study? We collected all available evidence that contained both occupation and age statements for this period. An important requirement was that our sources should not be socially selective, but instead the recording personnel sought to interview every individual in a given regional unit (specifically, every male, as we excluded females from our analyses[37]) (Table 3.1). Furthermore, the sources should not contain a substantial regional bias. Thus, we

[37] For females, it was less clear whether the (missing) occupational statements reflected their real situation. Some of them might not have reported an occupation even if they worked jointly with their husband and fulfilled the same tasks. Including female occupations yields nearly identical results, as can be seen in an earlier working paper version of this study.

included various regions of a given country and urban and rural locations. However, for Italy we were only able to representatively address the southern part of the country.

Table 3.1: Data Sources for the Early Modern Period

Country and Region	Survey Years	Survey Type	Source
Austria			
Carinthia	1757	CC	Vienna Database on European Family History. Numeric data file, Version 0.1 [SPSS file]. Vienna: University of Vienna, 2003, http://wirtges.univie.ac.at/famdat/.
Lower Austria	1751, 1754, 1762, 1787		
Upper Austria	1762		
Salzburg	1750, 1755, 1762, 1794		
Tirol	1781		
Germany			
Baden-Wuerttemberg	1749, 1758, 1771	CC	*Landeskirchliches Archiv Stuttgart* (Archive of the Protestant Church in Stuttgart): Deposit (Microfilm) No. 653–655, 657, 1110, 1904; *Diözesanarchiv Rottenburg* (Archive of the Diocese in Rottenburg): Deposit No. 19662–19663.
Holstein	1769, 1803	GC	*Arbeitskreis Volkszahl Register*: www.akvz.de (accessed 5 Oct. 2016).
Lower Saxony (Literacy data)	1675	CC	Von Husen, Gerhard C. (2003): "Seelenregister von 1675 der Ev.-Luth. Kirchengemeinde Abbehausen." In: *Oldenburgische Gesellschaft für Familienkunde e.V.* Kirchhatten.
North Rhine-Westphalia	1749, 1750	CC	*Westfälische Gesellschaft für Genealogie und Familienforschung*: http://www.genealogy.net, http://www.rheineahnen.de/listdoc/statusa1.htm (accessed 5 Oct. 2016); *Stadtarchiv Lippborg* (City archive of Lippborg): Deposit "Catalogus Familiarum Parochiae Libborgensis de dato 20. Martii 1750."
Rhineland-Palatinate	1799, 1804	CC	"Census of the French": *Landeshauptarchiv Koblenz* (Main Archive in Koblenz): Deposit 612, No. 3522, 4241–4243, "Einwohnerverzeichnisse".

Table 3.1: Data Sources for the Early Modern Period – Continued

Country and Region	Survey Years	Survey Type	Source
Italy			"Catasto Onciario":
Brindisi	1742	GC	http://www.cosenzaexchange.com/ comune.html (accessed 5 Oct. 2016).
Cosenza	1742/43, 1749, 1753/54		
Napoli	1754		*Archivo di Stato di Napoli*; http://www.cosenzaexchange.com/ comune.html (accessed 5 Oct. 2016).
Vibo Valentia	1741, 1743, 1745/46, 1754		http://www.archicalabria.it/Default.asp (accessed 5 Oct. 2016).
Toscana	1427		"Catasto Toscano": http://cds.library.brown.edu/projects/ catasto/overview.html (accessed 5 Oct. 2016).
Spain		GC	"Catastro de la Ensenada":
Granada	1750, 1752/53		*Archivo Histórico Provincial de Granada:* Deposit "Catastro de la Ensenada, Respuestas Particulares".
Guadalajara	1751/52		*Archivo Histórico Nacional*, Madrid: Deposit "Libros de Familias de la Provincia de Guadalajara".
Malaga	1752		*Archivo Histórico Provincial de Granada:* Deposit "Catastro de la Ensenada, Respuestas Particulares".
Soria	1752/53		*Archivo Histórico Provincial de Soria:* Deposit "Libros de Vecinos de la Provincia de Soria".
Toledo	1752/53		*Archivo Histórico Provincial de Toledo:* Deposit "Libros de Familias de la Ciudad de Toledo", No. H00688; *Archivo Regional de la Comunidad de Madrid*: Deposit (Microfilms) "Libros de Familias", No. MC009726, MC009673.
Switzerland			
Canton of Zurich (Literacy data)	Several years between 1634-1698 and 1708-1764	CC	*Staatsarchiv Zuerich* (National Archive of Zurich): Deposit "Visitationsprotokolle", No. 1634–1764, E II 210–2171.
Uruguay		GC	"Padrones" (Censuses):
Canelones	1826		*Archivo General de la Nación,* Montevideo: Deposit "Libros de los Padrones", No. 246, 148; http://pueblosynumeros.fcs.edu.uy/ (accessed 5 Oct. 2016).
Montevideo	1773, 1836		
Maldonado	1779, 1780		*Archivo General de la Nación Argentina*: Deposit Sala IX 20-4-3.

Note: CC stands for "Church Censuses", GC for "Governmental Censuses". If one census or soul register is used for several regions in a country, the type of survey and the source are only listed once. If the type of source is given once for a country, all of the surveys have the same type. However, the data sources may be different in this case.

Table 3.2: Rank of Countries in Europe and European Settlements by Numeracy Around 1820

Country	**Numeracy around 1820**
Sweden	100
Finland	100
Denmark	100
Switzerland	**99**
Belgium	99
Netherlands	99
Norway	98
Germany	**98**
France	97
Czech Republic	96
Austria	**96**
Estonia	96
UK	95
Canada	95
Hungary	89
Bulgaria	89
Romania	86
Spain	**85**
Italy	**85**
Portugal	85
USA	85
Ireland	84
Latvia	83
Slovakia	81
Uruguay	**79**
Poland	77
Argentina	66
Russia	64
Lithuania	59
Serbia	57
Greece	55
Moldavia	55

Note: Included are countries for which both (a) estimates for numeracy in 1820 existed and (b) in which a substantial number of persons of European descent lived. Source: Baten and Juif (2014).

To provide insights into the representativeness of the countries included in our study, we look at their rank in the numeracy distribution of European countries and European settlements during the early 19th century (Table 3.2).[38] The Scandinavian countries had already achieved complete basic numeracy by around 1820, while the western European countries were close behind. In contrast, Eastern Europe and parts of Southern Europe

[38] A comprehensive set of numeracy estimates does not exist before 1820.

exhibited a substantial deficit. Comparing our sample countries (indicated by bold letters in the table) to this distribution, we find that our data were representative of the middle three-quarters of European countries and European settlements – ranging between Switzerland and Uruguay – when sorted by numeracy.

3.2 Literature Review and Theoretical Model

Graff (1987, pp. 137–163) studied the development of literacy in Northwestern and Central Europe during the 17th and 18th centuries. He identified a number of literacy campaigns that aimed at improving the educational level of the population. However, these campaigns were not always successful because the public funds for improving education were often not provided in sufficient amount. Moreover, not only literacy – which was taught in schools – but also numeracy was at the heart of early development. The latter was more often acquired outside of schools, in the families and households. Werner Sombart and Joseph Schumpeter argued that the medieval Italian revolution in merchant economies depended to a great extent on the acquirement of mathematical skills and the introduction of techniques such as bookkeeping (A'Hearn et al. 2009, p. 784).

Between the 18th and 20th centuries, the world changed fundamentally from a world determined by agriculture to a world of industrial and service sector employees. During the 20th century, the agricultural sector suffered from low income and declining shares of national output. Industrialization seemed to be the key to income growth, and economists and economic historians subsequently used the share of employment outside of agriculture as a proxy indicator for income.

In prior studies, the authors often assumed that the basis for economic growth and increasing income emerged almost exclusively in urban centers; Bosker, Buringh, and Van Zanden (2013, p. 1418) stated that numerous authors who analyzed long-term trends in economic development empirically employed "the number of cities, or urbanization rates as the most reliably available proxy of economic success". Acemoglu, Johnson, and Robinson (2002, p. 1232), for example, used urbanization in 1500 as their "main measure of economic prosperity", presuming a strong relationship between per capita income and urbanization. Consequently, they employed urbanization as a proxy indicator for GDP per capita (see also Acemoglu, Johnson, and Robinson 2005, p. 552). North and Thomas (1973, pp. 114–115) assumed that the Western World experienced "a decline in productivity in agriculture, constant productivity in manufacture and increasing productivity in the transaction sector of the market" during the 16th century. All of these assumptions and proxy indicators imply declining productivity in rural areas, while growth in urban sectors was set to be equal to income growth. This literature tends to support our hypothesis (1) that urban population groups were the main driver of the enormous increase in human capital in early modern Europe. But does this reasoning imply that farming groups did not contribute to the increase? How educated were farmers before the Industrial Revolution fundamentally changed the world?

For two reasons we would expect farmers to achieve a relatively high numeracy. One is the proximity-to-food effect, the other high relative incomes.

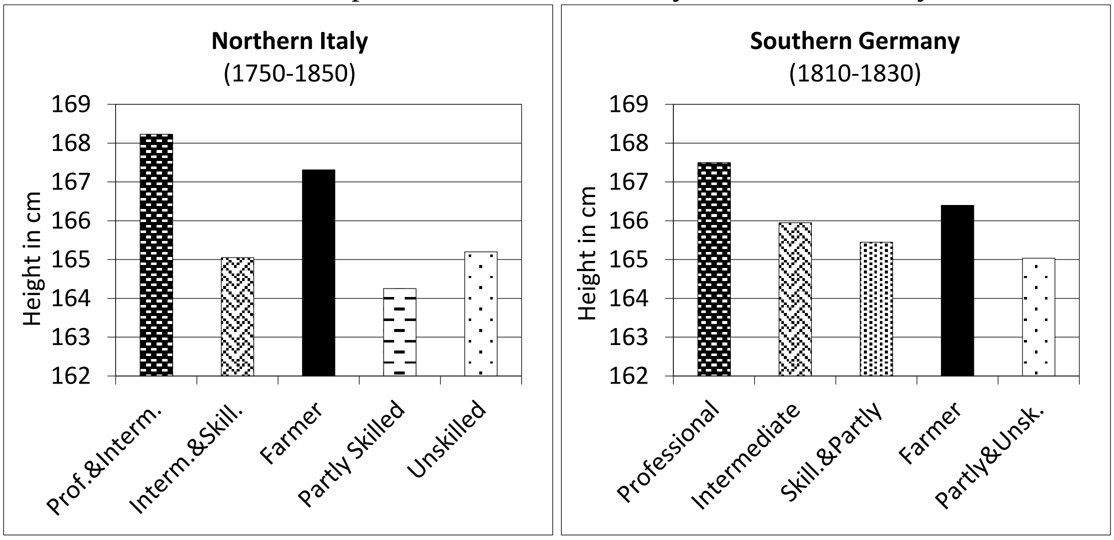
(1) We first discuss the proximity-to-food effect. A large body of literature has assessed the evidence that childhood nutrition matters strongly for cognitive ability and educational success. Baten, Crayen, and Voth (2014, pp. 419–420) recently reviewed the evidence. Malnutrition, particularly during the first 1.5 years of life, is a strong forecasting indicator of limited cognitive abilities (Lloyd-Still 1976, ch. 5). Paxson and Schady (2007, pp. 49–50) assessed whether height can be used as an indicator of cognitive abilities. They found that cognitive test scores for children of lower height were significantly lower relative to the taller ones (see also Magnusson, Rasmussen, and Gyllensten 2006, pp. 658–663).[39] Baten et al. (2014) also studied the "natural experiment" of the Napoleonic blockade in the early 1800s that caused malnutrition among the poorest. The cognitive ability and hence the numeracy of the British "blockade cohorts" was lower. Those who suffered the most from this starvation period during their first decade of life developed lower numeracy rates than others and were not able to find work in high-income occupations when competing with cohorts born before or after them. This development was the more pronounced the more vulnerable a social group was: unskilled workers and poorer craftsmen suffered systematically from malnutrition in periods of famine. Farmers, however, were one of the least vulnerable population groups (Baten et al. 2014, p. 427). In times of food crises they were able to sell a lower share of their products on the market such that their family would have a more or less sufficient amount of food to consume. Consequently, farmer children had a clear advantage relative to descendants of other occupational groups that had no direct

[39] Paxson and Schady (2007, pp. 49–51) concluded that the environmental impact – and nutrition in particular – on cognitive ability is great (which is also confirmed by twin studies).

access to nutrition. Thus, farmers were able to develop favorable cognitive skills – including numeracy – that have not been recognized by previous research.

One strategy to assess the relative nutrition of farmers is the anthropometric history method. Most scholars who were able to differentiate between occupations in their studies, particularly those that could identify parental occupations, found that farmers and farmers' sons were significantly taller than individuals from other occupations, except for the small elite group of the professionals (Figures 3.2.1–3.2.2 show the examples of Northern Italy and Southern Germany).

Figures 3.2.1–3.2.2: Height by Occupational Group,
for the Examples of Southern Germany and Northern Italy



Note: Sources: A'Hearn (2003), Baten (2000). For the Italian data, the intermediate professions were not separately listed but instead partly included in the professional group, and partly among the skilled. For Southern Germany, the partly skilled were not separately listed, but partly included among the skilled, and partly among the unskilled. For similar evidence on Austria-Hungary, see Komlos (1987).

(2) One reason for their high nutritional status and the investment in their children's education might be that farmers had high incomes relative to the population average. However, farmer income is difficult to assess for the 18th century because income evidence for the self-employed is scarce. Earlier studies focused mainly on wages of agricultural and industrial laborers, whereas studies with evidence on the incomes of self-employed craftsmen and farmers are very scarce. Furthermore, the heterogeneity within the "farmer" and "craftsman" categories poses a challenge, if average incomes should be estimated. Related to the farming group, there was a lot of variation concerning farm sizes, soil qualities and market access. Similarly, the term "craftsmen" includes persons fulfilling low human-capital intensive tasks (such as shoemakers, some textile and food processing etc.), but also entrepreneurs in big cities who employed lots

of workers and earned big fortunes.

One option to estimate average income would be to consider inheritance records, if we assume a correlation between income and wealth at death. However, the initial (inherited) wealth is often unknown and wealth at death also depends on the saving behavior during the lifetime of an individual. Studying early 19th-century German farmers, Kopsidis (1996, ch. 5) found that farmers had much higher saving rates than craftsmen.

What did recent studies find about relative incomes of farmers and craftsmen? For example, in Central Spain, the net median income of farmers was estimated as being around 650–700 Reales, similar to that of craftsmen, which was around 700 Reales (Fernando Ramos Palencia).[40] The gross income of farmers was higher, so if they managed to hide some of their income, they were probably slightly richer than craftsmen. For mid-19th century Northwestern Germany, Kopsidis estimated that a typical farmer with 10–20 hectares of land earned a similar net income as a craftsman (which was around 550 Marks annual income, 1861–1865). The evidence is less conclusive in other countries; most authors estimate average farmer incomes as being higher than for rural craftsmen (Switzerland: Pfister 1992, ch. 4), but lower than for urban artisans who usually employed additional labor (on Northern Italy, Guido Alfani provided a ranking in personal communication; see Appendix E.3).

Farmer incomes might have been fairly favorable in the 18th century, because their income increased stronger relative to craftsmen incomes over the preceding early modern period. The main argument in favor of this view is that population grew much stronger than arable land. Sources of income that later were generated by the Industrial Revolution were not yet widely available. Consequently, wages and other non-land income were more under pressure than land-based income. Particularly in regions in which farms were not divided into smaller plots over time, farmer incomes increased in relative terms. It is not unlikely that farmers reinvested some of this (relative) income increase into the education of their children. This might have taken place by teaching them in the family or by allowing them for more leisure and providing games that promoted numeracy.[41] In conclusion, we think that both factors, income and proximity

[40] Based on estimations by Fernando Ramos Palencia, whom we thank for personal communication.

[41] Even if farmers had a sufficiently high income to pay for schools, the logistic situation in rural areas was more adverse than in urban areas where distances were shorter so that children and teachers could meet more easily. This supports the role of nutrition being more favorable for farmer children. Moreover, social differences grew in the countryside during the early modern period. Rural day laborers did not have

to nourishment, mattered for the explanation that farmers developed a high numeracy.[42] These factors also interacted with and reinforced each other because higher income enabled better nutrition even independently of proximity effects, and better nutrition allowed higher labor productivity.

But, was numeracy at all desirable in an agrarian economy? Would education not be a burden if a farmer was required to perform dull and manual tasks in the field? We argue that while a high share of manual labor is characteristic of farm work, numeracy could increase productivity. A productive farmer was a person who would consider numerous weather indicators, for example. An incorrect decision about the specific day when the hay cutting or the grain harvest should begin could cause substantial income or welfare losses. In addition, the treatment of cattle diseases and the protection of crops against insects and parasitic plants were more efficient if a farmer was more educated and numerate.[43] Moreover, farmers who were able to count could negotiate the prices for their goods with intermediaries or directly with consumers on the market. While this is more of an advantage for larger farmers, smaller subsistence farmers also had incentives to be numerate: De Moor and Zuijderduijn (2013) demonstrate that smallholders in the Netherlands who lived in a market town and possessed at least a house or a small piece of land actively participated in asset markets. With the increase in trade and commercialization during early modern times, farmers with an interest in profits started to keep account books and followed price changes on the markets (Houston 2002, p. 107). Being able to count strongly increased their opportunities of participating in such activities. In addition, the monetization, commercialization, and the increase of piece work in the early modern economy required further numerical skills. The evolving labor and product markets required a certain mathematical knowledge, such as division, when they kept their accounts.[44] In Christopher Wase's words in 1678 (as cited in Thomas 1987, p. 108), "Even in hedging and ditching, men […] that comprehend Lines and Numbers, […] will be Master Work-men among the other laborers."[45]

the means to send their children to school. Hence, the critical mass of pupils needed to establish schools was often not achieved.

42 An additional obstacle to education could be the work load imposed on children. It is likely that the children of the poor suffered more from working during early youth, which prevented them from learning. Graff (1987, pp. 259–261).

43 On fertilizer use, see Huffman (1974, pp. 94–95).

44 Thanks to a referee for this hint.

45 Further evidence of farmers being educated is provided by Lorenzen-Schmidt (2002, p. 45), who

A better understanding of the environmental conditions required to maximize the output is a strong motive for farmers to acquire basic skills. In 18th-century Germany, calendars became bestsellers among the farmer population (Graff 1987, p. 142). This indicates that their numeracy and literacy enabled them to make use of the hints about meteorological evidence and other contents provided in these calendars.

Does this mean that for farmers numeracy was more important than for craftsmen and traders? This view would be an exaggeration. Numeracy skills were important for farmers, but they were also – and particularly – crucial for industrial and commercial self-employed persons who had to rely mainly on their skills (rather than their control over land).

Was there perhaps even selection by numeracy into the farmer occupation? A tentative answer can be given by considering inheritance of farms and father-son-relationships. In our dataset, for 728 young farmers, the occupation of their father is recorded. For 91% of those young farmers, we find that the father was also a farmer. Most likely, the son could expect to inherit the farm and was therefore indicated as a farmer. Hence, it seems unlikely that selection into the farmer occupation did play a substantial role (see Appendix F.3).

In summary, we argue that farmers were able to acquire relatively high numeracy for two reasons: (1) Farmers had the advantage of sufficient food security, as they were able to determine the share of their products that they would sell on the market. The church and the feudal lords initiated legal attempts to constrain farmers' decision making, but the farmers found means of concealing a share of their production. (2) The incomes of farmers were relatively high and might have increased to a certain extent during the early modern period.

However, the question remains: in which way did farmers and other rural population groups acquire their basic education in times in which schooling was rare, particularly in rural areas? Because sending children to school was often related to high costs, farmers with higher incomes had presumably better access to the few existing schools. Nevertheless, many studies conclude that basic numeracy is not only obtained at school, but to a large extent in the household, for example, by children playing games that stimulate their numeracy (Baten, Ma, Morgan, and Wang 2010, p. 357). Any child

mentions the existence of loans between peasants in Northern Germany from the 16th century onwards. "Weather-books", which were written by peasants in 16th-century Denmark, contained not only guidelines for weather forecasting, but also practical advice on farming (Stoklund 2002, pp. 87–95).

that does not suffer from malnutrition, an enormous amount of child labor or other constraints develops a natural curiosity and wants to learn.[46]

Another large strand of literature focuses on regional and religious differences in formal education. Among the countries included in this study, the educational situation of the northern and western European countries was better than for the southern and eastern areas. In many of the German states, the educational situation was relatively favorable in terms of schooling. A further, intermediate group consisted of Spain and the Habsburg Empire. Southern Italy, on the contrary, belonged to the least favored European regions related to formal education (Houston 2002, pp. 52–53).

Concerning religion, Protestantism presumably has a positive influence on numeracy. Protestants were usually better in reading and writing than their Catholic counterparts (Becker and Woessmann 2009, pp. 534–537). For Protestants, reading books – particularly the Bible – was an important part of their faith. However, there were also Catholic areas with high literacy levels (Houston 2002, pp. 37, 148). Therefore, we test for the impact of religion in the German data in section four of this chapter.

3.3 Data Characteristics and Potential Selectivity Issues

In the age-heaping analysis, we include five countries in Europe and Latin America: Austria, Germany, Spain, (Southern) Italy, and Uruguay.[47] To guarantee data comparability, we only include male individuals aged between 23 and 62 and born in the decades from 1700 to 1800. To complement the numeracy analysis, we use evidence on literacy from Switzerland and Northern Germany. The literacy data cover the birth decades from 1560 to 1730 to guarantee a sufficient number of observations.[48] It would have been possible to include England as well, but this would have exceeded the format

[46] Reis (2005, pp. 208–213) also emphasizes the positive emotions associated with learning.
[47] At this point, we thank several people for data entry: Frank Neupert (*Landeshauptarchiv Koblenz*) provided the data on Rhineland-Palatinate, Jan Neu contributed data mainly on the Catholic areas of Baden-Wuerttemberg, Gregor Babrowski and Sarah Hueller provided data on Southern Spain and Guadalajara, Ana-Carmela Melone contributed some of the Southern Italian data. Carolina Vicario provided the largest part of the Uruguayan data and Daniel Grad shared data on Swiss and Northern German literacy with us.
[48] To make the data comparable, we divided the Swiss data into two main periods for the analysis of reading skills, 1560–1650 and 1660–1730. Furthermore, we include those aged between 23 and 72 to guarantee a sufficient number of observations in the groups. Concerning the acquisition of literacy skills, age does not play an important role as it does in the case of numeracy. The robustness test yielded similar results. Critical on other literacy sources: Núñez (2003, p. 538).

of this article, given that the literature on England is extremely large. Additionally, England is a special case that deserves a separate study.

Table 3.3: Total Number of Observations by Country and Region

Country	Region	Data Type	No. of obs.	Percent
Austria	Carinthia	AH	289	7.3
	Lower Austria	AH	579	14.6
	Upper Austria	AH	328	8.3
	Salzburg	AH	2,328	58.8
	Tirol	AH	438	11.1
	Total		3,962	100.0
Germany	Baden-Wuerttemberg	AH	808	11.7
	Holstein	AH	4,234	61.5
	Lower Saxony	LIT	353	5.1
	North Rhine-Westphalia	AH	885	12.9
	Rhineland-Palatinate	AH	603	8.8
	Total		6,883	100.0
Southern Italy	Brindisi	AH	58	1.7
	Cosenza	AH	1,157	34.1
	Napoli	AH	138	4.1
	Vibo Valentia	AH	2,038	60.1
	Total		3,391	100.0
Spain	Granada	AH	1,671	27.8
	Guadalajara	AH	685	11.4
	Malaga	AH	127	2.1
	Soria	AH	1,013	16.8
	Toledo	AH	2,521	41.9
	Total		6,017	100.0
Switzerland	Canton of Zurich	LIT	1,160	100.0
Uruguay	Canelones	AH	44	1.7
	Maldonado	AH	858	32.8
	Montevideo	AH	1,710	65.5
	Total		2,612	100.0
Dataset AH	Total	AH	22,512	
Dataset LIT	Total	LIT	1,513	
Dataset	Total		24,025	
Additional data				
Central Italy	Toscana	AH	13,765	100.0

Note: AH=Age-heaping data, LIT=Literacy data. Sources: See Table 3.1.

Table 3.4: Observation Numbers by Occupational Group and Country (A), Unweighted Percentages (B), and Weighted Percentages (C)

	Austria	Germany	S. Italy	Spain	Switzer-land	Uruguay	Total
A	Obs.	Obs.	Obs.	Obs.	Obs.	Obs.	Obs.
Professional	255	375	280	400	32	136	1,478
Intermediate	403	978	59	582	40	143	2,205
Skilled	1,183	1,861	719	1,623	402	568	6,356
Partly skilled	211	467	393	667	93	53	1,884
Unskilled	988	1774	109	1,714	224	1,139	5,948
Farmers	922	1,428	1,831	1,031	369	573	6,154
Total	3,962	6,883	3,391	6,017	1,160	2,612	24,025
B	%	%	%	%	%	%	%
Professional	6.4	5.4	8.3	6.6	2.8	5.2	6.2
Intermediate	10.2	14.2	1.7	9.7	3.4	5.5	9.2
Skilled	29.9	27.0	21.2	27.0	34.7	21.7	26.5
Partly skilled	5.3	6.8	11.6	11.1	8.0	2.0	7.8
Unskilled	24.9	25.8	3.2	28.5	19.3	43.6	24.8
Farmers	23.3	20.7	54.0	17.1	31.8	21.9	25.6
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0
	Weighted percentages age-heaping data					Total Europe	
C	%	%	%	%			%
Professional	4.3	3.6	8.5	4.5			4.9
Intermediate	9.2	11.0	1.9	6.4			7.7
Skilled	23.3	24.0	21.6	21.8			22.8
Partly skilled	3.1	7.3	11.5	11.2			8.3
Unskilled	28.4	28.8	3.4	32.1			25.4
Farmers	31.7	25.3	53.2	23.9			30.9
Total	100.0	100.0	100.0	100.0			100.0

Note: A: observation numbers; B: percentages; C: weighted percentages. The dataset contains the following birth decades: Austria: 1700–1760; Germany (age-heaping data): 1700–1770; Germany (literacy data): 1600–1640; Southern Italy, Spain: 1700–1720; Switzerland (literacy data): 1560–1730; Uruguay: 1710–1800. Because the data from Switzerland cover a very long time period, we divide the sample into two periods for the analysis of reading skills: 1560–1650 and 1660–1730. S. Italy stands for Southern Italy. Sampling weights are calculated such that the urban observations correspond to the actual urbanization rates of the countries (if rural samples are underrepresented, they are weighted higher). Urbanization rates were not available for Uruguay. See Appendix A.3 for information about the urban weights. There are only rural observations from Switzerland. "Total Europe" stands for the European age-heaping data. Weighted percentages are only calculated for the age-heaping data because the literacy data stem only from rural areas. Sources: See Table 3.1.

With a total number of 24,025 observations (Table 3.3), this comprehensive dataset provides us with the opportunity to study the differences in basic education between various occupational groups. Because the process of numeracy formation within farming groups is a core issue of our study, a sufficient number of farmers and persons with other occupations who have control over main farming decisions is important. With a total number of 6,154 individuals with farming occupations (Table 3.4, A), this analysis is feasible on a broad and representative basis. The large group of farmers is subsequently divided into a group of medium-sized or larger farmers and another, representing smallholders (Table 3.5).

Table 3.5: Observation Numbers and Percentages of the Farmer Groups by Country

		Austria	Germany	S. Italy	Spain	Switzer-land	Uruguay	Total
		Obs.	Obs.	Obs.	Obs.	Obs.	Obs.	Obs.
1	Medium-sized/ larger farmer	768	1017	134	1,031	108	519	3,577
2	Smallholder	148	389	1,697	-	261	54	2,549
3	Other/mixed	6	22	-	-	-	-	28
	Total	922	1,428	1,831	1,031	369	573	6,154
		%	%	%	%	%	%	%
1	Medium-sized/ larger farmer	83.3	71.2	7.3	100.0	29.3	90.6	58.1
2	Smallholder	16.1	27.2	92.7	-	70.7	9.4	41.4
3	Other/mixed	0.7	1.5	-	-	-	-	0.5
	Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Note: The three different groups contain the following labels: *Austria*: 1=*Bauer*, 2=*Haeusler*, *Halbbauer*, 3=someone who lives of farming, but cannot clearly be aggregated to one of the first two groups. *Germany*: 1=*Hufner*, Partial *Hufner* (>=1/2 *Hufe*), property with land & agriculture, *Bauer*, *Colonus*, *Landwirt*, *Ackersmann*, 2=*Kaetner*, *Koetter*, *Haeusler*, Partial *Hufner* (<1/2 *Hufe*), 3=someone who lives of farming, but cannot clearly be aggregated to one of the first two groups. *S. Italy*: 1=*massaro*, 2=*bracciale*. *Spain*: 1=*labrador*. *Uruguay*: 1=*labrador*, *estanciero*, *quintero*, 2=*chacarero*. *Switzerland*: 1=*Bauer*, *Großbauer*, 2=*Kleinbauer*, *Haeusler*, *Kaetner*. See also Appendix D.3 for further information. Germany: because the division of partial *Hufner* is less clear-cut, we additionally control for different farmer groupings by including the individuals with at least 1/12 of a *Hufe* in the medium-sized or larger farmer group. Sources: See Table 3.1.

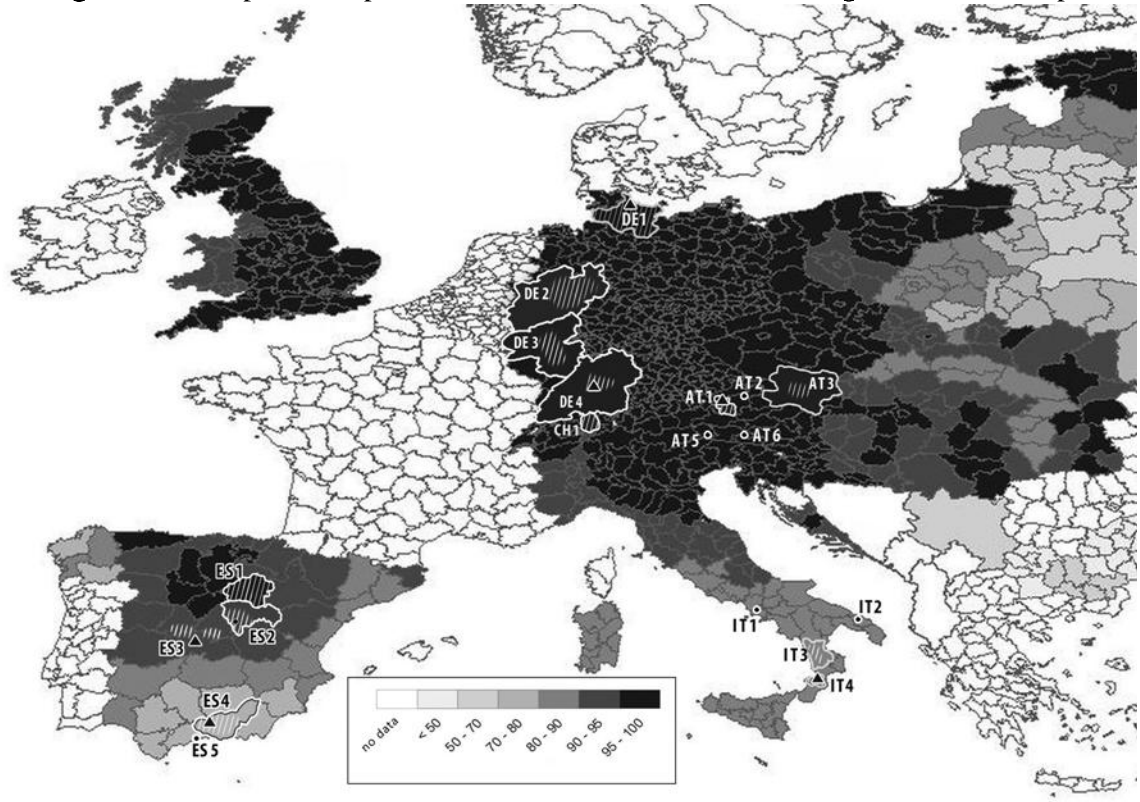
The datasets of the various countries stem from surveys in which information on families and households is reported. Our sources originate from governmental censuses on the one hand and from church censuses (*Libri Status Animarum*: soul registers) on the other (Table 3.1). The only difference between those two types of sources is that the governmental surveys include the entire population of a given place or region, while the church censuses only include members of a certain confession. Nonetheless, this difference is negligible because the territories under study were religiously fairly homogenous. In Germany, there were both Protestant and Catholic areas, but within a given territory, usually only one of the religious groups was represented.[49]

In Switzerland and Northern Germany, priests visited the families in their homes and asked them explicitly about their reading and writing skills, which they had to prove in most cases. This allows us to study literacy by occupational group. The data we

[49] There is only one of the religious groups per place included; hence, we do not have substantial religious minority groups within one place.

include from the censuses taken by the church or the local government are not socially selective to a significant degree. However, we need to carefully discuss the possibility of regional selectivity. The countries in our dataset are represented by a substantial number of regionally diverse observations, even if the availability of sources generates a stronger focus on certain regions in some of the countries (Figure 3.3).

Figure 3.3: Map of European ABCCs in the 1840s and the Regions of the Sample



Note: We report the modern boundaries (not the historical ones) to allow modern readers identifying regions. Sources: Map: Own illustration on basis of a map from Hippe and Baten (2012, p. 278). Data sources: See Table 3.1.

Legend

 indicates the regions from which data are available

● indicates the place of a region from which data are available (if there are not more data available from this region)

▲ indicates the urban places from which data are available:
Austria: Salzburg, Germany: Kiel and Ludwigsburg, Spain: Toledo and Granada, Italy: Monteleone

AT indicates the Austrian regions from which data are available:
AT 1: Salzburg, AT 2: Upper Austria (Gmunden), AT 3: Lower Austria, AT 4: Carinthia (Sirnitz), AT 5: Tirol (Villgraten)

CH indicates the Swiss regions from which data are available: CH 1: Zurich (Canton)

DE indicates the German regions from which data are available:
DE 1: Holstein, DE 2: North Rhine-Westphalia, DE 3: Rhineland-Palatinate, DE 4: Baden-Wuerttemberg

ES indicates the Spanish regions from which data are available:
ES 1: Soria, ES 2: Guadalajara, ES 3: Toledo, ES 4: Granada, ES 5: Malaga (Estepona)

IT indicates the (Southern) Italian regions from which data are available:
IT 1: Napoli (Crispano), IT 2: Brindisi (Carovigno), IT 3: Cosenza, IT 4: Vibo Valentia

Italy is represented by its southern regions, primarily covering rural areas, villages, and a small city, Monteleone.[50] For 18th-century Southern Italy, the data are fairly representative because various regions are included. The German age-heaping evidence contains data from throughout the country, including its southern, western and northern regions. We have slightly more evidence from the north because there were a larger number of sources available. The German regions contain both rural observations and cities (south: Ludwigsburg, north: Kiel). The German data on literacy skills stem from a rural parish in Lower Saxony in Northern Germany, Abbehausen. For Spain, we have data from several provinces of the country, including its northeastern, central and southern regions. The data cover both rural areas and two representative cities, one in the center, Toledo, and another in the south, Granada. Granada had an important service sector for trade and administration, while Toledo was a center for the production of swords and other metal-related products. The Uruguayan data include rural observations from three different provinces in the south of the country, and urban observations from the city of Montevideo. As the country was rather scarcely inhabited in the northern region during the observed period, the population from the southern areas can be considered representative. For Switzerland, we have literacy evidence from the canton of Zurich, which lies in the center of the country, containing a number of rural locations.

To assess the representativeness of our data, the map (Figure 3.3) contains the numeracy levels of the European countries in the 1840s and the location of the urban and rural places our data stems from. The observations are fairly evenly distributed across the educational types of regions within the countries considered. Where data from only one urban place were available (as in Southern Italy), it was located in the center of the rural regions, such that the urban and rural samples are comparable. Because we are mainly interested in occupational differences, slight deviations from regional representativeness should be less crucial, but we need to take care that the urban and rural sample components are appropriately weighted.[51] By weighting the observations, we ensure that a potential oversampling of urban observations, for example, does not lead to an overrepresentation of urban occupations.[52] The robustness check without sampling weights delivers relatively homogeneous results.

[50] City definition: > 5,000 inhabitants.

[51] The samples are weighted such that urban observations precisely represent the respective urban shares of the countries in the early modern period. Thus, the rural observations receive a higher weight to ensure that the urban samples are not overrepresented (see also Appendix A.3).

[52] Due to data availability, urban locations are oversampled in Germany, Austria, and Spain, whereas the

The classification we use to organize the occupational groups is a compromise of the HISCLASS and Armstrong schemes (Van Leeuwen and Maas 2011, ch. 4; Armstrong 1972, pp. 215–223; Van de Putte and Buyst 2010, pp. 15, 23). The Armstrong scheme suggests six different occupational categories. The professionals, primarily individuals with a higher education, such as merchants, doctors, and lawyers, are represented in the first group. Additionally, the remaining members of the upper strata of society were included in this group (mayors, the nobility). Individuals with occupations such as administrators and clerks represent the second group, the semi-professionals (or intermediate). The third group contains skilled persons who typically completed several years of apprenticeship, including craftsmen and similar professions. Furthermore, we include partly skilled individuals, such as herdsmen (who do not own animals) and rope makers in the fourth group. Unskilled persons without a degree of formal education, such as servants and day laborers, are classified into the fifth group (see also Appendices C.3 and D.3).

The individuals with farming occupations are allocated to their own category.[53] Differentiating whether a person is a farmer or a large landowner, for example, is achieved using the term employed in the respective language. If we consider the Spanish census, for example, a farmer, as we define the term in this study, was always indicated by the word *labrador*, while a large landowner would be indicated by the word *hacendado*. In contrast, persons indicated as "agricultural laborers" were classified into the unskilled group.[54] The farmers were most likely able to nourish themselves and their families, even during times of higher food prices, whereas the poorer population groups, such as agricultural laborers, were not (see, for example, Appleby 1975, p. 1). Concerning the distribution of cases among the groups, see Table 3.4, B.

The HISCLASS scheme is a newly created approach, which consists of twelve major groups. It considers not only the skill level, but also the level of supervision (Van Leeuwen and Maas 2011, pp. 52–57). In our case, the groups need to be condensed into seven groups because some of the highly skilled categories are represented by small

Southern Italian data approximately represent the appropriate urban share. By applying representative, country-specific weights to the samples, the share of farmers increases to approximately 32% in Austria, 25% in Germany and 24% in Spain, while southern Italian farmers represented 53% of the occupational groups. Overall, the share of farmers amounts to approximately 31% in all of the European countries considered in this study (Table 3.4, C).

[53] Large landowners are assigned to the professional group.

[54] When distinguishing between occupational groups, we had to rely on the expressions used for the occupations in the original surveys. The groups are formed as homogeneously as possible based on the translation.

numbers (see also Maas and Van Leeuwen 2005, p. 280). Divided into seven major groups, the HISCLASS categories resemble the Armstrong groups to a large extent. Two differences are (1) the division of unskilled laborers into agricultural and other workers and (2) the categorization of farmers with small plots.

On (1), HISCLASS differentiates between unskilled farm workers and other unskilled workers. This represents a difficulty for the 18th-century census data because for the majority of workers (simply "day laborers"), it is impossible to decide whether a person works on a farm or for a rural craftsman. One potential way to address this problem is to keep the workers in urban areas in the unskilled (non-farm) group, and allocate all rural (unskilled) workers to the "unskilled farm group". However, this ignores that many worked for rural craftsmen. The second option is to assign all of the day laborers to the unskilled workers, again implying measurement error.

On (2), small subsistence farmers are assigned to the group "lower and unskilled farm workers" in HISCLASS. Hence, there is no differentiation made between a poor day laborer who works on a farm and a small subsistence farmer who has at least a small piece of land at his disposal and some animals over which he has the decision power. We instead decided to use a compromise between the HISCLASS and Armstrong scheme, taking the idea of supervision from the HISCLASS scheme. Consequently, if we learned from our lists that craftsmen had more than three employees, we classified them as entrepreneurs into a higher occupational group, while assigning smallholders to the farming group (see also Appendices C.3 and D.3).[55]

3.4 Methodology

To assess our hypothesis that farmers enjoyed numerical advantages, we perform several steps of analysis. First, we conduct descriptive analyses in which we measure the human capital levels of the occupational groups and countries using the age-heaping technique. Second, we analyze literacy by occupational group to test our hypothesis using an additional human capital indicator. Third, we conduct regression analyses to determine the significance of our results.

[55] As the "usual" classifications yield almost identical results, we kept them as they were defined in the Armstrong scheme. The Armstrong scheme also allows including the number of employees as a criterion of classification.

We employ the age-heaping technique as an estimator of numeracy. Therefore, we calculate the percentage shares of the heaped ages using the so-called "ABCC" index, which is based on the Whipple index (under the assumption that circa 20%, or one-fifth, of all ages end in a five or zero in the true age distribution):[56]

$$(1)\ Wh = \frac{\sum(n_{25}+n_{30}+\cdots+n_{60})}{\frac{1}{5}\sum_{i=23}^{62} n_i} \times 100$$

For a more convenient interpretation, A'Hearn, Baten, and Crayen (2009, p. 788) developed the ABCC index, which is derived from a transformation of the Whipple index. It delivers an estimate of the proportion of individuals who are able to state their ages precisely:

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

Of course, age-heaping-based indicators are not immune to potential biases. One concern could be whether the census taker influenced the level of heaping, for example, by correcting age statements that seemed implausible to him.[57] Another doubt could refer to questions such as "Do you know your year of birth?" in case the person seemed not to know his (precise) age. If the person knew his correct year of birth, the interviewer would – in case he was numerate – be able to calculate the exact age. If ambitious census takers asked for more detailed information and received it, it is possible that we observe numeracy on the upper bound of the strata. In this case, the interpretation of differences between occupational groups is still valid. However, it is unlikely that such questions led to more precise age statements for several reasons. First, in societies with considerable heaping because of age non-awareness, it is unlikely that people knew their year of birth, but not their age. Second, even when individuals were asked for both age and year of birth, such as in the US census of 1900, considerable age (and/or birth year) heaping was still present (A'Hearn, Baten, and Crayen 2009, pp. 788–789; Crayen and Baten 2010, p. 84).

[56] For a detailed overview and the use of the following two indices see Tollnek and Baten (2016) or chapter two, section two of this thesis as well as Manzel and Baten (2009, pp.45–46), Crayen and Baten (2010b, p. 457), Baten and Mumme (2010, Appendix, p. 35), Manzel et al. (2012, Appendix, p. 59), Hippe and Baten (2012, p. 261), Juif and Baten (2013, pp. 231–233 and Appendix B, pp. 47–48), and Baten (2016, pp. 6–8), for example.
[57] A hint could be if statements were replaced by other numbers. This is not the case in the original documents we were able to look through.

The share of persons able to state an exact age is highly correlated with other indicators of human capital, such as literacy and schooling, across countries and over time (see, for example, Mokyr 1983, ch. 8; Crayen and Baten 2010, pp. 88–91). A'Hearn et al. (2009, Appendix) find that illiteracy and age heaping were strongly correlated in less developed countries. The correlation coefficient between age heaping and illiteracy was approximately 0.7, while the correlation with the results from the famous PISA (Program for International Student Assessment) study for mathematical skills even amounted to approximately 0.8. This phenomenon was observed for a large number of countries.

To determine the differences in the numerical skills via a regression analysis, we create a binary variable "numerate" that takes a value of zero if the person reported a rounded age ending in zero or five and, otherwise, a value of one for the numerate. Clearly, 20% of the population may have correctly reported ages ending in zero or five. To account for this bias, we proceed as follows: the regression coefficients reflect the case in which the dependent variable's conditions are met ("numerate"=1), meaning that the person reported an exact age. However, we know that this outcome only represents 80% of the precise age statements, as 20% of those who reported a multiple of five ("numerate"=0) were also doing so correctly. By increasing the outcome coefficients by 20%, we account for the downward bias of correct age statements ending in a zero or five. We achieve this by multiplying the coefficients by 1.25 (and by 100 to obtain percentages) (see also Juif and Baten 2013, p. 233 and Appendix B.3 of this thesis).

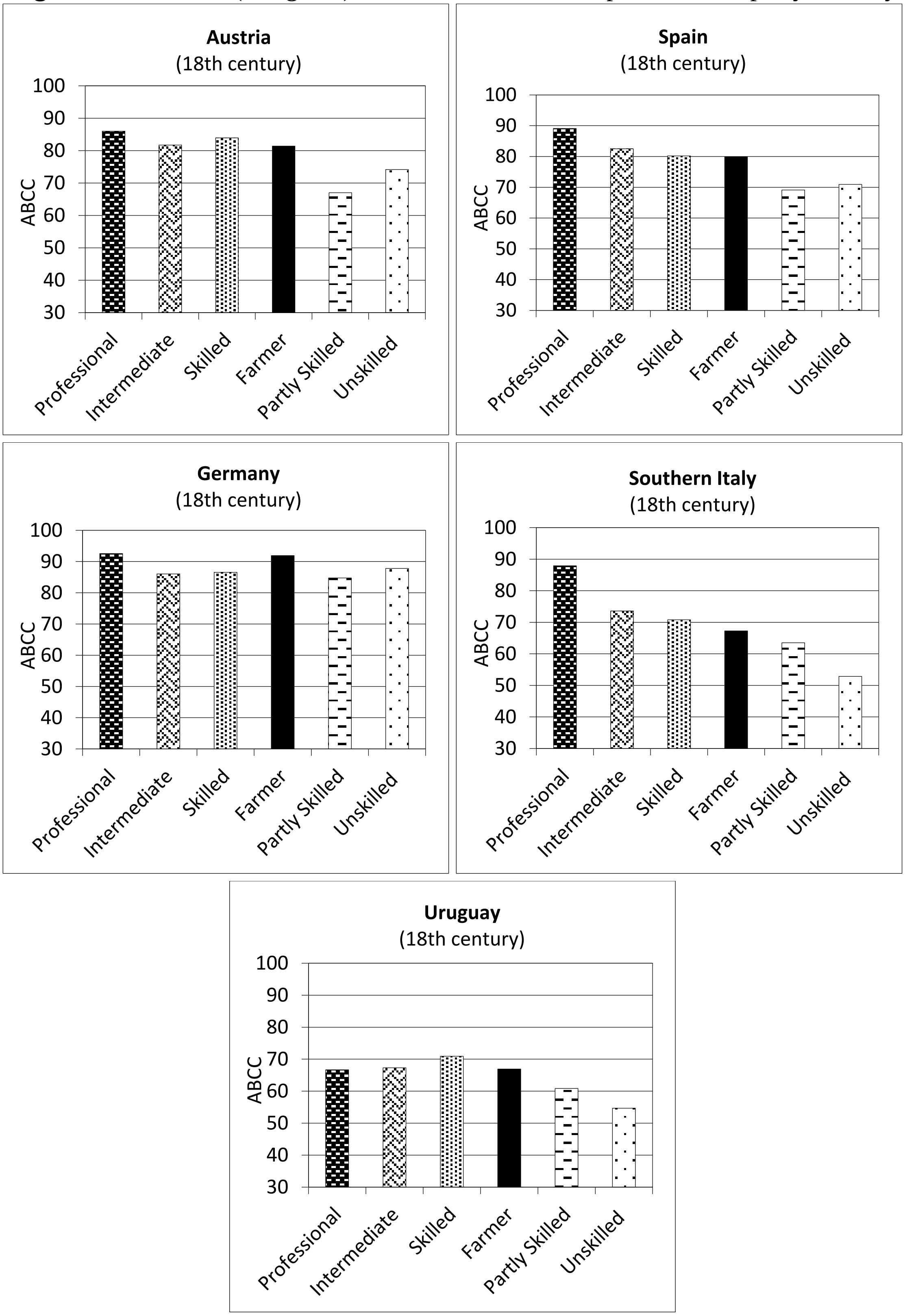
In the regression analysis, we include the occupational groups, the countries, and the birth half-century dummy variables as independent variables to control for possible changes in numeracy over time and across space.[58] In the German data, we also include a dummy variable "Protestant" in the German regression.[59]

[58] All of the regressions only contain individuals for whom an occupation was reported. We also control for individual age because younger individuals tend to know their ages more precisely, whereas older individuals might exaggerate their ages (A'Hearn et al. 2009, p. 797).

[59] Another problem might occur when implementing logit regression models because we cannot control for those individuals who state an age not ending in a multiple of five incorrectly. As this type of bias may be more problematic in logistic than in linear models, we also estimated all of our regressions using an Ordinary Least Squares (OLS) model (see, for example, Hausman 2001, pp. 59–60, 63–64). We find that the relative proportions and the significance of the coefficients remain nearly the same as in the logit models. Consequently, we assume this type of bias to be negligible.

3.5 Human Capital of Farmers and Other Occupational Groups

Figures 3.4.1–3.4.5: (Weighted) ABCC Values for Occupational Groups by Country

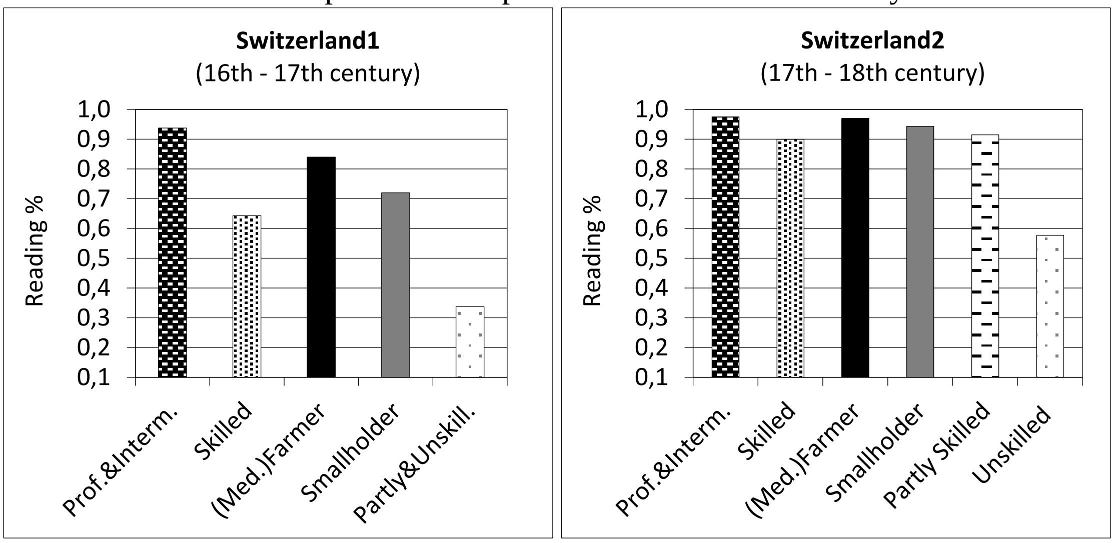


Note: Included are only individuals aged 23-62. The European data are weighted. Sampling weights are calculated such that the urban observations correspond to the actual urbanization rates of the countries. On the numbers of observations see Table 3.4 and Appendix A.3. Because the farmers' ABCC values were relatively similar to those of the skilled group in most of the countries, we ranked them between the skilled and partly skilled. Sources: See Table 3.1.

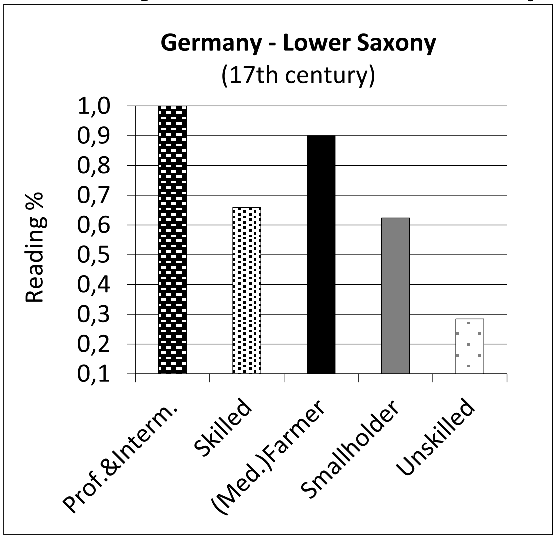
We expect the occupational groups with higher incomes and social status to correlate with higher values of human capital relative to groups with lower social status. This finding holds for the weighted numeracy values of all the countries in the age-heaping dataset. The values of the professionals are consistently higher than those of the partly skilled and unskilled individuals (Figures 3.4.1–3.4.5). In Germany, there is no large observable difference among the intermediate, skilled, partly skilled, and unskilled individuals, which might be the case because the ABCC level is already relatively high in general. This might have been an effect of the literacy campaigns in Germany that presumably had an egalitarian impact.

In nearly all of the countries in our dataset – Austria, Spain, Southern Italy, and Uruguay – the farmers' ABCC values are fairly high and equal or similar to those of the skilled group. In Germany, the value obtained for the farmers is higher than that of the skilled and unskilled groups and similar to the value of the professionals.

Figures 3.5.1–3.5.3: Reading Abilities (in Percent) for Occupational Groups in Switzerland and Germany



Figures 3.5.1–3.5.3: Reading Abilities (in Percent)
for Occupational Groups in Switzerland and Germany – Continued



Note: Included are individuals aged 23 to 72. Similar occupational groups are aggregated if the number of observations in one group is N<30 (professional and intermediate; partly skilled and unskilled). On the numbers of observations see Table 3.4 and Appendix A.3. Sources: See Table 3.1.

To check the robustness of favorable farmer numeracy, we use Swiss and German data on literacy as further measures of human capital.[60] In Figures 3.5.1 and 3.5.2, the ability of Swiss persons to read is displayed for the birth decades from 1560 to 1650 and from 1660 to 1730, respectively.[61] As stated for the other countries, we observe a difference in reading ability between the two highest groups and the unskilled and partly skilled groups. Again, the farmers exhibit higher values than most of the other groups. Similar differences are observable in the literacy data from Northern Germany (Figure 3.5.3). In general, the level of reading skills of the German and Swiss data seems to be relatively high in the 17th century. This might be due to the origin of the data, which stem from Protestant areas in Germany and Switzerland.

In summary, in all of the samples under study the farmers represent a large group with literacy and numeracy values above the partly skilled and unskilled, although a modestly sized elite of professionals and semi-professionals is slightly better educated, and the skilled craftsmen are on a similar level as the farmers.

[60] The Swiss and Northern German occupational groups are also constructed using the modified Armstrong taxonomy. Because there were no data available on the number of servants in these regions, the groups are exclusively based on the occupational information.
[61] On writing abilities, see Appendix A.3.

Table 3.6: (Weighted) Logit Regressions of Numeracy, All Available Countries

Logit, marginal effects	**L1**	**L2**	**L3**	**L4**
Dependent variable:	**Numerate**			
Included countries:	**All**		**European**	
Weighted?	no		yes	
Professional	18.66***	17.63***	19.93***	19.71***
	(0.00)	(0.00)	(0.00)	(0.00)
Intermediate	11.84***	10.85***	9.19***	9.00***
	(0.00)	(0.00)	(0.00)	(0.00)
Skilled	9.73***	8.73***	7.29***	7.10***
	(0.00)	(0.00)	(0.00)	(0.00)
Partly skilled	3.84**	ref	0.74	ref
	(0.03)		(0.72)	
Unskilled	ref	ref	ref	ref
Farmer	9.73***	8.65***	9.35***	9.14***
	(0.00)	(0.00)	(0.00)	(0.00)
Austria	ref	ref	ref	ref
Southern Italy	-18.89***	-18.43***	-15.08***	-14.98***
	(0.00)	(0.00)	(0.00)	(0.00)
Germany	4.41***	4.41***	3.35*	3.36*
	(0.00)	(0.00)	(0.06)	(0.06)
Spain	-5.61***	-5.44***	-2.78*	-2.74*
	(0.00)	(0.00)	(0.07)	(0.08)
Uruguay	-22.59***	-22.86***	-	-
	(0.00)	(0.00)		
Time dummies included?	yes	yes	yes	yes
Chi² (p-val.)	0.00	0.00	0.00	0.00
Pseudo R^2	0.031	0.031	0.024	0.024
Observations	22,512	22,512	19,900	19,900

Note: Robust p-values in parentheses. ***, **, * indicate significance on the 1%-, 5%- and 10%-level. "ref" indicates the reference category. Time dummy variables are birth half centuries. Control group=a person from Austria, born in birth half century 1700. It is controlled for individual age. Sampling weights are calculated such that the urban observations correspond to the actual urbanization rates of the countries. Uruguay is excluded in two of the models to test only European countries and because urbanization rates are not available. Marginal effects are reported. Coefficients are multiplied by 125 to correct for the missing 20% of the population that reported an age ending on 0 or 5 correctly. See Appendix B.3 for further information. Sources: See Table 3.1.

In the following, we estimate a set of logit regressions to determine whether the skill differences were significant and whether group composition effects could play a role (such as a higher share of one occupational group among subsequent cohorts). Models L1 and L2 include all of the countries for which age-heaping evidence was available, while L3 and L4 only include the European countries (Table 3.6).

In the models L1 and L2, we observe that the two upper groups, the skilled, and the farmers had a significant advantage over the two least skilled groups of society (the pooled reference category comprising the unskilled (L1) and partly skilled groups (L2)). Being a member of the professional class increased an individual's likelihood of being numerate by approximately 17.6 percentage points (model L2). Considering the European sample, a farmer had the second best chance for success in both models L3 and L4: his probability of being able to count was approximately 9.4 (L3) and 9.1 percentage points (L4) higher than that of the two lowest groups. This coefficient is slightly higher than that of both the intermediate and the skilled groups. When including Uruguay in the sample, the farmers have a similar probability of being numerate as the skilled (approximately 8.7%, model L2).

To determine whether the differences between the occupational groups are significant in each of the countries, we estimate logit regressions on numeracy for each of the individual countries. The weighted models for the European countries again confirm the previous results (Table 3.7).

Table 3.7: (Weighted) Logit Regressions of Numeracy/Literacy by Country

Logit, marginal effects	**M1**	**M2**	**M3**	**M4**	**M5**	**M6**	**M7**
Dep. variable:	**Numerate**					**Reading**	
Included country	**Austria**	**S. Italy**	**Germany**	**Spain**	**Uruguay**	**Germany**	**Switzer-land**
Weighted	yes	yes	yes	yes	no	no	no
Professional	23.33***	19.95***	10.43**	22.66***	18.66***	-	0.47***
	(0.00)	(0.00)	(0.05)	(0.00)	(0.00)		(0.00)
Intermediate	17.44***	8.01	0.98	15.98***	16.80***	-	0.45***
	(0.00)	(0.25)	(0.76)	(0.00)	(0.00)		(0.00)
Skilled	14.33***	4.11	2.03	9.98***	14.09***	0.43***	0.32***
	(0.00)	(0.10)	(0.42)	(0.00)	(0.00)	(0.00)	(0.00)
Partly skilled	ref	ref	ref	ref	ref	-	ref
Unskilled	ref	ref	ref	ref	ref	ref	ref
Farmer	7.98**	5.19**	6.61**	10.63***	13.08***	0.45***	0.40***
	(0.02)	(0.01)	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)
Protestant	-	-	4.25	-	-	-	-
			(0.53)				
Time dummies included?	yes	yes	yes	yes	yes	yes	yes

Table 3.7: (Weighted) Logit Regressions
of Numeracy/Literacy by Country – Continued

Logit, marginal effects	**M1**	**M2**	**M3**	**M4**	**M5**	**M6**	**M7**
Dep. variable:			**Numerate**			**Reading**	
Included country	**Austria**	**S. Italy**	**Germany**	**Spain**	**Uruguay**	**Germany**	**Switzer-land**
Weighted	yes	yes	yes	yes	no	no	no
Province dummies included?	yes	yes	yes	yes	yes	no	no
Chi² (p-val.)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pseudo R^2	0.026	0.057	0.039	0.069	0.034	0.138	0.203
Observations	3,962	3,391	6,530	6,017	2,612	353	1,160

Note: Robust p-values in parentheses. ***, **, * indicate significance on the 1%-, 5%- and 10%-level. "ref" indicates the reference category. Time dummy variables are birth half centuries or birth decades, depending on the number of decades. Control group=a partly skilled or unskilled person, born in birth decade 1700 (Austria, Southern Italy, Spain), birth half century 1700 (Germany (numerate), Uruguay), 1650 (Switzerland), or birth decade 1640 (Germany, reading) and from the province Lower Austria (Austria), Vibo Valentia (Italy), Soria (Spain), North Rhine-Westphalia (Germany), Maldonado (Uruguay). From Switzerland, individuals of all the time periods (birth decades 1560-1730) are included to guarantee a sufficient number of observations. S. Italy stands for Southern Italy. Sampling weights are calculated such that the urban observations correspond to the actual urbanization rates of the countries. Urbanization rates were not available for Uruguay. There are only rural observations from Switzerland and Lower Saxony. Marginal effects are reported. Coefficients of the "numerate" models are multiplied by 125 to correct for the missing 20% of the population that reported an age ending on 0 or 5 correctly. The reading evidence from Germany refers to Lower Saxony. The professional, intermediate and skilled groups are aggregated for Lower Saxony to guarantee a sufficient number of observations. It is controlled for age in the age-heaping analysis, but not in the reading regression because the age effect in literacy data is minor. See Appendix B.3 for further information. Sources: See Table 3.1.

In Germany and Southern Italy, only the farmers and the professionals have a significant advantage over the reference category (Table 3.7, models M2/M3), while in the other countries the upper two groups, the skilled, and the farmers clearly perform better than the two lower groups. In Uruguay, the farmers' coefficient is only slightly smaller than that of the skilled (model M5), while in Spain the farmers perform better than the skilled group (M4). Only in Austria is the farmers' probability of being numerate smaller than that of the skilled, but they still perform better than the two lowest groups. In Germany, we additionally control for Protestantism, which has a positive but insignificant influence on individual numeracy when also controlling for the provinces (Appendix A.3).

We find further evidence for our hypothesis using the literacy evidence from Northern Germany (Table 3.7, model M6). The probability of being able to read was approximately 45 percentage points higher for a farmer than for an unskilled or partly skilled person. The reading abilities of the Swiss occupational groups differed similarly to those elsewhere (M7). The farmers have a significantly higher probability of being able to read than the two lowest occupational groups, and their coefficient is again higher than the coefficient of the skilled.

As we classify the farmers into a single category, one could object that farmers are a fairly heterogeneous group, with small-scale subsistence farmers on the one hand and large farms with a high number of farmhands on the other.

To assess these potential objections, we examine the terms used for farmers in the various countries in the dataset in greater detail. These terms (such as *Bauer*, *Haeusler* in Austria and similar terms in other countries) might provide insights into the social structure of the farmer group because the contemporaries used these terms to describe their society and hierarchy. In most of the countries in our dataset one to three or four labels may indicate a farmer, and the division into smallholders and medium-sized or larger farmers is relatively clear. However, we have to be more precise about the terms in Germany, as there is a greater variety than in other countries.[62] To adequately analyze the different categories of farmers, we construct subcategories following the most relevant terms (Table 3.5).

In the Austrian dataset, we have two main subcategories: more than 83% of the Austrian farmer group consists of those for whom the term *Bauer* is used, denoting medium-sized or larger farmers. The subcategory of smallholders (*Haeusler*, *Halbbauer*) corresponds to approximately 16% of the entire farmer group (see also Heinsius 1840, p. 270).

In Germany there are a few terms indicating a farmer. The most prominent terms for the farmers in Northern Germany (Holstein) differentiate between smallholders (*Kaetner*) and medium-sized or larger farmers (*Hufner*) (Lorenzen-Schmidt 1996; Heinsius 1840).[63] We decided to include the individuals with at least half of a *Hufe* in the medium-sized or larger farmer group and the ones with smaller pieces of land in the smallholder group. In Western and Southwestern Germany several terms designate persons with larger or medium-sized farms (*Ackersmann*, *Landwirt*, *Bauer*, *Colonus*). We contrast these with a group of smallholders (*Kaetner*, *Casettarius*) (Heinsius 1840,

[62] In our analyses, we jointly consider farmers owning and renting their land, as their contemporaries considered control over land to be the most decisive criterion (also renting meant control). Moreover, "ownership" was not a clear-cut concept in the early modern period.
[63] The *Hufner* is denoted by the size of the land he owns or rents, the *Hufe* (=30 to 42 acres in most areas) (Lorenzen-Schmidt 1996, entry *Hufner*; Heinsius 1840, pp. 426–427).

p. 626).[64] In total, we identify approximately 71% of the German farming group as medium-sized or larger farmers and approximately 27% as smallholders.

In the Uruguayan data, the medium-sized or larger farmers, who are called *labradores*, amount to 90.6%. The group of smallholders, *chacareros*, accounts for only 9.4% because the inhabitants of this Latin American country were often able to gain access to medium-sized farms. The only term indicating a farmer in Spain is *labrador*. He may be the owner of a larger, medium-sized or smaller farm. There was no specific term for smaller farmers in Spain in the census.

The differentiation between farmer subcategories in Southern Italy is more complicated, particularly because of the land tenure structure in this region. On the one hand, there were a limited number of very wealthy landowners owning a large share of land. The smallholders, in contrast, were relatively poor (Galt 1986, pp. 432, 437–439). In our dataset, we are able to identify two terms that can classify a farmer: *massaro* and *bracciale*. While the former rather describes a yeoman, the latter relates to a smallholder.[65] However, the differentiation between these two terms does not necessarily reflect the actual position or wealth of the person. The only clear difference is that a *bracciale* did not have herd animals by definition, whereas a *massaro* generally did (Galt 1986, pp. 437–439). Although the differentiation between the two subcategories is less clear-cut than in other countries, we assume that *bracciale* stands for a smallholder, representing 92.7% of the farmers, and a *massaro* is a farmer with slightly more land, corresponding to 7.3% of the Southern Italian farmers.

Smallholders in Switzerland represent approximately 70.7%, whereas the medium-sized farmers correspond to 29.3% of the farming group. The distribution of the smaller and larger farmers here seems to differ from the observations of most of the neighboring European countries. However, a large number of the Swiss farming households in this area were engaged in dairy farming, which can be managed more efficiently in small-scale farming.

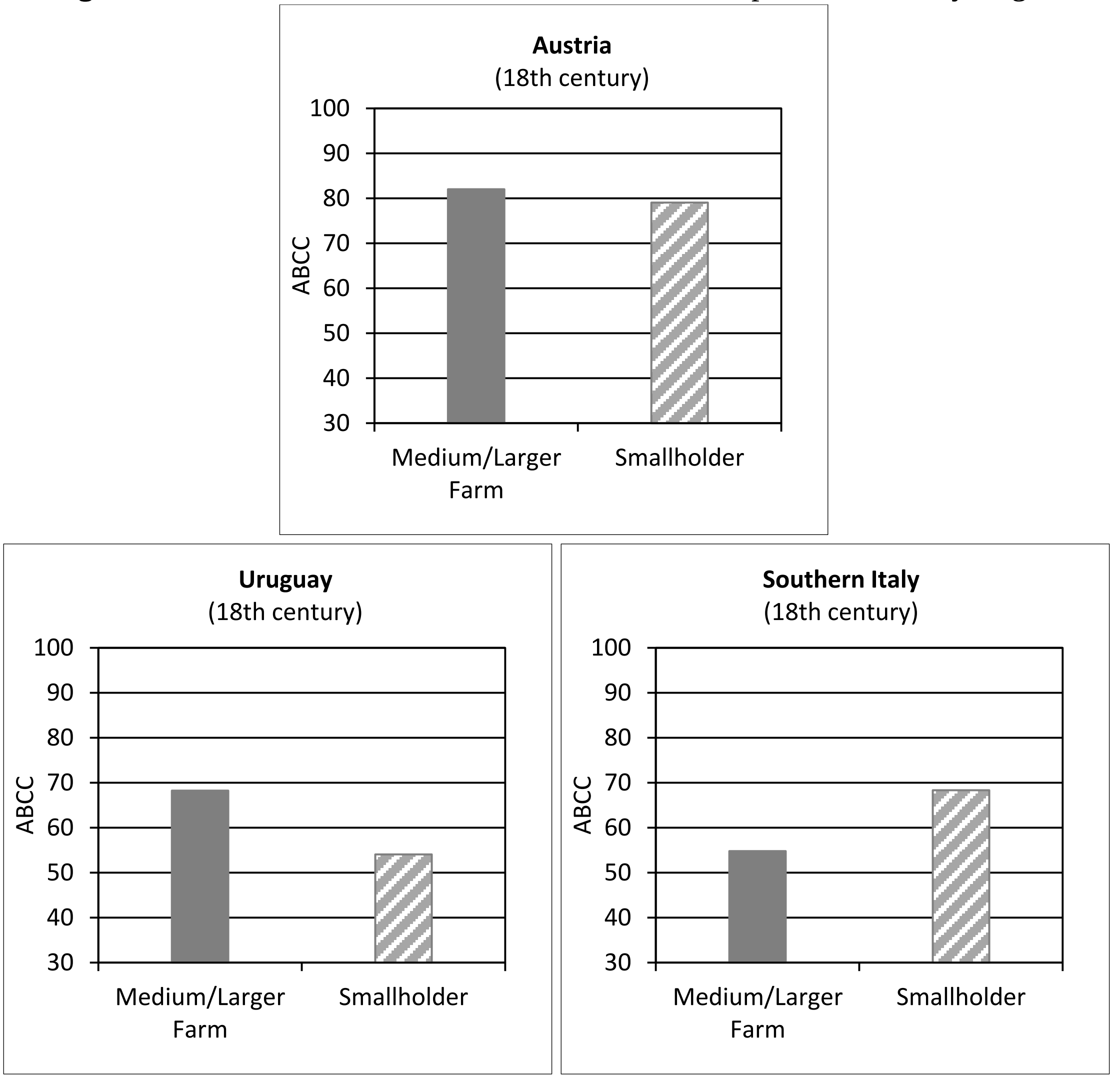
In general, we observe a strong relationship between the medium-sized or larger farmers and the presence of servants in the households. More than 91% of all servants in the farming group worked on farms of medium or larger size, whereas only 9% reported to live in the households of smallholders (Appendix A.3). This finding

[64] Colonus, Casettarius: Latin for Bauer, Kaetner.
[65] The word bracciale can also indicate an agricultural laborer who controls some land. Nonetheless, we assume that the bracciale in 18th-century Southern Italy indicates a smallholder. In the 20th century, the term only stands for a laborer.

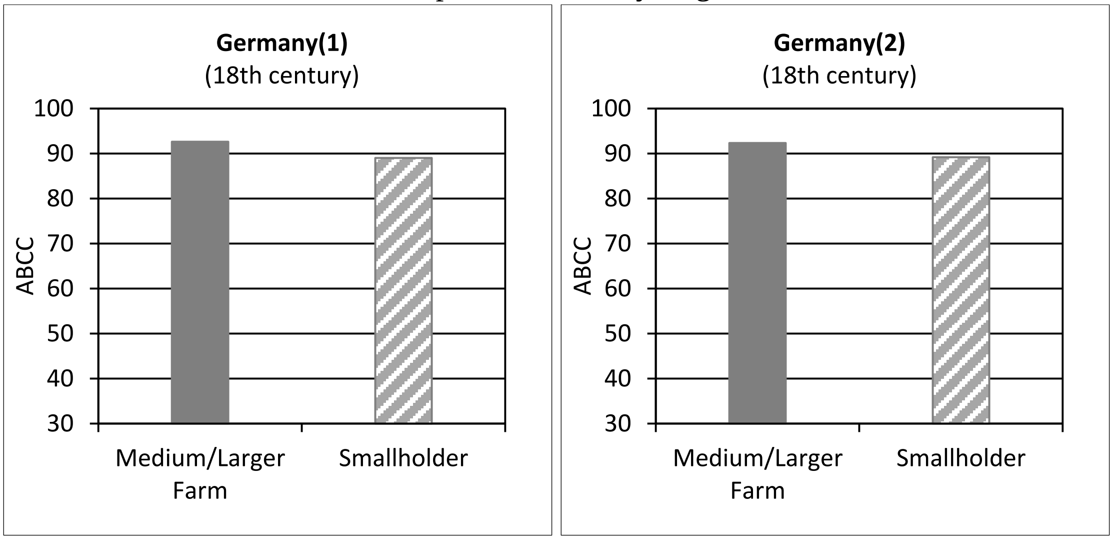
strengthens the assumption that there is a correlation between the terms for the medium-sized or larger farmers and the existence of capital in their households.

In the following, we analyze whether there are (significant) differences in the numeracy levels between farmer groups. Under normal conditions, we would *a priori* expect the medium-sized or larger farmers to have higher numerical skills than the smallholders.

Figures 3.6.1–3.6.5: ABCC Values for Different Groups of Farmers by Region



Figures 3.6.1–3.6.5: ABCC Values
for Different Groups of Farmers by Region – Continued



Note: Included are individuals aged 23 to 62. On the numbers of observations see Table 3.5 and Appendix A.3. Germany(1) stands for the original German farmer groups as described in the text; Germany(2) stands for alternative German farmer groups, in which 60 observations ("border cases") were switched from their original group to another to control for potential changes in the ABCC values. Sources: See Table 3.1.

The results in Figures 3.6.1–3.6.4 reflect this assumption in most of the cases considered: in Austria, Germany(1), and Uruguay, the smallholders have lower numeracy values than the larger farmers. For Germany, we also tested the results with alternative farmer groupings by shifting about 4% of the "border cases" of farmer observations from one group to the other. This is an important robustness test, as one could imagine the occupational classifications to be slightly arbitrary. However, the results remain almost the same as for the original farmer groups and can thus be considered robust (Figure 3.6.5). The only country for which we cannot verify the expected difference between larger farmers and smallholders is Southern Italy for which we observe the opposite relationship: the group of smallholders seems to have a higher numeracy value than the medium-sized farmers. However, as we noted above, the distinction between smallholders and medium-sized farmers in Southern Italy is less clear than in the other countries, as the average farm size was small for both groups.

The differences of literacy values between farming subcategories in Switzerland and Northern Germany are comparable to the differences in numeracy in the other countries (Figures 3.5.1–3.5.3 and Table 3.8, models F5/F6).

Table 3.8: Logit Regressions
of Numeracy/Literacy of Different Farmer Groups by Country

Logit, Marginal effects	**F1**	**F2**	**F3**	**F4**	**F5**	**F6**
Dependent var.:	**Numerate**				**Reading**	
Included country	**Austria**	**S. Italy**	**Germany**	**Uruguay**	**Germany**	**Switzer-land**
Medium-sized/ larger farmer	ref	ref	ref	ref	ref	ref
Smallholder	-8.75	5.00	-7.50	-13.75	-0.22***	-0.06**
	(0.13)	(0.12)	(0.16)	(0.10)	(0.01)	(0.02)
Province dummies included?	yes	yes	yes	yes	-	-
Time dummies included?	yes	yes	yes	yes	yes	yes
Chi² (p-val.)	0.00	0.00	0.00	0.00	0.00	0.00
Pseudo R^2	0.039	0.070	0.036	0.021	0.098	0.061
Observations	910	1,831	1,279	573	127	281

Note: Robust p-values in parentheses. ***, **, * indicate significance on the 1%-, 5%- and 10%-level. "ref" indicates the reference category. Time dummy variables are birth half centuries or birth decades, depending on the number of decades. The control group is a medium-sized/larger farmer aged 50 years and born in birth decade 1700 (Austria, Italy), birth half century 1700 (Germany (numerate), Uruguay) or 1650 (Switzerland), birth decade 1640 (Germany, reading) and from the province Salzburg (Austria), Vibo Valentia (Italy), Soria (Spain), North Rhine-Westphalia (Germany), Maldonado (Uruguay). In the Swiss data, only the province of Zurich is included in the data. S. Italy stands for Southern Italy. Because of low numbers of observations, Lower and Upper Austria (Austria), Canelones (Uruguay) and birth half century 1700 (Switzerland) are excluded. The category "other" is excluded. Marginal effects are reported. Numeracy coefficients are multiplied by 125 to correct for the missing 20% of the population that reported an age ending on 0 or 5 correctly. The reading evidence from Germany refers to Lower Saxony. It is controlled for age in the age-heaping analysis, but not in the reading regression because the age effect in literacy data is minor. See Appendix B.3 for further information. Sources: See Table 3.1.

Concerning numeracy, we do not find a significant difference between the two farming groups in the four observed countries (models F1–F4). Hence, the numeracy of the different farmer groups does not seem to be as heterogeneous as one might have expected.

These results are not necessarily surprising. Most of the smallholders also had control over land and animals and operated on their own account. Thus, they had substantial motivation and the necessary resources to provide numerical skills to their offspring. This is confirmed by the findings of De Moor and Zuijderduijn (2013) who reveal that smallholders saved or invested capital. It is likely that factors such as nutritional advantages could explain the high numerical skills exhibited by all of the farmers. For England, Thirsk outlines that milk production in the early modern period was primarily done on small-scale family farms (Thirsk 1989, p. 735, and 2000, p. 166). Thus, milk was included in the "poorer" farming family's diet. This finding provides further evidence in favor of the proximity-to-food effect because nutritional advantages in terms of milk consumption not only relate to farmers with large holdings but also and especially to smaller family farms.

3.6 The Situation Before the Early Modern Human Capital Revolution

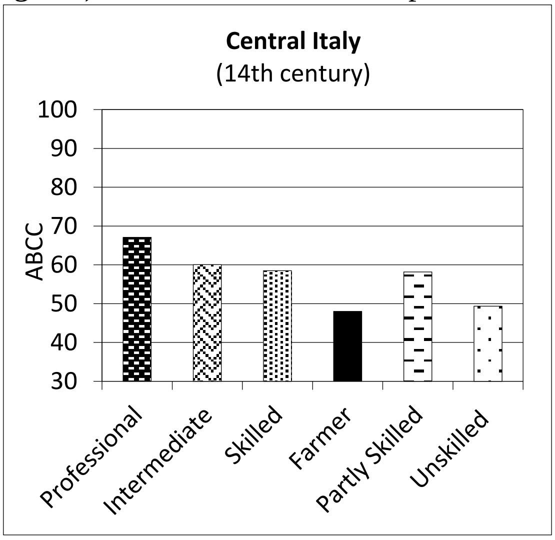
Theoretically, one could imagine that farmers had a high numeracy level before the human capital revolution. This would be a potential contradiction to our hypothesis (2), as under this assumption the numeracy increase could only be attributed to the other large population groups, the professionals, skilled and unskilled. Even if this might not seem *a priori* plausible, we prefer to assess the possibility of high initial numeracy among farmers.

Therefore, we ask: was the relatively favorable situation of the farmers always the case? How did the occupational groups rank before the human capital revolution began? Unfortunately, there are very few sources that list both age and occupation for the 14th and 15th centuries. One exception is the famous *Catasto* of Tuscany in Central Italy of 1427, which was performed to collect tax information of the inhabitants of Florence, other cities and rural areas in Tuscany. It covers such a large part of the population that many scholars considered it to be an early version of a census.[66]

By analyzing these data, we find that farmers in Central Italy were certainly not on par with skilled craftsmen; on the contrary, the farmers had the lowest numeracy level of all of the occupational groups (Figure 3.7).

[66] Unskilled workers might have been underrepresented as the aim was collecting information about the tax revenue. See Appendix A.3 for the number of observations by group.

Figure 3.7: (Weighted) ABCC Values for Occupational Groups by Country



Note: Included are only individuals aged 23-62. The European data are weighted. Sampling weights are calculated such that the urban observations correspond to the actual urbanization rates of the countries. On the numbers of observations see Appendix A.3. Because the farmers' ABCC values were relatively similar to those of the skilled group in most of the countries, we ranked them between the skilled and partly skilled. Source: See Table 3.1.

The professionals exhibited the highest numeracy index with an advantage of nearly 20 percentage points relative to the farmer group. The partly skilled occupations represented a relatively high level of numeracy in Tuscany. The individuals in this group were generally employed in the textile trades, which were unusually highly developed in Tuscany during the late Middle Ages (Herlihy and Klapisch-Zuber 1978, p. 294). For other countries, evidence containing both ages and occupations and representing a substantial number of observations of farmers has thus far not been found for this early period.

Given the results for 14th-century Tuscany, it seems unlikely that farmers occupied a similarly favorable situation before the human capital revolution as they did in the 18th century. However, we must bear in mind the important caveat of the local nature of this early source. Clearly, more research is needed to identify additional sources for the 14th and 15th centuries containing both age and occupational information. Thus, we arrive at the preliminary result that the farmers significantly contributed to the human capital revolution before the 18th century. The farmers' contribution was at least as high as their population share (approximately one-third), but probably higher. If we compare the Italian ABCC values from the 14th century with the Italian evidence from the 18th century, the farmers seem to have increased their numeracy level by approximately 20 percentage points (Figures 3.4.3 and 3.7) The contribution of the professionals, intermediates, and skilled might have been approximately one-third because this aggregated population group maintained or increased their numeracy advantage and represented approximately one third of the population. The partly skilled and unskilled occupations had a significantly lower numeracy rate than the other groups during the 18th century – i.e., towards the end of the human capital revolution. As they did not begin from a very low level, at least in the Italian case, and reached less impressive numeracy levels during the 18th century, we conclude that they probably contributed less than their population share (of around one third) to the human capital revolution.

Evidence on Swiss literacy provides additional insights into the dynamic development of the occupational groups. Between the early sample (1560–1650) and the later sample (1660–1730), particularly the smallholders and skilled craftsmen gained in literacy, whereas the unskilled did not reach a high level towards the end. In our Swiss sample the smallholders account for 71% of the farmers; hence, the farmer effect in this sample is heavily influenced by the majority of smallholders. Their children did not suffer as much from protein malnutrition, as the Swiss smallholders specialized in dairy farming. They could provide protein to their children even in difficult times. To conclude, the Swiss data have a modest longitudinal character, which allows us tracing the occupational groups over time. As the typical Zurich-canton farmer was a smallholder, the human capital increase of this group supports the hypothesis that farmer households were one important pillar of the European human capital transformation.

3.7 Conclusion

The 18th century corresponds to the second-last phase of the human capital revolution: there were still substantial differences in numeracy between occupational groups and countries, but parts of the transition were already accomplished. Using a new and large dataset containing several countries and more than 24,000 observations with information on occupations, ages, and household members, we demonstrated that farmers enjoyed a favorable position with respect to basic education during the 18th century. Our findings suggest that a high share of farmers was able to process simple numerical tasks, an ability that was far from widespread in the early modern period. The favorable human capital skills enjoyed by the farmers were also illustrated by their ability to read and write. Not only in Northwestern Europe, but also in the center and south of Europe (and in the European settlements in the New World), farmers developed particularly high skills. Farmers started to work with account books and tried to follow price changes in other regions. Also, calendars containing climatic information became bestsellers among the farming population (Graff 1987, p. 142). This indicates that their numeracy and literacy enabled them to make use of books and calendars.

In this article, we carefully considered in which way farmers acquired their basic education and concerning this point we can only describe the situation with high probability (given limited evidence): human capital formation was not so much based on learning in schools but rather on informal teaching in the household. Most of the educational historians conclude that learning at home was of great importance for all social groups. For example, some parents encouraged their children to calculate by playing games that required simple mathematics. Children growing up in favorable circumstances usually have a natural tendency to learn, even more if their parents encourage them to do so. However, many children of the early modern period faced a tough environment, characterized by severe malnutrition, an adverse disease environment, and child labor. Farmers, who had control over land and food production, were able to provide better circumstances for their offspring.

While Gregory Clark (2007) suggested that the wealthy groups in society, such as merchants, provided their offspring with favorable skills, we argue that farmers – who represented one of the largest occupational groups during this period – accounted for at least one-third of the increase experienced during the human capital revolution.

The proximity-to-food production and a high income position are the two potential hypotheses that might explain the high numeracy level of farmers. We find support for the proximity-to-food hypothesis in the results delivered by height data, which reflect the influences of the access to nutrition, the nutritional quality, and the disease environment. Farmers had very high anthropometric values.[67] As a second factor, the income position of farmers mattered. It was favorable in the 18th century and might have improved over the early modern period. A part of this additional income was reinvested into education.

Additionally, we gain insights by the dynamic development of basic education in individual countries. In Switzerland, for example, we have a modest longitudinal

[67] As a third factor, one could imagine that farmers had special incentives to invest in numeracy, but we would argue that these incentives also existed for skilled craftsmen and merchants. Clearly, other determinants such as religion, market experience, and social change also played an important role.

character that allows tracing occupational groups over time. The Swiss farmers did not suffer as much from protein malnutrition as other occupational groups because they specialized in dairy farming. Unlike other occupational groups, they were able to provide protein to their children even in difficult times. This is reflected in the dynamics of human capital acquisition from the 16th to the 18th century in Switzerland, where the smallholders even overtook the skilled craftsmen in terms of literacy.

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Appendix A.3: Additional Tables and Figures

Table A.3.1: Urbanization Rate in the Data and Real Urbanization Rate

	Urbanization Rate Data	Actual Urbanization Rate
Austria	33.9	8.9
Germany	32.8	10.8
Italy	17.1	19.4
Spain	39.8	14.0

Note: The urban sampling weights are calculated such that the urban observations correspond to the actual urbanization share. Hence, rural observations are weighted appropriately higher in case urban observations are oversampled. The places counted as "urban" in the data are Salzburg (Austria), Monteleone (Southern Italy), Toledo and Granada (Spain) and Kiel and Ludwigsburg (Germany). The actual urbanization rates are based on estimates for urban centers with 5,000 or more inhabitants in 1750 (Malanima 2010, p. 262). For Uruguay, there is no urbanization rate available for the respective time period. Our data for Switzerland contain only rural areas and therefore are not weighted by urban shares. Sources: See Table 3.1 on the data and Malanima (2010) on the actual urbanization rates as well as Bairoch et al. (1988) for Austria.

Table A.3.2: Numbers of Observations and Percentages
by Occupational Groups for Switzerland and Germany (Literacy Samples)

	(Northern) Germany	Switzerland1	Switzerland2	Switzerland	Total
	Reading & Writing	Reading	Reading	Writing	
Professional Intermediate	15	32	40	47	134
Skilled	88	84	318	285	775
Partly skilled	-	86	82	83	638
Unskilled	123		149	115	
Farmer	127	125	244	198	694
Total	353	327	833	728	2,241
	%	%	%	%	%
Professional Intermediate	4.2	9.8	4.8	6.5	6.0
Skilled	24.9	25.7	38.2	39.1	34.6
Partly skilled	-	26.3	9.8	11.4	28.5
Unskilled	34.8		17.9	15.8	
Farmer	36.0	38.2	29.3	27.2	31.0
Total	100.0	100.0	100.0	100.0	100.0

Note: Individuals aged 23 to 72 are included to guarantee a sufficient number of observations. Switzerland1 refers to birth decades 1560-1650; Switzerland2 refers to birth decades 1660-1730. We have information on reading skills for all individuals from Switzerland and, for a smaller share, on writing skills. Hence, for the individuals for which we have information on writing skills, we have also information on reading skills. For the analysis of writing skills, Switzerland is not divided into two time periods because the numbers of observations was not sufficiently high in some groups. Northern Germany refers to Lower Saxony (Abbehausen), including the birth decades 1600-1640. The German data contain both information on reading and writing skills. Sources: See Table 3.1.

Table A.3.3: Observation Numbers by Occupational Group (A), Unweighted Percentages (B), and Weighted Percentages (C) for Central Italy

Central Italy	**A**	**B**	**C**
Professional	724	5.3	4.2
Intermediate	493	3.6	2.8
Skilled	5,161	37.5	28.5
Partly skilled	646	4.7	4.1
Unskilled	321	2.3	2.1
Farmer	6,420	46.6	58.4
Total	13,765	100.0	100.0

Note: A: observation numbers; B: percentages; C: weighted percentages. The dataset contains the following birth decades: 1360-1390. Sampling weights are calculated such that the urban observations correspond to the actual urbanization rates of the countries (if rural samples are underrepresented, they are weighted higher). See Appendix A.3, Table A.3.1 for information about the urban weights. Source: See Table 3.1.

Table A.3.4: Observation Numbers and Percentages of the (Changed) Farmer Groups in Germany (AH Data)

		Original farmer categories		**Changed farmer categories**	
		Obs.	%	Obs.	%
1	Medium-sized/ larger farmer	967	74.3	1,001	76.9
2	Smallholder	312	24.0	278	21.4
3	Other/mixed	22	1.7	22	1.7
	Total	1,301	100.0	1,301	100.0

Note: Included are only farmer groups of the AH dataset. In the changed farmer categories, 13 observations were assigned from medium-sized farmers to smallholders and 47 observations from smallholders to medium-sized farmers. This means a change of 60 observations or 4.6% of the total. For the labels of the three different groups see Table 3.5 and Appendix E.3. Sources: See Table 3.1.

Table A.3.5: Percentage Distribution of Servants Among the Farmer Groups by Country

	Austria	**Germany**	**S. Italy**	**Spain**	**Uruguay**	**Total**
Medium-sized/larger farmer	95.1	84.4	71.4	100.0	92.6	91.1
Smallholder	4.9	14.6	28.6	-	7.4	8.5
Other/mixed	-	1.0	-	-	-	0.4
Total	100.0	100.0	100.0	100.0	100.0	100.0

Note: Included are only the individuals who had servants. In Spain, there is only one title for farmers, *labrador*. 20.3% of those *labradores* had servants. The evidence from Southern Italy (S. Italy) contains only 7 farming households with servants. Sources: See Table 3.1.

Table A.3.6: Robustness Test:
Unweighted Logit Regressions of Numeracy, European Countries

Logit, marginal effects	**R1**	**R2**
Dependent variable:	**Numerate**	
Included countries:	**European**	
Weighted?	yes	
Professional	18.09***	17.25***
	(0.00)	(0.00)
Intermediate	10.63***	9.85***
	(0.00)	(0.00)
Skilled	8.06***	7.26***
	(0.00)	(0.00)
Partly skilled	2.70	ref
Unskilled	ref	ref
Farmer	8.54***	7.66***
	(0.00)	(0.00)
Austria	ref	ref
Southern Italy	-16.85***	-16.46***
	(0.00)	(0.00)
Germany	2.45	2.44
	(0.10)	(0.10)
Spain	-4.21***	-4.09***
	(0.00)	(0.00)
Time dummies included?	yes	yes
Chi² (p-val.)	0.00	0.00
Pseudo R^2	0.025	0.025
Observations	19,900	19,900

Note: Robust p-values in parentheses. ***, **, * indicate significance on the 1%-, 5%- and 10%-level. "ref" indicates the reference category. Time dummy variables are birth half centuries. Control group=a person from Austria, born in birth half century 1700. It is controlled for individual age. Uruguay is excluded to test only European countries and because urbanization rates were not available. Marginal effects are reported. Coefficients are multiplied by 125 to correct for the missing 20% of the population that reported an age ending on 0 or 5 correctly. See Appendix B.3 for further information. Sources: See Table 3.1.

Table A.3.7: Robustness Test:
Unweighted Logit Regressions of Numeracy and Writing Skills by Country

Logit, marginal effects	**R3**	**R4**	**R5**	**R6**	**R7**	**R8**
Dependent var.:	**Numerate**				**Writing**	
Included country	**Austria**	**S. Italy**	**Germany**	**Spain**	**Germany**	**Switzerland**
Weighted	no	no	no	no	no	no
Professional	19.48***	19.40***	9.49**	19.04***	-	0.63***
	(0.00)	(0.00)	(0.03)	(0.00)		(0.00)
Intermediate	17.75***	7.38	1.63	14.99***	-	0.64***
	(0.00)	(0.29)	(0.56)	(0.00)		(0.00)
Skilled	11.00***	4.21*	1.68	10.98***	0.36***	0.29***
	(0.00)	(0.10)	(0.47)	(0.00)	(0.00)	(0.00)
Partly skilled	ref	ref	ref	ref	-	ref
Unskilled	ref	ref	ref	ref	ref	ref
Farmer	5.43*	5.08**	6.69***	10.19***	0.45***	0.39***
	(0.10)	(0.02)	(0.01)	(0.00)	(0.00)	(0.00)
Protestant	-	-	-0.69	-	-	-
			(0.91)			
Time dummies included?	yes	yes	yes	yes	yes	yes
Province dummies included?	yes	yes	yes	yes	no	no
Chi² (p-val.)	0.00	0.00	0.00	0.00	0.00	0.00
Pseudo R^2	0.027	0.057	0.033	0.065	0.151	0.105
Observations	3,962	3,391	6,530	6,017	353	728

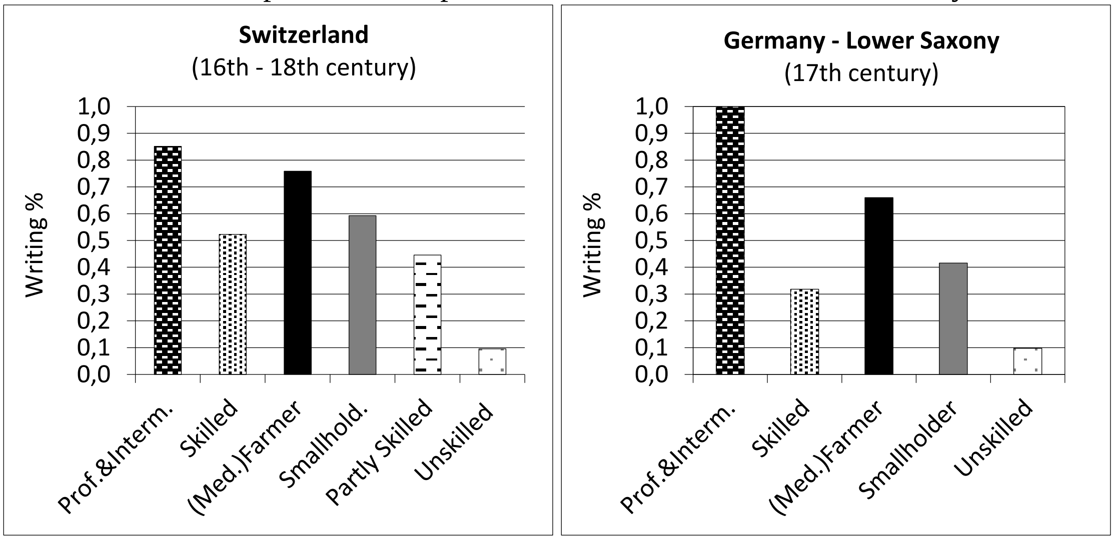
Note: Robust p-values in parentheses. ***, **, * indicate significance on the 1%-, 5%- and 10%-level. "ref" indicates the reference category. Time dummy variables are birth half centuries or birth decades, depending on the number of decades. Control group=a partly skilled or unskilled person, born in birth decade 1700 (Austria, Southern Italy, Spain), birth half century 1700 (Germany (numerate), Uruguay), 1650 (Switzerland), or birth decade 1640 (Germany, writing) and from the province Lower Austria (Austria), Vibo Valentia (Italy), Soria (Spain), North Rhine-Westphalia (Germany). From Switzerland, individuals of all of the time periods (birth decades 1560-1730) are included to guarantee a sufficient number of observations. There are only rural observations from Switzerland and Lower Saxony. It is controlled for individual age. Marginal effects are reported. Coefficients of the "numerate" models are multiplied by 125 to correct for the missing 20% of the population that reported an age ending on 0 or 5 correctly. The writing evidence from Germany refers to Lower Saxony. The professional, intermediate and skilled groups are aggregated for Lower Saxony to guarantee a sufficient number of observations. Age is not included in the writing regression because the age effect in literacy data is minor. See Appendix B.3 for further information. Sources: See Table 3.1.

Table A.3.8: Robustness Test:
Logit Regression of Alternative Farmer Groupings in Germany

Logit, marginal effects	**F3**	**F3a**
Dependent variable:	**Numerate**	
Farmer group	**original**	**alternative**
Medium-sized/larger farmer	ref	ref
Smallholder	-7.50	-5.00
	(0.16)	(0.29)
Province dummies included?	yes	yes
Time dummies included?	yes	yes
Chi² (p-val.)	0.00	0.00
Pseudo R^2	0.036	0.036
Observations	1,279	1,279

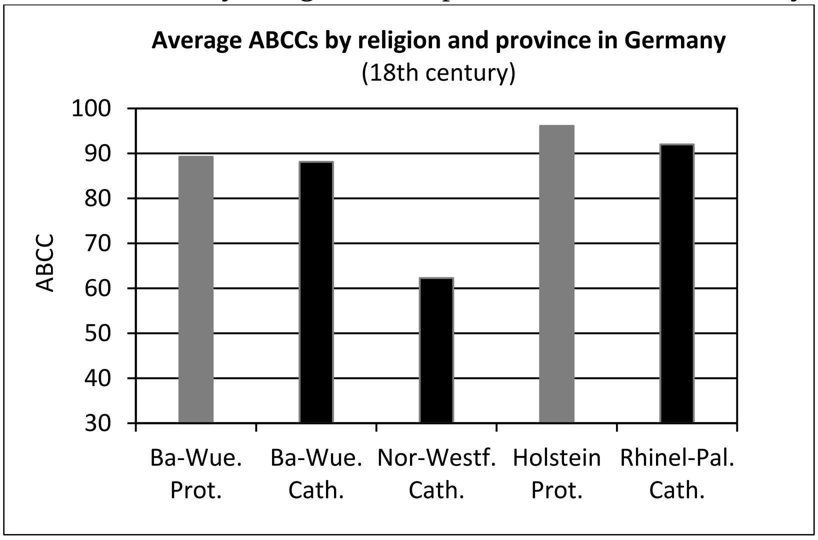
Note: Robust p-values in parentheses. ***, **, * indicate significance on the 1%-, 5%- and 10%-level. "ref" indicates the reference category. Time dummy variables are birth half centuries or birth decades, depending on the number of decades. The control group is a medium-sized/larger farmer aged 50 years and born birth half century 1700, from the province North Rhine-Westphalia The category "other" is excluded. Marginal effects are reported. Numeracy coefficients are multiplied by 125 to correct for the missing 20% of the population that reported an age ending on 0 or 5 correctly. It is controlled for age. "Original" stands for the original farmer groups in Germany, as described in the text; "alternative" stands for alternative farmer groups, in which 60 observations were switched from one group to another to control for potential changes in the coefficients. See text and Appendix B.3 and D.3 for further information. Sources: See Table 3.1.

Figures A.3.1.1–A.3.1.2: Writing Abilities
for Occupational Groups in Switzerland and Northern Germany



Note: Included are individuals aged 23 to 72. Similar occupational groups are aggregated if the number of observations in one group is N<30 (professional and intermediate; partly skilled and unskilled). For the numbers of observations see Appendix A.3, Table A.3.2. For the analysis of writing skills, Switzerland is not divided into two time periods (as for the analysis of reading skills) because the numbers of observations was not sufficiently high in some of the groups. Sources: See Table 3.1.

Figure A.3.2: Weighted Average
ABCC Values by Religious Groups and Province in Germany



Note: Ba-Wue stands for Baden Wuerttemberg, Nor-Westf. for North Rhine-Westphalia, and Rhinel-Pal. for Rhineland-Palatinate. Prot. stands for Protestant and Cath. for Catholic. Observations are weighted by their respective urban share. Sources: See Table 3.1.

References (Appendix A.3)

Bairoch, Paul, Batou, Jean and Chèvre, Pierre (1988). *La Population des Villes Européennes de 800 á 1850: Banque de Données et Analyse Sommaire des Résultats*. Genève: Droz.

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Appendix B.3: Notes on Numeracy Estimations[68]

Assume that $\frac{1}{m}$ of the population are numerate and that age is uniformly distributed.

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

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

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

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

The fraction of the population assumed to be numerate is recovered by multiplying by $\frac{5}{4}$, since $\frac{4}{5m} \cdot \frac{5}{4} = \frac{1}{m}$.

References (Appendix B.3)

Juif, Dácil and Baten, Joerg (2013). “On the Human Capital of ‘Inca’ Indios Before and After the Spanish Conquest. Was there a ‘Pre-Colonial Legacy’?” *Explorations in Economic History*, 50(2), 227–241.

[68] This Appendix is also used by Juif and Baten (2013).

Appendix C.3: HISCLASS and Armstrong Classification

To reveal the parallels and differences of the two schemes, we chose one example that, related to numeracy, was close to the average of our countries. Table C.1 shows that the majority of the observations in the "pure" HISCLASS groups are assigned to the respective Armstrong/HISCLASS groups (cross distribution table containing the common observations in the groups of the two schemes; read from left to right) (Van Leeuwen and Maas 2011; Armstrong 1972).[69] Because of the difficulties mentioned in our article and our definition of the farmer group, we prefer to proceed with the division of occupations according to our compromise Armstrong/HISCLASS scheme.

Figures C.1 and C.2 show the ABCC values of the HISCLASS grouping for Spain. Except for the unskilled workers, the results are very similar compared to the compromise HISCLASS/Armstrong groups. The three upper groups have higher ABCC values, and the farmers are close behind. The high value of the unskilled group reveals the problem related to the division of workers in HISCLASS: In Figure C.1 all of the *urban* day laborers are assigned to unskilled workers ("Unskilled Urb."), while all of the *rural* day laborers are aggregated to lower-skilled and unskilled farm workers ("Low&Unskill."). The ABCC value of unskilled workers is most likely upwardly biased because it contains only urban observations. In Figure C.2, we assign all of the day laborers to the unskilled workers ("Unskilled All"), which leads to the expected result of low ABCC values among the unskilled group. If we would aggregate the lower-skilled and unskilled farm workers, the group of the lower skilled would disappear, reducing the precision. We believe that HISCO and HISCLASS are important tools for the analysis of specialized occupations, but for the broad classes that make sense here – and because subsistence farmers (which would be assigned to the lower and unskilled farm workers) are an important group in our study – a compromise of the Armstrong and HISCLASS schemes is better suited for our study.

[69] The Spanish dataset contains only one word for farmer (*labrador*). Therefore, we do not differentiate between small subsistence farmers and medium-sized farmers.

References (Appendix C.3)

Van Leeuwen, Marco H. D. and Maas, Ineke (2011). *HISCLASS: A Historical International Social Class Scheme*. Leuven: Leuven University Press.

Armstrong, Alan (1972). "The Use of Information About Occupation." In: Wrigley, Edward A., *Nineteenth-Century Society: Essays in the Use of Quantitative Methods for the Study of Social Data*, 191–310. Cambridge: Cambridge University Press.

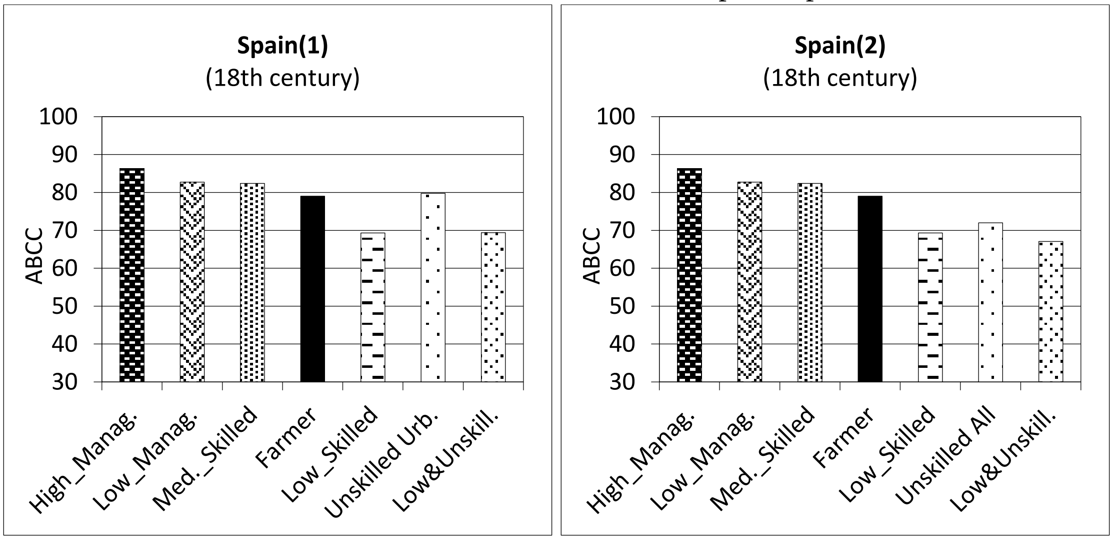
Maas, Ineke and Van Leeuwen, Marco H. D. (2005). "Total and Relative Endogamy by Social Origin: A First International Comparison of Changes in Marriage Choices During the Nineteenth Century." *International Review of Social History*, 50 (Supplement S13), 275–295.

Table C.3.1: Percentage Distribution of Observations in "Pure" HISCLASS Groups Compared to Compromise HISCLASS/Armstrong Groups for Spain

	ARMSTRONG/HISCLASS						
	Prof.	**Interm.**	**Skilled**	**Partly skilled**	**Unskill.**	**Farmer**	**Total**
HISCLASS	%	%	%	%	%	%	%
Higher managers & professionals	83.2	16.2	0.6	0.0	0.0	0.0	100.0
Lower managers & professionals	11.1	47.4	37.0	4.3	0.2	0.0	100.0
Medium skilled & foremen	2.2	18.8	77.3	1.8	0.0	0.0	100.0
Farmers & fishermen	0.0	0.3	1.6	1.6	0.0	96.5	100.0
Lower-skilled workers	0.0	1.4	43.9	50.2	4.5	0.0	100.0
Unskilled workers	0.2	0.0	2.6	0.0	97.3	0.0	100.0
Lower- & unskilled farm workers	0.0	0.0	0.5	20.5	79.0	0.0	100.0

Note: Categorizing the smallholders in Spain is not a problem because there are only *labradores* (medium to larger sized farmers) in Spain listed in the sources. The columns intentionally do not add up to 100%, but the lines do. Read from left to right to obtain the HISCLASS/Armstrong groups over which the 100% of HISCLASS observations are scattered. Example: From the 100% HISCLASS "Higher managers & professionals", 83.2% are allocated to the professional HISCLASS/Armstrong group, 16.2 to the intermediate HISCLASS/Armstrong group, and so on. The 12 original HISCLASS groups are aggregated to 7 groups (according to Maas and Van Leeuwen 2005): 1 & 2; 3, 4 & 5; 6 & 7; 8; 9; 11; 10 & 12. The abbreviations of the Armstrong/HISCLASS groups stand for professional, intermediate (semi-professional), skilled, partly skilled, unskilled and farmer. We used the following grouping to condense 12 HISCLASS groups into seven: 1. Higher managers and professionals; 2. lower managers and professionals, clerical and sales personnel; 3. foremen and skilled workers; 4. farmers and fishermen; 5. lower-skilled workers; 6. unskilled workers; 7. lower-skilled and unskilled farm workers. This also leads to a bias of the "unskilled non-farm group", as this group contains only urban individuals that generally have higher skill levels than rural individuals. Source: See Table 3.1.

Figures C.3.1–C.3.2: (Weighted) ABCC
Values for "Pure" HISCLASS Groups in Spain



Note: The last three groups on the left refer to Low_Skilled non-farm worker, Unskilled urban, and low and unskilled farm workers. The last three groups on the right refer to Low_Skilled non-farm worker, Unskilled non-farm all workers, and low and unskilled farm workers. Included are only individuals aged 23 to 62. Sampling weights are calculated such that the urban observations correspond to the actual urbanization rates of the country. The twelve original HISCLASS groups are condensed to seven groups (Maas and Van Leeuwen 2005). In Spain(1) only the urban day laborers are assigned to "Unskilled Urb." (unskilled workers), while the rural day laborers are assigned to "Low&Unskill." (lower-skilled and unskilled farm workers). In Spain(2) all of the day laborers are assigned to "Unskilled All". On the numbers of observations see Table 3.4. Source: See Table 3.1.

Appendix D.3: Occupational Groups and Farmer Categories

The occupational groups should not only represent the educational background of the people, but also include social and financial aspects. HISCLASS emphasizes the supervising function of entrepreneurs in crafts and industry. Therefore, we use an additional criterion for assigning the first three groups (professionals, semi-professionals or intermediates and skilled). Also Armstrong promotes the differentiation between people who are self-employed and have their own business and those who are employed. Hence, he suggests transferring people with certain occupations from the third group to the second, semi-professional or intermediate group if they had at least one employee or servant. Furthermore, we assign small entrepreneurs to the first group if they have at least four employees or servants.[70] This decision is based on the assumption that a certain amount of capital was necessary to pay or to nourish these persons. We propose this number of servants in derogation from Armstrong who assigns only individuals to the first group who employ at least 24 servants. The reason for our approach is that the Armstrong-taxonomy refers to a later point in time. We work with data mainly from the mid-eighteenth century, whereas Armstrong's taxonomy is developed for the middle or end of the nineteenth century. The farmers are always categorized in the sixth category, independent of their number of servants. To distinguish different groups of farmers within this group, we build subcategories of farmers by the respective term used in the survey.

Farmer Subcategories

For the analysis of the farmer group, we build two main categories of farmers: the medium-sized or larger farmers and the smallholders. In some of the regions in the dataset, we find a certain variety of labels that define medium-sized farmers or smallholders, especially in those regions from which we have a large amount of data.

This is the case for Holstein, Germany, for example: While a first group (*Hufner*) represents approximately 46% of the whole farmer group in Holstein, a second group (*Halbhufner*, *Dreiviertelhufner*, etc.) stands for approximately 7%.[71] While a *Hufner* is a person who owns a piece of land as large as *Hufe*, a *Halbhufner* owns half of a *Hufe* and a *Dreiviertelhufner* owns three quarters of a *Hufe*.This person is also a member of the village community (Lorenzen-Schmidt 1996). Heinsius (1840) notes that

[70] Because we aim to apply this criterion consistently, owners of four or more slaves in Uruguay were also moved into the first category.
[71] A small share of these partial *Hufner* reported an additional occupational title (e.g. craftsman).

the *Hufe* consisted of 30 to 42 acres of land in most regions. The group with the smallest holdings (*Kaetner*, Boedner) represents approximately 13% of the farmer group in Holstein.[72] While the division between *Kaetner* and *Hufner* in smallholders and medium-sized to larger farmers is clear by the definition of Lorenzen-Schmidt (1996) and Heinsius (1840), our source also contains a number of *Hufner* for whom only parts of a *Hufe* are mentioned, varying between 3/4 and 1/48 of a *Hufe*. We decided to include the individuals with at least half of a *Hufe* (representing approximately 7% of the farming group in Holstein) in the medium-sized or larger farmer group and the ones with smaller pieces of land (approximately 18%) in the smallholder group. Because the division of partial *Hufner* is less clear-cut, we additionally control for different farmer groupings by including the individuals with at least 1/12 of a *Hufe* in the medium-sized or larger farmer group. Another very small group of medium-sized farmers consists of *Hufner* for whom an additional occupational title is provided (e.g. craftsman, 1.7%). To control for potential changes in the results, this group is assigned to the smallholders in the second step of analysis. Shifting those individuals to the smallholders and some of the partial *Hufner* to the medium-sized farmers corresponds to a change of about 4% of the farmer observations in Germany. Comparing the two different farmer groupings in both the descriptive and regression analysis, reveals that even with the shifting of about 4% of the farmers from one group to the other, the results remain almost the same.

Furthermore, there is another occupational title in the census records that could indicate both, a smallholder or a larger farmer ("lives of land or agriculture/farming") (Lorenzen-Schmidt 1996). This subcategory represents approximately 1% of the farmers in Holstein. Because this group is not clearly described, it is classified as "others", for the analysis.[73] The remaining 15% consist of medium-sized farmers as well as smallholders for whom other labels are indicated (e.g. *Hollaender*, *Bauer*, "has property and land"). However, the division of these observations is clear by the indicated term.

In Rhineland-Palatinate (Southwest Germany) we are able to differentiate between two terms that both designate persons with larger or medium-sized farms (*Ackersmann*, approximately 45%, and *Landwirt*, circa 55%). Furthermore, the

[72] A small part of the smallholders reported an additional occupational title (e.g. craftsman), and all of those smallholders stated to have land at their disposal.
[73] The group "others" refers to all types of farmers who cannot clearly be assigned to one of the two main groups. However, this group is fairly small, corresponding to approximately 1.5%.

medium-sized farmers (*Bauer*/*Colonus*, *Hofbesitzer*), correspond to roughly 93% in Baden-Wuerttemberg and 71% in North Rhine-Westphalia, while the minor subcategory, which contains smallholders (*Kaetner*/*Koetter*/*Casettarius*), stands for approximately 7% in Baden-Wuerttemberg and 29% in North Rhine-Westphalia (on the definition of the farmer terms see Heinsius 1840 and Lorenzen-Schmidt 1996). In summary, 71.2% of the German farmers are medium-sized or larger farmers, 27.2% are smallholders, and the remaining 1.6% are considered as "others".

In general, we observe a strong relationship between the medium-sized or larger farmers and the presence of servants in the households. More than 91% of all servants in the farming group worked on farms of medium or larger size, whereas the remaining share was reported to live in the households of smallholders (Appendix A.3). This finding strengthens the assumption that there is a correlation between the terms for the medium-sized or larger farmers and the existence of capital in their households. Our assumption is strengthened by Shaw-Taylor (2005) who worked explicitly on the relationship between the size of farms or holdings and the number of servants (or laborers) to analyze the degree of capitalization of farming in England. Shaw-Taylor states that only 2% of the farmers with holdings over 100 acres do not report to hire laborers, but the author assumes that all farms of this size were run most likely with additionally paid servants or laborers. By implication, this means that our classification of farming groups can be assumed to be relatively valid, considering the shares of servants in the subcategories. Of course, there are exceptional cases such as the Southern Italian farmers, which also deal with very different preconditions.

References (Appendix D.3)

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Appendix E.3: Relative Farmer Incomes During the 15th to 18th Centuries

An important question concerning farmers' incomes in early modern times is – did farmer incomes exceed those of other occupational groups such as craftsmen in the 18th century? After reviewing a substantial literature on Germany, Austria, Switzerland, Spain, Italy, Uruguay and neighboring countries, the answer is probably that this cannot be estimated with precision. The main argument in favor of this view is that population grew much stronger than arable land, which lead to a certain population pressure.[74] This would suggest that farmers were in a better situation, as they had the control over agricultural land. Particularly in regions in which farms were not divided into smaller and smaller plots over time, farmers' incomes might have increased in relative terms.

However, assessing the question of relative farmer income is difficult because of the heterogeneity of both the farmer and craftsmen groups. Generally, we have only evidence on income for a few individuals, and farmers' conditions varied a lot due to different farm sizes, soil qualities and market access. Hence, heterogeneity poses a challenge, if average incomes are to be estimated. Similarly, the term "craftsmen" includes persons fulfilling low human-capital intensive tasks (such as shoemakers, some textile and food processing etc.), but also entrepreneurs in big cities who employed a lot of workers and earned big fortunes. Nevertheless, it provides insights to compile some of the existing evidence in the following.

Germany

For the early 19th century (i.e. the period directly following our period of study), Kopsidis (1996) and Pfister (1992) provide important insights.[75] Engel (1867) calculated the net revenue of land on the occasion of the creation of the new cadaster of Prussian agricultural land in 1861–1865. Engel (1867) defines net revenue as the total revenue minus all costs of producing agricultural goods including labor input. The annual net revenue per acre (Morgen) in Prussian Silbergroschen in 1861–1865 was 91.4 (Engel 1867: p. 153). In 1871 Marks, this would amount to 9.14. An acre is equal

[74] Later-on, the industrial revolution generated income opportunities for the masses and induced income growth. However, these alternatives to reduce pressure on wages and non-land incomes were not yet available in the early modern period until the eighteenth century in continental Europe.

[75] We thank Ulrich Pfister for important insights in personal communication on the situation in Germany and Switzerland. A number of studies have been done in the Goettingen project a few decades ago, for example by Achilles (1982) and Henning (1970). However, the income that they estimated is difficult to compare to craftsmen income. Furthermore, they show that the income depended strongly on a large number of different parameters.

to 0.2553 hectares. Hence, the annual net revenue per hectare in Mark is 35.8. The annual income from labor in 1861–1865 following Hoffmann et al. (1965) is 553 Marks in the building trades (p. 469), for example. In industry and crafts it is 425 (p. 492) and day laborers in agriculture earned 304 Marks (p. 492, p. 458f, p. 491). If we consider that the annual net revenue per hectare in Mark totals 36, then the income of farmers exceeds the income of building craftsmen from a plot size of 7 hectares and more. However, we have to take into account that feudal obligations reduced land income. After the Prussian land reform that abolished feudalism debts were imposed on the farmers amounting to roughly the same size as the former feudal obligations. Typically, in Prussia this was 25% of the land value, so that 27 of the 36 Marks per hectare “survived”. If we assume a lower-bound estimate of farmer labor input value as being similar to the one of agricultural labor, the threshold for a farmer’s income to exceed the building craftsmen’s income would be around 9 hectares. Median farm sizes in Prussia were around 10 to 20 hectares and there were some farmers who owned 30 hectares and more (as well as the famous large landowners who are not in central focus here). Those who did own more than 10 hectares were clearly much better off than rural craftsmen. In addition, the farmers’ income also had the advantage that the farmers could bind their children to the land and therefore more easily receive a rent payment when they grew old. Craftsmen, on the other hand, had this opportunity to “bind their children” to overtake their (small) business to a much lower extent. That is the reason why even small plots of land made agricultural incomes attractive in certain cases. In both cases additional income from entrepreneurial spirit was not considered.

In a specialized study of Westfalia, Kopsidis (1996) found that the income of farmers with an area of 10 to 20 hectares was roughly equal to the income of craftsmen. Farmers with 30 hectares land of medium quality were relatively rich and their income exceeded at least the one of rural craftsmen.

It is more challenging to compare farmers with urban craftsmen. The latter potentially served a specialized market and might have employed a number of workers. The entrepreneurial additional income was probably much higher, particularly in flourishing big cities. As a caveat, it should be noted that the German evidence refers to the early 19th century.

Switzerland

In Switzerland, the situation was broadly similar. The urban craftsmen engaging in very specialized tasks and relatively human-capital-intensive activities are very difficult to compare to farmers, whereas rural craftsmen with relatively modest skills, such as in the building trades, in textiles and parts of food processing, had definitely lower incomes than average farmers. This becomes also evident from the fact that they tried to give up their rural crafts and aimed at becoming farmers (Pfister 1992, ch. 4).

Spain

For Spain, we have the best evidence. Recently, Nicolini and Ramos Palencia (2015) studied the inequality of income in 18th century Spain. While in their recently published study there was no differentiation between farmer and craftsman income, but mainly a comparison between agricultural, industrial and service sectors, in personal communication they were so nice to calculate the income of these occupational groups for us.[76]

Ramos Palencia collected, jointly with several coauthors, rich evidence on incomes of all occupational groups in mid-18th century Spain. The background of this data collection and analysis effort was the availability of the Catastro de Ensenada, which aimed at simplifying and modernizing the Spanish tax system. For the analytic purpose, evidence on about 5,300 households was collected from Guadalajara, Madrid, and Palencia, including both urban and rural locations from the central and northern parts of Spain. It was possible to identify farmers and their incomes, as well as the size of their land.[77] As a result, farmers' medium income can be estimated as being around 1,300 Reales, whereas a richer craftsman, such as a carpenter, had only a medium income of ca. 900 Reales. Hence, the gross income was clearly higher for farmers. The relatively low income of craftsmen might have been caused by the slower industrial development of Spain, although craftsmen in Southern Palencia had a more favorable development. On the other hand, the relatively high gross income of farmers was usually reduced by a high tax rate on land, which could amount to 50% on total farmers' income. The total income of carpenters, on the contrary, would only be taxed by about 20%, which was due to the greater contribution of labor, in comparison to land, to the

[76] We thank Fernando Ramos Palencia for sharing some of his insights with us, which are going to be published by him and his coauthors in the near future.
[77] *Hacendados*, i.e., rich landowners mostly living in cities, were not included.

overall income.[78] This results in a net income that would be fairly similar for farmers (650–700 Reales net at the median) and craftsmen (ca. 700 Reales net) – and the net income obviously determines the opportunities for reinvestment into the education of children.

Italy

For Southern Italy, we know relatively little about self-employed farmers. Malanima (2013) finds that agricultural workers had a relatively low income during the early modern period. Given the Southern Italian agricultural structure, we assume that the small peasants in Southern Italy probably had a relatively low income in comparison to craftsmen. However, craftsmen in Italy, particularly the rural ones, did not have a very high income either.

For Northern Italy, Guido Alfani was so nice to give us a very preliminary estimate for the income ratio between rural craftsmen, urban artisans, and farmers (who tended to have relatively small farms in the region of Piemonte which Alfani can document). He would estimate the income of urban artisans as being clearly higher than that of farmers, whereas the rural craftsmen and farmers in this region had fairly similar income levels (we thank Guido Alfani for friendly email communication).

Conclusion

In conclusion, the available evidence suggests that in the 18th and 19th centuries, the income of farmers and craftsmen were relatively similar. The gross incomes of farmers in Spain were higher, but the net incomes were not necessarily higher (although farmers might have used strategies to hide a part of their products, and it might have been easier for them than for craftsmen). In 18th-century Switzerland, rural craftsmen wanted to become farmers. This might have been caused by the higher incomes of farmers (including income at retirement age), but it could also be partially caused by the higher food security that farmers clearly enjoyed, as we described in the main text. In early 19th-century Germany, farmers had also probably a slightly higher income (and higher savings) than craftsmen, at least those who were not in human-capital intensive urban crafts.

[78] However, the tax rates on land and industrial labor varies from region to region.

References (Appendix E.3)

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Appendix F.3: Occupational Mobility into Farming Occupations?

Was there occupational mobility – and perhaps self-selection from other occupations – into farming? We can address this question with the census and church census evidence that we are using. For 728 young farmers, the occupation of their father is recorded. We find that in 91% of all cases in which it was known, the father of a farmer was also a farmer (Tables F.1 and F.2).

The few exceptions of farmer sons with fathers who had other occupations were interestingly fathers belonging to the "skilled" groups. But these were rare exceptions. We can conclude that there was almost no mobility into the farmer group visible in this source; hence selection into farming on the basis of numeracy skills would seem unlikely.

Was there potential selectivity into this group of 728 cases in which both son and father had reported occupations? For example, we could imagine that a certain occupation naming behavior might play a role. In fact, in the vast majority of cases, the occupation of sons was not listed in the register (as the father was household head, normally only he was considered or asked). Dead or retired fathers were not documented with occupations. We checked, whether cases in which both occupations were reported were restricted to smaller regions, but this was not the case (note though that it was more frequent in Southern Italy than elsewhere). It is possible that in the cases in which both – the father and the son – are indicated as farmers, the son played a more active role in working the farm than in the other cases. This would not suggest that this sample is affected by systematic selectivity bias, but rather by random individual characteristics of fathers and sons.

Table F.3.1: Percentage Shares of Fathers and Their Occupations, if Their Sons Were Farmers

%	**Southern Italy**	**Other Europe**	**Total**
Professional	-	2.4	0.1
Intermediate	0.4	14.3	1.2
Skilled	3.5	2.4	3.4
Partly skilled	3.1	-	2.9
Unskilled	1.2	-	1.1
Farmer	91.8	81.0	91.2
Total	100.0	100.0	100.0

Sources: See Table 3.1.

Table F.3.2: Numbers of Fathers and Their Occupations, if Their Sons Were Farmers

Obs.	**Southern Italy**	**Other Europe**	**Total**
Professional	-	1	1
Intermediate	3	6	9
Skilled	24	1	25
Partly skilled	21	-	21
Unskilled	8	-	8
Farmer	630	34	664
Total	686	42	728

Sources: See Table 3.1.

4 The Reproductive Success of Farmers? A Cross-Country Analysis of Occupational Groups in Early Modern Europe and Latin America

Abstract:

In this paper, we analyze the average number of children in the household ("in-household" reproductive success) among different socioeconomic groups from the mid-17th to the beginning of the 19th century. In this period, the fertility transition, which subsequently led to lower fertility rates, had not yet begun. Because a large number of descendants were associated with high income and a good provision for older ages, fertility within marriage was mainly uncontrolled. However, were all of the early modern groups *successful* in having a large number of descendants? Probably not. Within the framework of the "Malthusian equilibrium", in which living standards were generally low, reproductive success was the result of high birth and death rates. Consequently, it is most likely that groups with higher incomes and thus higher living standards could provide better for their offspring, which resulted in a significantly higher "in-household" reproductive success. Moreover, we find that farmers – who were not necessarily perceived as a high-income group in the early modern period – reproduced on a level similar to the highly skilled groups.

This chapter is based on a paper co-authored with Joerg Baten (University of Tuebingen). The concept of the paper was jointly developed, analyses and writing were equally shared.

4.1 Introduction

The events that led to the groundbreaking changes at the beginning of the early modern period towards modernity have been thoroughly discussed by a large number of scholars (for example, Galor and Weil 2000; Galor and Moav 2002; Clark 2007). One of the great achievements of mankind that paved the way for the onset of modernity was the Industrial Revolution in England. However, other important changes accompanied this core event. Simultaneously as the "preparations" for the great revolution continued, the European population experienced an enormous increase in human capital, which some scholars describe as a human capital revolution (A'Hearn, Baten, and Crayen 2009; Baten 2016, pp. 74–75; Tollnek and Baten 2017, section I).[79] After the Industrial Revolution, the European population underwent another great change, the demographic transition that finally led to decreasing mortality rates, followed by declining fertility. Although there is a consensus about *where* and *when* the great changes occurred, the question of *how* all these changes were achieved is controversial. Several authors seek the cause in the population history of the early modern era (Clark and Hamilton 2006; Clark 2007, Cummins 2013).

Gregory Clark (2007) has famously argued that the wealthiest groups of society, such as merchants and other professionals, were able to pass on their favorable skills – "middle class values", as he calls them – to their children. Because this group was the most reproductively successful, not all of its numerous descendants were able to remain in this class. Consequently, they had to face downward mobility. Although this may have been a disadvantage for these children (and later adults), it was a favorable development for English society because these downward-moving individuals spread their "middle class values" among the poorer groups to which they moved. After a certain time, the individuals of all layers of society were provided with these values, which later enabled the Industrial Revolution.[80] However, there is a major issue

[79] A'Hearn et al. (2009) and Tollnek and Baten (2017) use the now well-established age-heaping method to approximate human capital (basic numeracy). This method is based on the rounding behavior of people. When people were asked for their age in earlier times (in which passports did not yet exist) and they did not know it, they tended to round their ages to a multiple of five. This tendency can be translated into an index such as the so-called "ABCC" that represents the share of people who are able to state their precise ages in relation to those rounding their ages (A'Hearn et al. 2009, p. 788). For more information on the ABCC index and the age-heaping method see chapter two, section two, and chapter three, section four, of this thesis. For a detailed description of the human capital revolution see chapter three, section one of this thesis.

[80] This is a very basic description of Clark's theory. We narrowed down the process that Clark describes in an entire chapter of a book to the core results (Clark 2007, pp. 112–132).

concerning this theory: the wealthiest group of society represented a fairly small share of the entire population. Even with a large number of descendants, it is hardly imaginable that there may have been a sufficient number of people as to reach all layers of society (see also Boberg-Fazlic, Sharp, and Weisdorf 2011, p. 383).

Instead, we propose a different theory based on the findings of Tollnek and Baten (2017). Although the authors find high human capital values for the higher groups of society, such as professionals and semi-professionals, they show that farmers were also provided with favorable skills.[81] Because the farming group represented a large share of the population in the early modern era, it is most likely that they significantly contributed to the human capital revolution achieved during the 18th and 19th centuries in Europe. On the basis of Italian data, Tollnek and Baten (2017, section VI) show that farmers managed to substantially increase their human capital between the late middle ages and the early modern period.

We argue that not only were farmers provided with favorable skills but also they were reproductively very successful. If this was the case, it is most likely that farmers passed on their skills to their numerous children who, in the next step, managed to significantly contribute to the increase in human capital in Europe. Additionally, arguing on the basis of acquired human capital suggests the assumption that human capital skills were transmitted from one generation to the other. This view stands in contrast to Clark (2007), who considers the possibility that "capitalistic" properties (or "middle class values") were genetically inherited.

Finally, we add a theoretical notion to this debate: to date, the nutritional component has been an undervalued issue. Farmer families had direct access to high-quality nutrition that most likely enabled them to develop human capital and increase their fertility. Malnutrition, on the other hand, limits cognitive abilities and increases susceptibility to diseases that may lead to higher infant mortality (Baten, Crayen, and Voth 2007, p. 419; Gray 1983, p. 116).

The large dataset we created to test our hypothesis of farmers' reproductive success contains several countries in Europe and Latin America: Austria, Germany,

[81] The word "farmer" typically refers to a person who practices under a "market economy", whereas the term "peasants" describes those who mainly live by subsistence (Crone 1989, p. 21). In this study, we use the term "farmers" or the "farming group" to describe the large group of people that includes both the subsistence farmers and the somewhat market-integrated farmers. We refer to individuals who controlled land temporarily or permanently (the land can be rented or owned). Persons for whom the information was provided that they did not control land were not included in the farmer category. Day laborers or servants who may have worked or lived on a farm were not included in the farming group.

Denmark (Sleswick), Spain, Southern Italy, and Uruguay.[82] In addition to the Western and Central European countries, we consider one of the New World economies because many Europeans in this time period had the opportunity to emigrate. If we consider only those who stayed in Europe, then the sample could be viewed as slightly biased.[83] To test our assumption, we compare the mean number of children in the household between occupational groups and find that farmers had the highest number of offspring in several countries under study.[84] Hence, it is possible that the behavior of farmer families played the core role in the process that led to the human capital formation that (after a certain delay) enabled modern economic growth.

While Clark (2007, pp. 112–132) analyzes the number of surviving children between groups of different levels of wealth, we focus on occupational groups, which allow us to approximate socioeconomic status.[85] Focusing on the large group of farmers as the decisive group is a core issue in this debate because we argue that the numerical size of the socioeconomic groups is of major importance in the process of human capital formation. The merchants and professionals occupational groups did not provide a share of the population that was sufficiently large to play a numerically substantial role (see also Boberg-Fazlic, Sharp, and Weisdorf 2011).

[82] For the sources of the data, see Table 4.1. Some of the data stem from the beginning of the 19th century, which by definition does not necessarily imply the early modern period (for example, the later periods in Uruguay). However, because the vast majority of our data stem from the period before 1800, and because the Malthusian period in terms of fertility was still ongoing at the beginning of the 19th century, we refer to the "early modern period" for convenience. In chapter three of this thesis, I also use a certain share of this dataset, including the Austrian, German, Spanish, Southern Italian, and Uruguayan male individuals aged 23 to 62 and born between 1700 and 1800. Therefore, some of the data description parts of this chapter may be similar as in chapter three.

[83] See also chapter three, section one of this thesis.

[84] Because the underlying dataset is composed of census data, we refer to the observable number of children in the household.

[85] Nevertheless, Clark (2007) also provides literacy evidence by occupational groups in his study. Occupational groups are frequently used in the literature to approximate socioeconomic status (see, for example, Case and Paxson 2008, pp. 500, 513; A'Hearn 2003, p. 361). When assigning the occupational groups in our data, we take into account not only the occupation of a person but also the number of servants whom people employed, which provides additional information about supervision and partially financial means of the persons because a certain amount of resources was necessary to pay them or to nourish them.

4.2 Theoretical Background and Literature Review

When analyzing the reproductive success of different groups, we have to consider the particular situation of the early modern period that had first been described by Malthus in 1798. The world was still in a state that several scholars call the "Malthusian trap" – a mechanism that prevented continuous economic and population growth and kept the living standards on a relatively low level. This situation lasted throughout several centuries or even thousands of years before the Industrial Revolution finally changed the world (Galor and Weil 2000, p. 806; Galor and Moav 2002, pp. 1135–1136; Clark 2007, pp. 2, 30).

The "Malthusian equilibrium" is based on assumptions about three determinants: (1) The birth rate was determined by a regulating behavior, such as the delay of marriage ("preventive check"), and it increased with rising living standards.[86] (2) The death rate, on the other hand, declined with rising living standards, enabling population growth for a limited time span. (3) The living standards began to decline as soon as population numbers increased, accompanied by an increase in malnutrition and diseases ("positive check"). These adapting mechanisms continued until the point in time in which mortality rates permanently declined due to achievements in health technology, for example. It was only after the continuous decrease in death rates that people had incentives to reduce their fertility (Galor and Weil 1999, p. 153; Galor and Weil 2000, p. 807; Lee 2003, pp. 168–169; Clark 2007, pp. 19–39, 72). With the exception of France, where the process of conscious birth control and decreasing fertility started already at the beginning of the 19th century (or even earlier), most of the European regions reached that stage towards the end of the 19th century or the beginning of the 20th century (Coale and Treadway 1986).[87] Galor and Weil (1999, p. 153) argue that, once technological progress advances, the demand for a skilled labor force increases. Consequently, the "return to human capital" skills – i.e., wages – increase as well. This mechanism finally creates incentives for parents to reduce their fertility and invest more in every single child, resulting in the "quantity-quality trade-off" in children all over Europe (Becker 1960; Galor and Weil 2000, p. 810).

[86] The delay of marriage was practiced in Western Europe. In the early modern period, the average age of women at marriage was approximately 25 years (Lee 2003, p. 169).
[87] Some scholars claim that the fertility transition started even earlier in France. Cummins (2013, p. 449) finds evidence for a decline in fertility already at the end of the 18th century.

However, fertility is high in most of the European regions during the time period under consideration. Assumption (1) – i.e., that fertility was regulated by certain behaviors – does not contradict a high fertility rate because, although marriage was delayed during certain times, fertility within marriage remained fairly high and mainly "uncontrolled" (Lee 2003, p. 169; Cummins 2013, p. 450, citing Cleland and Wilson 1987). The reasons for high marital fertility were, on the one hand, the aim of "replacing" deceased children such that the population managed to maintain at least its current size or grow at a moderate level (Lee 2003, p. 168).[88] On the other hand, a large number of children were associated with high income and good provision for old age. Hence, we can assume that the vast majority of couples aimed at a large number of offspring. However, were all socioeconomic groups capable of achieving the same high level of reproductive success?

The findings of several authors such as Hadeishi (2003), Clark (2007), and Cummins (2013), including the results of this study, suggest that this was not the case. In times of relatively low living standards and high death rates, it is most likely that population groups with a higher income had an advantage over other, poorer groups. This hypothesis is supported by the findings of Hadeishi (2003, p. 504) who observes that income and fertility have a positive correlation in 18th-century France. Moreover, Weir (1995, p. 24) identifies significantly lower (infant) mortality rates of families with higher income. In times in which malnutrition led to high (infant) mortality rates, it seems likely that population groups that had access to high-quality nutrition were also provided with a certain advantage over groups that had no direct access, particularly when they did not have the financial means to purchase the required goods (see, for example, Appleby 1975, pp. 4–6).

Through the provision of high-protein food, fertility – i.e., the number of all children born to a woman or couple – could be increased. Malnutrition or even starvation, which some population groups were facing, leads to lower fertility because the female body is primarily occupied with self-preservation, making pregnancy and short birth intervals less likely (Gray 1983, pp. 117–120).[89] Additionally, access to nutrition provides an advantage even when fertility rates were high and birth intervals

[88] Accordingly, "replacement level" means that each individual of a generation is replaced by an individual of the next generation (see, for example, Lee 2003, p. 175).
[89] Gray (1983, p. 116–120) argues that diseases might lead to a reduction of intercourse, anovulation, and amenorrhea. Additionally, he states that pregnancy and lactation can result in chronic undernutrition, which most likely leads to lower fertility.

were short because, once the child was born and the mother breastfed it, the mother's provision of (qualitatively good) nutrition was essential to reduce infant mortality because breastfeeding requires a large amount of calories. If the necessary amount of calories could not be supplied, then the mother and child were more likely to become ill (Gray 1983, p.118). Furthermore, it is most likely that women of poorer socioeconomic groups needed to work in physically demanding fields, which increased their likelihood of miscarriage (Standing 1983, p. 431).

Several scholars subsume this mechanism, which leads to variation in the mean number of surviving children between socioeconomic (or wealth) groups, under the term "reproductive success" (see, for example, Clark 2007; Cummins 2013).[90] In this study, we compare the "in-household" reproductive success between occupational groups, including the observable children in the household that survived until the day of the census.

We assume that the two above-described factors – access to high-quality nutrition and a relatively high income – caused the great reproductive in-household success of the farmers' observable in the underlying data. The favorable human capital skills of the farming group found by Tollnek and Baten (2017) may have been an additional advantage in preventing childhood diseases.

Related to the presumed nutritional advantage of farmers, we examine the results of several authors who implemented the anthropometric history method. Height is currently a well-established indicator for approximating available net nutrition, the provision of protein, and the relative well-being of population groups. A'Hearn (2003), Baten (2000), and Komlos (1987) analyze the height differences between the descendants of occupational groups, and they find that farmers' sons were particularly tall compared to the sons of fathers with other occupations, which strengthens our assumption that farmers had good access to nutrition.[91]

By contrast, the relative income of farmers, which also may have contributed to their reproductive in-household success, is not easy to quantify because farmers had strong incentives to hide their production from taxation authorities. For feudal lords or the church, grain production was easy to tax because they could directly observe the harvest and remove a certain share of the production. However, the dozens of side

[90] When referring to reproductive success, they consider the number of children surviving up to a certain age. Cummins (2013, p. 459) considers children surviving until the age of 10.
[91] See also chapter three, section two of this thesis.

products and other agricultural items were more difficult to observe because they could be hidden. Farmers could also claim that they had been destroyed by adverse circumstances.

Several authors who have analyzed agricultural output compared to the industrial sector have found that the numbers of agricultural productivity may have been underestimated in past centuries. For example, Van Zanden (2002, pp. 624–625) shows that per capita income during certain periods in the early modern Netherlands was actually higher in agriculture than in the industrial sector. Further evidence is found by Broadberry et al. (2011), who argue that the income from cattle farming had been underestimated for medieval and early modern England. Tollnek and Baten (2017, section II) are also able to provide evidence that farmers' income was relatively high. For Central Spain and Northwestern Germany, the income of farmers was similar to that of skilled craftsmen or even slightly higher (Kopsidis 1996, ch. 5).[92] Additionally, when farmers had the opportunity to hide some of their production, their net income may even have been slightly higher than that of craftsmen.[93]

In summary, the preconditions for the large reproductive in-household success of farmers were presumably given in terms of income and nutritional advantages compared to other socioeconomic groups of the early modern period. Tollnek and Baten (2017) argue that these were also the factors that led to the favorable human capital values of farmers who substantially contributed to the human capital revolution in early modern Europe. However, the question remains: how did this contribution evolve? Did the children of farmers inherit the ability to handle numbers?[94]

While Gregory Clark (2007) argues that "capitalistic" values may have been inherited by the children of the wealthy, we argue that farmers' offspring were able to develop fairly high numerical advantages that were driven by two factors: (1) the provision of protein-rich nutrition that favors the development of the brain – the basis for the acquisition of cognitive skills – and (2) the transmission of numerical skills by the children's parents.

Our argument that parents passed on their skills to children is well-documented in various studies on the intergenerational transmission of human capital (for example,

[92] The evidence on Northwestern Germany stems from Kopsidis; the evidence on Central Spain has been provided by Ramos Palencia in personal communication with Tollnek and Baten (2017).
[93] For a more thorough discussion of farmers' income, see chapter three, section two of this thesis.
[94] Tollnek and Baten (2017) approximated the ability to handle numbers by the ABCC index (see chapter three, section four of this thesis).

Fitzgerald Krein and Beller 1988; Behrman and Rosenzweig 2002). In their studies on the 20th century, authors generally find a positive relationship between the human capital of parents and the educational attainment of their children, also when controlling for a number of other potential family characteristics. Haveman and Wolfe (1995) draw three important conclusions that support our hypothesis: First, they emphasize the importance of the parents' human capital in the educational outcome of the child. They argue that the parents' human capital – usually approximated by "years of schooling attained" – always has a statistically significant and great positive impact on children's outcomes (Haveman and Wolfe 1995, p. 1855). Second, they conclude that, if children are growing up in low-income families, their chances for (a higher) education and labor market participation are generally lower compared to children with a "better" family background (Haveman and Wolfe 1995, p. 1870). Third, they emphasize the health status of parents and their children as a potentially important determinant of children's educational success (Haveman and Wolfe 1995, p. 1875). Furthermore, in her study on twins, Pronzato (2012, pp. 606–607) is able to show that both the education of the father and the education of the mother have a positive and significant influence on children's educational outcomes.[95] Consequently, there is strong evidence that parents are able to pass on their human capital to their offspring. It is more than likely that this was also the case for the transmission of basic numeracy from parents to their children in the early modern period.

Theoretically, the transmission of human capital might have been possible for all occupational groups. For example, Dumont, Trautwein, Nagy, and Nagengast (2014, p. 155) analyzed the effects on parents' support in the homework process of their children. They found that the socioeconomic background of parents did not have a significant influence on the quality of their help, impliying that parents with lower socioeconomic background were also able to provide their children with quality help during their homework.[96] However, this example might not be applicable to the early modern period for several reasons. First, formal education in terms of schooling was rarely available in the 18th century, and when it was available, it was the occupational groups with a higher income that could afford to send their children to school. Second, farmers' children had the particular advantage of available nutrition, which helped them develop their brains

[95] Twin studies are typically implemented to differentiate between the effect of parents' human capital on children's outcomes and other unobservable family background characteristics (Pronzato 2012, p. 594).
[96] However, this does not necessarily imply that the school performance of students improved (Dumont et al. 2014, p. 153).

to understand and process numerical tasks – an advantage that many of the children of poorer families did not have.

Because the number of farmers' descendants was high, some farmers' children possibly had to face downward mobility. Consequently, these children may not have been able to provide their descendants with a direct and great nutritional advantage as may have been the case for themselves. However, even when farmers' descendants moved downwards in the occupational hierarchy, they were still able to transfer their acquired skills to their children. Through the transmission of human capital, the numerous children of farmers were provided with a high basic numeracy that they were able to spread among other groups to which they moved.

4.3 Data and Methodology

4.3.1 Data Description

Table 4.1: Data Sources

Country and Region	Survey Years	Survey Type	Source
Austria			
Carinthia	1757	CC	Vienna Database on European Family History. Numeric data file, Version 0.1 [SPSS file]. Vienna: University of Vienna, 2003, http://wirtges.univie.ac.at/famdat/.
Lower Austria	1751, 1754, 1762, 1787	CC	
Upper Austria	1762	CC	
Salzburg	1647/48, 1690, 1733, 1750, 1755, 1762, 1794	CC	
Tirol	1781	CC	
Denmark			
Sleswick	1769, 1803	GC	*Arbeitskreis Volkszahl Register*: www.akvz.de (accessed 5 Oct. 2016).
Germany			
Baden-Wuerttemberg	1749, 1758, 1771	CC	*Landeskirchliches Archiv Stuttgart* (Archive of the Protestant Church in Stuttgart): Deposit No. (Microfilm) 653–655, 657, 1110, 1904; *Diözesanarchiv Rottenburg* (Archive of the Diocese in Rottenburg): Deposit No. 19662–19663.
Holstein	1769, 1803	GC	*Arbeitskreis Volkszahl Register*: www.akvz.de (accessed 5 Oct. 2016).

Table 4.1: Data Sources – Continued

North Rhine-Westphalia	1749, 1750	CC	*Westfälische Gesellschaft für Genealogie und Familienforschung*: http://www.genealogy.net, http://www.rheineahnen.de/listdoc/statusa1.htm (accessed 5 Oct. 2016); *Stadtarchiv Lippborg* (City archive of Lippborg): Deposit "Catalogus Familiarum Parochiae Libborgensis de dato 20. Martii 1750."
Rhineland-Palatinate	1799, 1804	CC	"Census of the French": *Landeshauptarchiv Koblenz* (Main Archive in Koblenz): Deposit 612, No. 3522, 4241–4243, "Einwohnerverzeichnisse".
Italy		GC	"Catasto Onciario":
Brindisi	1742		http://www.cosenzaexchange.com/comune.html (accessed 5 Oct. 2016).
Cosenza	1742/43, 1749, 1753/54		
Napoli	1754		*Archivo di Stato di Napoli*; http://www.cosenzaexchange.com/comune.html (accessed 5 Oct. 2016).
Vibo Valentia	1741, 1743, 1745/46, 1754		http://www.archicalabria.it/Default.asp (accessed 5 Oct. 2016).
Spain		GC	"Catastro de la Ensenada":
Granada	1750, 1752/53		*Archivo Histórico Provincial de Granada*: Deposit "Catastro de la Ensenada, Respuestas Particulares".
Guadalajara	1751/52		*Archivo Histórico Nacional*, Madrid: Deposit "Libros de Familias de la Provincia de Guadalajara".
Malaga	1752		*Archivo Histórico Provincial de Granada*: Deposit "Catastro de la Ensenada, Respuestas Particulares".
Soria	1752/53		*Archivo Histórico Provincial de Soria*: Deposit "Libros de Vecinos de la Provincia de Soria".
Toledo	1752/53		*Archivo Histórico Provincial de Toledo*: Deposit "Libros de Familias de la Ciudad de Toledo", No. H00688; *Archivo Regional de la Comunidad de Madrid*: Deposit (Microfilms) "Libros de Familias", No. MC009726, MC009673.
Uruguay		GC	"Padrones" (Censuses):
Canelones	1826		*Archivo General de la Nación*, Montevideo: Deposit "Libros de los Padrones", No. 246, 148; http://pueblosynumeros.fcs.edu.uy/ (accessed 5 Oct. 2016).
Montevideo	1773, 1836		
Maldonado	1779/1780		*Archivo General de la Nación Argentina*: Deposit Sala IX 20-4-3.

Note: CC stands for "Church Censuses", GC for "Governmental Censuses".

The datasets of the different countries stem from surveys in which information about families and households is reported (Table 4.1).[97] Our sources originate from governmental censuses on the one hand and from church censuses (*Libri Status Animarum*: soul registers) on the other. The only difference between these two types of sources is that the governmental surveys include (parts of) the entire population whereas the church censuses include only members of a certain faith. Nonetheless, this difference is negligible because the territories under study were somewhat religiously homogenous. Germany includes Protestants and Catholics, but the territories in which the censuses were taken are either Protestant or Catholic regions.[98] While the datasets from Spain, Italy, and Uruguay are based on governmental census data, a significant part of the Austrian and a smaller fraction of the German datasets consist of church census data.[99] All of the surveys share in common that people reported detailed information about their age, their occupation (at least for the head of household), their sex, and the number of children living in their household. Furthermore, the number of other persons living in the household, e.g., servants, employees, and additional family members (parents, aunts, cousins, etc.), can be obtained from these lists.

[97] On the following description of the dataset and the regional composition see also chapter three, section three of this thesis.
[98] Hence, there were no minorities of either religion in a village, for example.
[99] A significant amount of the German and Danish datasets was created by the so-called *Volkszahl-Register* project, which is composed of different censuses. Today, the Danish area partially belongs to Germany (Sleswick).

Table 4.2: Total Number of Observations by Country and Region

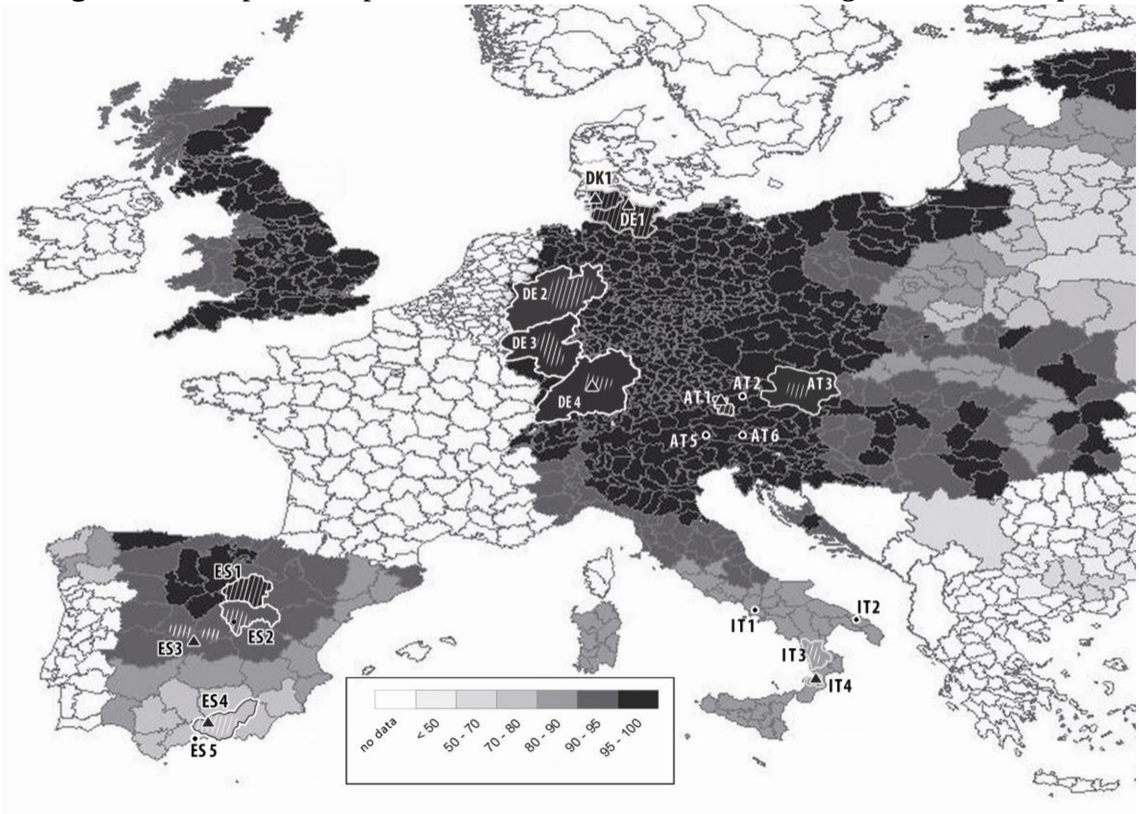
Country	Region	No. of obs.	%
Austria	Carinthia	1,450	4.5
	Lower Austria	4,929	15.2
	Upper Austria	1,820	5.6
	Salzburg	21,150	65.1
	Tirol	3,151	9.7
Total		32,500	100.0
Denmark	Sleswick	46,511	100.0
Germany	Baden-Wuerttemberg	4,986	3.3
	Holstein	138,845	90.7
	North Rhine-Westphalia	6,580	4.3
	Rhineland-Palatinate	2,633	1.7
Total		153,044	100.0
Italy	Brindisi	436	1.8
	Cosenza	7,695	31.9
	Napoli	1,061	4.4
	Vibo Valentia	14,971	62.0
Total		24,163	100.0
Spain	Granada	10,215	36.2
	Guadalajara	3,494	12.4
	Malaga	1,076	3.8
	Soria	1,501	5.3
	Toledo	11,939	42.3
Total		28,225	100.0
Uruguay	Canelones	2,200	16.1
	Maldonado	3,205	23.4
	Montevideo	8,296	60.6
Total		13,701	100.0
Dataset Total		298,144	100.0

Note: Included are all family members, servants, and other persons living in the households. Sources: See Table 4.1.

With a total number of more than 298,000 observations (Table 4.2), this comprehensive dataset provides us with the possibility of studying the relationship between the number of children and the socioeconomic background in the early modern era. Because a main focus of this study involves the patterns of farmers, a sufficient number of farmers and farming families is important. With a total number of 12,486 male farmers between 23 and 62 years of age (see Table 4.3 below), this analysis is feasible on a broad and representative basis.[100]

[100] The large group of farmers is subsequently divided into a group of medium-sized or larger farmers and another group representing smallholders; this division is discussed more thoroughly below in section six of this study.

Figure 4.1: Map of European ABCCs in the 1840s and the Regions of the Sample



Note: We report the modern boundaries (not the historical ones) to allow modern readers identifying regions. Sources: Map: Own illustration on basis of a map from Hippe and Baten (2012, p. 278). Data sources: See Table 4.1.

Legend

indicates the regions from which data are available

• indicates the place of a region from which data are available (if there are not more data available from this region)

▲ indicates the urban places from which data are available:

Austria: Salzburg, Denmark: Husum, Germany: Kiel and Ludwigsburg, Spain: Toledo and Granada, Italy: Monteleone

AT indicates the Austrian regions from which data are available:

AT 1: Salzburg, AT 2: Upper Austria (Gmunden), AT 3: Lower Austria, AT 4: Carinthia (Sirnitz), AT 5: Tirol (Villgraten)

DK indicates the Danish regions from which data are available: DK 1: Sleswick

DE indicates the German regions from which data are available:

DE 1: Holstein, DE 2: North Rhine-Westphalia, DE 3: Rhineland-Palatinate, DE 4: Baden-Wuerttemberg

ES indicates the Spanish regions from which data are available:

ES 1: Soria, ES 2: Guadalajara, ES 3: Toledo, ES 4: Granada, ES 5: Malaga (Estepona)

IT indicates the (Southern) Italian regions from which data are available:

IT 1: Napoli (Crispano), IT 2: Brindisi (Carovigno), IT 3: Cosenza, IT 4: Vibo Valentia

The countries in our dataset are represented by a substantial number of observations, even if the availability of sources generates a stronger focus on certain regions in some countries (Figure 4.1 and Table 4.2). Italy and Denmark are represented by the countries' southern regions, whereas in Germany, more evidence from the northern region is available. For Spain, we have evidence for the center and the southern regions. To emphasize the representativity of our data, we include a map of the numeracy levels in the 1840s in which we differentiate between the rural and urban observations of our samples (Figure 4.1).The numeracy levels are displayed using the ABCC index, which can be interpreted as the percentage share of individuals who were able to state their ages exactly in contrast to those who rounded to a multiple of five (A'Hearn, Crayen, and Baten 2009, p. 788).[101] It is observable that urban and rural places are fairly randomly scattered over the educational types of regions within countries. If there were only data from a single urban place available (Southern Italy, Denmark), it was located in the center of the rural regions. However, because we are mainly interested in occupational differences, these regional composition issues should be less crucial.

The classification we use to organize the occupational groups is based on the Armstrong scheme (1972, pp. 215–223). In addition to the skill level of a person, Armstrong takes into account the social background of the occupation, which allows approximating the socioeconomic background by occupational groups.[102] Below, we consider six different occupational categories in this study. The professionals, representing the first group, are individuals with higher education; the most prominent examples would be merchants, doctors and lawyers. Additionally, the remaining members of the upper strata of society are included here (mayors, nobility). Semi-professional (or intermediate) people, such as administrators and clerks, are allocated to the second category. The third group contains skilled persons who typically completed several years of apprenticeship, including blacksmiths and craftsmen. The partly skilled group includes individuals with basic ("vocational") training, such as rope makers and carriage drivers, whereas the unskilled category contains individuals without a degree of (formal) education. Finally, we allocate farmers to their own category, including medium to larger-sized farmers and smallholders.[103] Large landowners, on the other hand, are allocated to the first group.[104]

[101] For more information about the ABCC, see chapter two, section two, and chapter three, section four, of this thesis.

[102] Furthermore, we differentiate whether a person employed servants or laborers. When a person employed servants, he was transferred to another, higher occupational group. See chapter three, Appendix D.3 of this thesis on more information. On the description of the Armstrong scheme, see also chapter three, section three of this thesis.

[103] In the figures, farmers are placed behind the skilled group, following Tollnek and Baten (2017).

[104] When distinguishing between occupational groups, we had to rely on the expressions used for the occupations in the original surveys. The groups are formed as homogeneously as possible based on the translation. The differentiation of whether a person is a farmer or a large landowner is made based on the

Table 4.3: Numbers of Observations and Compositional Percentages by Occupational Group and Country, Male Individuals Aged 23–62 Years

	Austria1	**Austria2**	**S. Italy**	**Spain**	**Germany**	**Denmark**	**Uruguay**	**Total**
	Obs.	Obs.	Obs.	Obs.	Obs.	Obs.	Obs.	Obs.
Professional	106	261	228	453	920	343	124	2,435
Intermediate	190	430	79	671	3,454	1,337	124	6,285
Skilled	301	1,276	661	1,743	6,894	2,780	385	14,040
Partly skilled	90	216	376	596	2,661	1,238	37	5,214
Unskilled	134	1,076	46	1,536	8,733	2,520	557	14,602
Farmer	187	1,135	1,752	1,226	6,253	1,433	500	12,486
Total	1,008	4,394	3,142	6,225	28,915	9,651	1,727	55,062
	%	%	%	%	%	%	%	%
Professional	10.5	5.9	7.3	7.3	3.2	3.6	7.2	4.4
Intermediate	18.8	9.8	2.5	10.8	11.9	13.9	7.2	11.4
Skilled	29.9	29.0	21.0	28.0	23.8	28.8	22.3	25.5
Partly skilled	8.9	4.9	12.0	9.6	9.2	12.8	2.1	9.5
Unskilled	13.3	24.5	1.5	24.7	30.2	26.1	32.3	26.5
Farmer	18.6	25.8	55.8	19.7	21.6	14.8	29.0	22.7
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Note: Displayed are the male individuals aged 23-62 for whom occupation and marital status were reported. These observations are relevant for the regression analysis of the number of children. Austria1 indicates the early period of Austrian data (half centuries1600-1650), Austria2 indicates the later period (half centuries1700-1750). S. Italy stands for Southern Italy. Excluded are individuals for which we could not reconstruct from the census records whether they had children or not: married or widowed males without reported children and who were not family heads (their children may not be indicated as such or they could have currently left the family to work elsewhere); slaves in Uruguay; families with identifiable children of former marriages because we cannot control if the children are genetic children of the mother or father; individuals without information on marital status. Sources: See Table 4.1.

Clearly, not all of the more than 298,144 people in the dataset reported occupations because many of them were children or housewives. When observing the occupational data, we refer to male individuals because it was not always clear in which cases the occupations of women were reported.[105] Among the male adults between 23 and 62 years of age who reported occupations, approximately 4% were professionals, 11% semi-professionals (intermediates), 26% skilled, and 23% farmers (Table 4.3).[106]

term used in the respective language. Typically, a large landowner is indicated by a term different from farmer. If we consider the Spanish census, a farmer, as we define the term in this study, is always indicated by the word *labrador*, whereas a large landowner is indicated by the word *hacendado*. By contrast, persons indicated as "agricultural laborers", who may also have had a small garden at their disposal but not large enough to provide subsistence, were classified into the unskilled group, following the term *jornalero*. For more information about the classification of occupations, see chapter three, Appendix D.3 of this thesis.

[105] It is possible that, for a woman who worked equally on a farm with her husband and performed the same tasks, the occupation "farmer" was provided, whereas for another woman in the same position, the occupation was not reported.

[106] We introduce urbanization weights such that the observations represent the urban share of the respective period. In cases where urban observations in our dataset were underrepresented, they received a higher weight and vice versa. When occupational groups are weighted, the farmers represent

Approximately 36% of the observed male population consisted of unskilled or semi-skilled persons.[107]

Table 4.4: Numbers of Observations and Compositional Percentages by Occupational Group and Country, Male Family Heads With Children Aged 23–62 Years

	Austria1	**Austria2**	**S. Italy**	**Spain**	**Germany**	**Denmark**	**Uruguay**	**Total**
A	Obs.	Obs.	Obs.	Obs.	Obs.	Obs.	Obs.	Obs.
Professional	74	130	141	255	503	206	86	1,395
Intermediate	114	258	60	425	2,321	800	68	4,046
Skilled	162	457	540	1,219	3,510	1,457	157	7,502
Partly skilled	58	80	317	410	1,740	445	65	3,031
Unskilled		67	37	1,023	4,146	952		6,309
Farmer	155	859	1,458	897	4,896	1,009	336	9,610
Total	563	1,851	2,553	4,229	17,116	4,869	712	31,893
B	%	%	%	%	%	%	%	%
Professional	13.1	7.0	5.5	6.0	2.9	4.2	12.1	4.4
Intermediate	20.2	13.9	2.4	10.0	13.6	16.4	9.6	12.7
Skilled	28.8	24.7	21.2	28.8	20.5	29.9	22.1	23.5
Partly skilled	10.3	4.3	12.4	9.7	10.2	9.1	9.1	9.5
Unskilled		3.6	1.4	24.2	24.2	19.6		19.8
Farmer	27.5	46.4	57.1	21.2	28.6	20.7	47.2	30.1
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Note: Displayed are male individuals aged 23-62 who are married heads of household with children. These observations are relevant for the analysis of the number of children in Zero Truncated Poisson models. Austria1 indicates the early period of Austrian data (half centuries1600-1650), Austria2 indicates the later period (half centuries1700-1750). S. Italy stands for Southern Italy. Similar groups are aggregated if the number of observations in one group is N<30 (professional and intermediate; partly skilled and unskilled). Sources: See Table 4.1.

Because the age structure might differ between occupational groups, we perform a robustness check including only those individuals who were family heads and had children (Table 4.4).[108] In doing so, we reduce a potential bias from a lower number of children because of a younger mean age of the individuals. Among the male family heads with children in the dataset, we obtained the following results: approximately 29% were partly skilled or unskilled persons, and approximately 24% were skilled people (mostly craftsmen).[109] The farmers represented the largest occupational group of

approximately 24% of all occupations; of those individuals who are family heads and have children, the farmers even represent 31%. See also Appendix A.4 for the urbanization shares and the composition of weighted occupational groups.

[107] We use the same age range as in Tollnek and Baten (2017) to guarantee for certain comparability between the analysis of numeracy and the analysis of fertility in this study. In Tollnek and Baten (2017), a sample of the same database is used for the analyses of numeracy.

[108] While the mean age of farmers or professionals tends to be higher, the mean age of the large group of unskilled workers is generally slightly lower, which could lead to a lower mean number of children in this group.

[109] For both the total working population and the family heads, the term “farmers” captures only those

the family heads with children, with more than 30%. The professionals and the intermediates corresponded to significantly smaller shares of approximately 4% and 13%, respectively.

4.3.2 Estimation Methodology

To assess our hypothesis of a large number of children among farmer families, we include two steps of analysis. First, we analyze the number of children by occupational group and country, as reported in the surveys. Our proxy indicator for the reproductive success of occupational groups is the number of children surviving until the census year and living with their parents (who are assumed to be the adults who are reported as the father and mother in the sources).[110]

The "in-household" component is important because some of the children may leave home early to work in another household or are placed as foundlings in front of church doors if the family was very poor. The abandonment of children rose in Europe particularly during the 18th century (Viazzo 2001, p.176). Only if children remained at home during early childhood could the family culture and its educational values be provided to the child.

As described above, the number of children in a family is determined by various factors. While modern fertility control did not play a large role in the early modern period, infant and child mortality are clearly major components of reproductive success: if the offspring dies young, then this outcome is clearly the opposite of success. Age at marriage (and the remarriage of widows or widowers) may be partially endogenous components: if farmers had the means of subsistence to support a family, then the share of farmers able to marry was larger than among poorer contemporaries (Figure 4.2). In Central Europe, in many if not all regions, the marriage of couples was forbidden or strongly discouraged if the sufficient subsistence level was not met.

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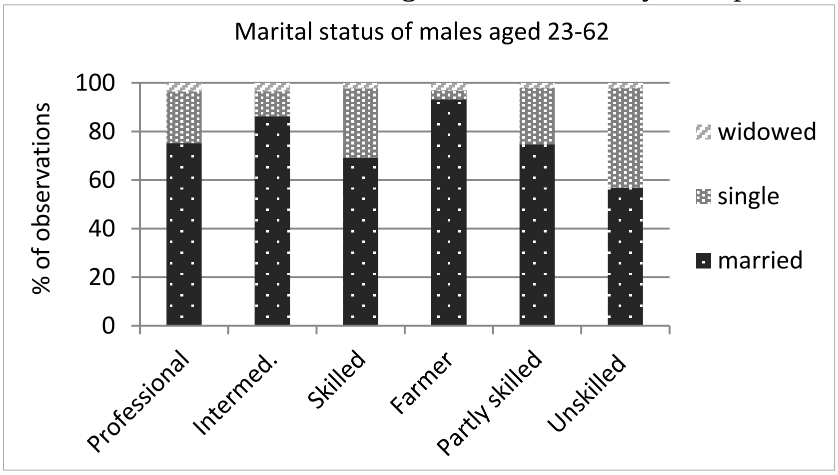
people who presumably had their own (small) farm. The total share of people working in agriculture was much higher because persons from the partly skilled or unskilled group were often either herdsmen or laborers on farms.

[110] The numbers of children were calculated very carefully on basis of the labels indicating the different family members in the sources. The relationships of the household members were reported in relation to the head of household; from this relationship, we derived the number of children for the heads of households. Whenever possible, the last names of the family members were compared as to ensure that fathers and children really belonged together. However, we had to rely on the labels for the family members that were listed in the sources; therefore, very small biases are possible in the cases where a person indicated as "child" was in fact not the child of the head of family but of any other household member (who not necessarily would have been indicated as the mother or father of this child). While we assume that these types of biases are of minor influence, we reduce the probability for such biases by creating very strict robustness tests (see further details below).

Figure 4.2: Marital Status of Males Aged 23–62 Years by Occupational Group



Note: Included are the same individuals as in the regression analysis (males aged 23-62 for whom occupation and marital status were reported). The observations for which marital status was not provided (about 6%, mainly children and servants) were not included in the regressions. See Table 4.3 for more information and numbers of observations. Sources: See Table 4.1.

To analyze reproductive success approximately, we study regressions with count data in which the number of children (1) per individual and (2) per head of the family is the dependent variable.[111] We employ occupational groups and country dummy variables as independent variables. When including all individuals, we also control for marital status because we assume that a married person had a larger number of children than an unmarried or widowed individual. Additionally, there are two effects that could influence the number of children over time. Because we consider data from the 17th to the early 19th centuries, it is possible that the number of children changes between the different time periods. To capture this potential time effect, we implement time dummy variables, with each covering half a century. The respective census periods are allocated to the half centuries. Furthermore, we assume that the number of descendants increases with the individual age of a person. We control for this second time effect by including the individual age of a person as a further control variable.[112]

The number of children is a count variable that takes small values between a minimum of 0 and a maximum of 13. In the first part of the analysis, we take into

[111] At (1): we excluded cases for which we could not reconstruct from the census lists whether the person did have children or not, such as married and widowed persons without reported children and who were not family heads (they could have currently left the family to work elsewhere or their children may not be indicated as such on the census list), slaves in Uruguay, families with identifiable children of former marriages (because we cannot control if the children are biological children of the mother or father), and individuals without information on marital status (mainly children and servants). These exclusion rules are fairly strict and should deliver robust regression results when referring to the farmer group. At (2): included are only married family heads with children. The results of the various modifications show that the results are robust.
[112] For the regressions that contain only one census period or census year, we only test for the individual age effect.

account all the individuals included in the age range of 23 to 62. The underlying type of count data is often considered to suffer from overdispersion, which can be ruled out by implementing a Negative Binomial regression model.[113] In the second part of the regression analysis, the robustness check, we include only those individuals who are heads of households and reported having at least one child. By following this strategy, we can rule out some uncertainties in the sources; i.e., if an individual reported that he or she has no children, we cannot be absolutely certain whether this person actually did not have any children or whether there were reasons for not reporting this information. For example, a father who was surveyed could have left his family for seasonal work on foreign farms to increase the family income (see also Mooser 1984, p. 204).

Furthermore, because farmers had a very large number of children, we assume that not all of the farmers' sons had the opportunity to also become a farmer immediately upon reaching adulthood. It is more likely that particularly the younger sons left the family home to work as paid laborers on other farms for a period of time before being able to establish their own household or farm (see, for example, Galt 1986, p. 437–438). Consequently, there was a period of mobility of farmers' sons in which they could not be counted as belonging to the farmer group but instead to the unskilled group of workers. Hence, the proportion of young unmarried males who are not yet heads of families is relatively high for the unskilled group and could bias the result for the regression including all individuals in the analysis of reproductive success. For this reason, we additionally perform the robustness test in a separate regression analysis in which we include only the family heads with children.

When excluding individuals without children, the range of the dependent variable extends from a minimum of 1 child to a maximum of 13 children. Given that, in this case, we are addressing data truncated at zero, we compute a Zero Truncated Poisson (ZTP) regression model, which is more appropriate for this type of data. Furthermore, with a sample mean of approximately 2.6 and a sample variance of 2.5, the truncated data suffer from slight underdispersion rather than from overdispersion.[114] To correct for this slight underdispersion, we generate a model with robust variance-covariance matrices, resulting in a pseudo-maximum likelihood estimation rather than a

[113] Overdispersion means that the variance is larger than the mean; underdispersion means the opposite effect.
[114] The sample statistics refer to the number of children per family head. In the case of underdispersion, the standard errors tend to be overestimated (Winkelmann 2003, pp. 169–172). On the use of zero truncated models, see Cameron and Trivedi (2010, pp. 584–588).

maximum likelihood estimation and thus delivering a robust regression model (Winkelmann 2003, p. 172).[115] For an easier interpretation of the coefficients, we compute the marginal effects, which can be interpreted as a unit change in the dependent variable.[116]

A further bias in the data under study might result from children who had already left the family home to start their own family. Thus, to further verify the robustness of our regression analyses and to control for possible biases of these types, we perform regression analyses in which we consider only "children up to 12 years of age" as the dependent variable. This strategy is based on the assumption that most of the children stay in their family home at least until their 12th birthday.[117] In general, we assume that the mean number of children per social group is informative, although we are not able to observe the development of the children following the time of the survey.

To ensure the representativity of our analyses, we perform the regression analyses with a further modification: because our data stem from many different places and regions across the countries, we use sampling weights to correct for possible biases through rural-urban composition issues. The sampling weights guarantee that our regressions represent the actual urbanization rates of the countries in the respective time period (see Appendix A.4). Hence, the urban samples in our dataset in which the population may represent higher numeracy skills or lower numbers of children do not receive a higher weight than they actually had.

[115] Another method of analyzing underdispersed data is to use a generalized linear model (Winkelmann and Zimmermann 1994), which we also performed to compare the two models. There are minimal differences in the standard errors, but the significance of the independent variables is always the same in both models. Additionally, the Akaike Information Criterion (Akaike 1973) delivers a better (smaller) value for the ZTP model than for the generalized Poisson model.

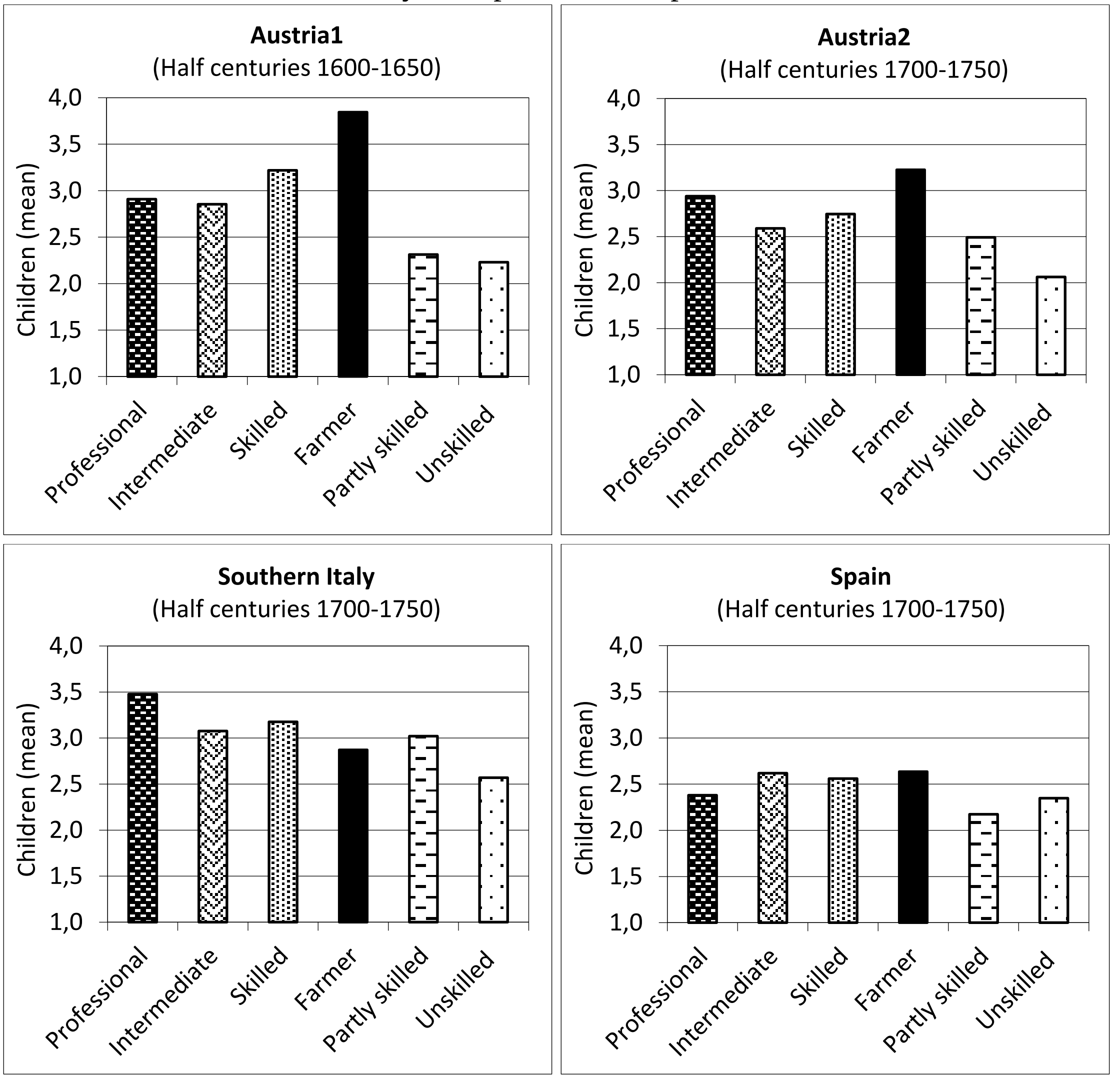
[116] To ensure the reliability of the ZTP regression model, in the robustness checks, we include only the family heads who are not widowed or single and whose children have not been declared to stem from an earlier marriage. Thus, the children are likely to be genetic children of the mother and father who are indicated as parents in the survey, which allows us to eliminate possible undesirable side-effects, such as a higher number of children for married or even re-married individuals compared to that of widowed people.

[117] This assumption is particularly important for female children because marriage was often arranged after reaching physical maturity (Crone 1989, p. 111). In general, we assume that the mean number of children per social group is informative, although we do not observe the development of the children following the time of the survey.

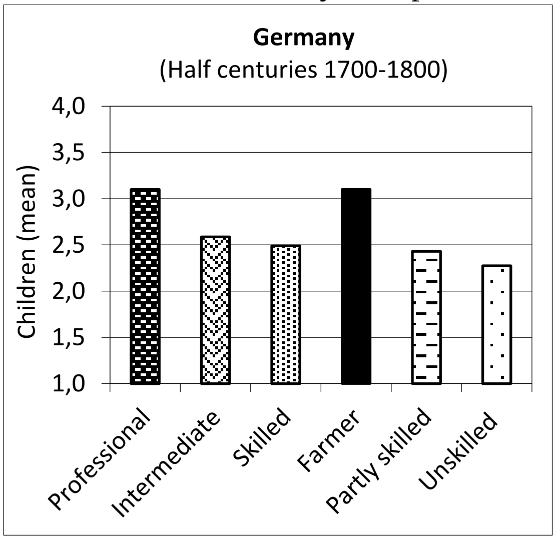
4.4 The Reproductive Success of Farmers and Other Occupational Groups

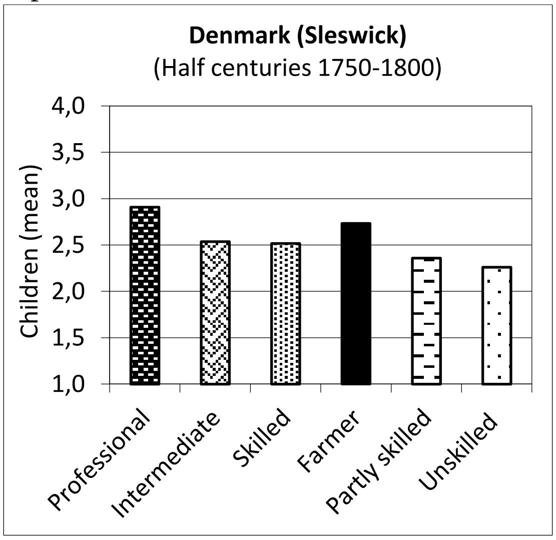
4.4.1 Descriptive Results

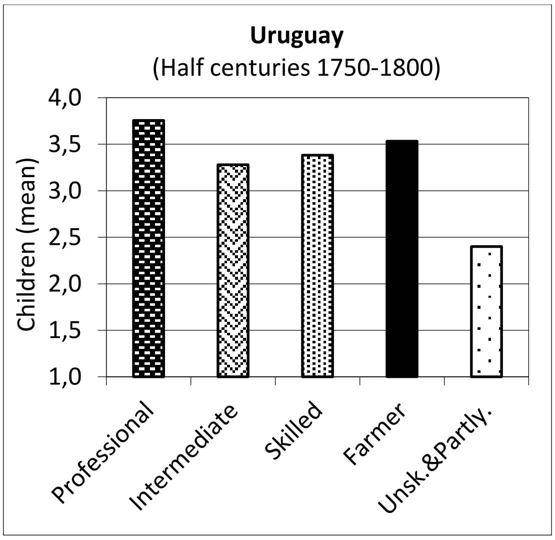
Figures 4.3.1–4.3.7: (Weighted) Mean Numbers of Children by Occupational Groups and Countries



Figures 4.3.1–4.3.7: (Weighted) Mean Numbers of Children by Occupational Groups and Countries – Continued







Note: Included are male family heads aged 23-62 years who had children. For the underlying numbers of observations see Table 4.4. Similar occupational groups are aggregated if the number of observations in one group is N<30 (partly skilled and unskilled). The European observations are weighted by their respective urban weights. For more information on urban weights and weighted percentages, see Appendix A.4. Information on urbanization was not available for Uruguay in the respective time period. Sources: See Table 4.1.

Finally, we test our assumption of great reproductive in-household success among the farming group. The numbers in Figures 4.3.1–4.3.7 are based on the more robust measure of comparing only the numbers of children among family heads. The figures show that farmers had a large number of children. While the farmers were on a similar level as the professionals in Germany, they had the highest number of children in Austria and Spain (Figures 4.3.5, 4.3.1–4.3.2, 4.3.4).[118] In Uruguay and Denmark

[118] The relatively low number of children in the professional group in Spain could be due to the fact that a large part of this dataset (especially for the professionals) stems from Toledo, an important center for trade and production in early modern Spain. As Livi Bacci (1986) argues, some of the higher social

(Figures 4.3.7, 4.3.6), the farming group had the second largest number of children, only surpassed by the professionals. In Southern Italy, farmers had a lower number compared to the three higher groups and the partly skilled, but they still had more children than unskilled people (Figure 4.3.3).[119] In the early period in Austria, farmers had almost four children surviving up to the year of the survey, whereas partly skilled and unskilled people had less than 2.5 children (Figure 4.3.1). Professional and skilled Austrians only had between 2.5 and 3 children. In the later period, the differences slightly decreased but were still observable (Figure 4.3.2). The number of children per family in Austria was generally very high and larger than in the other European countries. This finding may be due to the fertility pattern identified by Woods (2000), who found that, in 19th century Austria, nuptiality rates were also low whereas marital fertility was high.

The fact that, in almost all of the countries, farmers had the largest or second largest number of children compared to the other occupational groups is important for the contribution to human capital improvement in the 18th and early 19th centuries. The one exceptional case is Southern Italy, where farmers had the second lowest reproductive success in terms of the mean number of children. A possible explanation for why these results differ from the other European countries is the agricultural land tenure structure in preindustrial Southern Italy (Galt 1986, p. 438): most of the land belonged to very large landowners who lived in towns and leased their lands to smallholders (*bracciali*) who worked the soil. The number of farmers with a medium-sized plot or large plot of land was small.

classes of larger cities were "social group forerunners" in limiting fertility.

[119] The case of the farmers from Southern Italy is discussed more thoroughly in chapter three, section five of this thesis.

4.4.2 Regression Results

Table 4.5: (Weighted) Negative Binomial Regressions on the Number of Children and Robustness Tests, All Available Countries and Individuals Included

Neg. Bin. Marg. eff.	**M1**	**M2**	**M3**	**M4**	**R1**	**R2**	**R3**	**R4**
Dep. var.:	**No. of children**				**Children up to 12 years**			
Included countries:	**All**		**European (weighted)**		**All**		**European (weighted)**	
Professional	0.44***	ref	0.44***	ref	0.29***	ref	0.30***	ref
	(0.00)		(0.00)		(0.00)		(0.00)	
Intermediate	0.15***	ref	0.14***	ref	0.07***	ref	0.06**	ref
	(0.00)		(0.00)		(0.00)		(0.02)	
Skilled	0.20***	-0.03	0.18***	-0.04	0.08***	-0.05**	0.05**	-0.06**
	(0.00)	(0.24)	(0.00)	(0.21)	(0.00)	(0.04)	(0.01)	(0.01)
Partly skilled	ref	-0.16***	ref	-0.15***	ref	-0.10***	ref	-0.09***
		(0.00)		(0.00)		(0.00)		(0.00)
Unskilled	ref	-0.26***	ref	-0.25***	ref	-0.14***	ref	-0.12***
		(0.00)		(0.00)		(0.00)		(0.00)
Farmer	0.63***	0.40***	0.61***	0.40***	0.34***	0.21***	0.31***	0.20***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Married	ref	ref	ref	ref	ref	ref	ref	ref
Single	-1.84***	-2.06***	-1.94***	-2.15***	-1.46***	-1.59***	-1.55***	-1.66***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Widowed	-0.51***	-0.56***	-0.52***	-0.58***	-0.58***	-0.62***	-0.59***	-0.64***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Austria	0.08*	0.10*	0.10*	0.12**	0.10**	0.11**	0.11**	0.13**
	(0.09)	(0.06)	(0.05)	(0.04)	(0.03)	(0.02)	(0.02)	(0.01)
S. Italy	-0.02	-0.00	-0.01	-0.00	-0.10***	-0.10**	-0.12***	-0.12***
	(0.71)	(0.94)	(0.78)	(0.99)	(0.01)	(0.02)	(0.00)	(0.01)
Spain	0.28***	0.32***	0.26***	0.30***	0.08*	0.09*	0.06	0.07
	(0.00)	(0.00)	(0.00)	(0.00)	(0.07)	(0.05)	(0.22)	(0.16)
Germany	ref	ref	ref	ref	ref	ref	ref	ref
Denmark	0.13***	0.15***	0.13***	0.14***	0.12***	0.13***	0.11***	0.12***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Uruguay	0.44***	0.52***	-	-	0.27***	0.31***	-	-
	(0.00)	(0.00)			(0.00)	(0.00)		
Age included?	yes	yes	yes	yes	yes	yes	yes	yes
Time dummies included?	yes	yes	yes	yes	yes	yes	yes	yes
Chi² (p-val.)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pseudo R^2	0.179	0.178	0.177	0.177	0.190	0.190	0.188	0.188
Observations	55,062	55,062	53,335	53,335	49,494	49,494	47,968	47,968

Note: Robust p-values in parentheses. ***, **, * indicate significance on the 1%-, 5%- and 10%-level. "ref" indicates the reference category. Time dummy variables are census periods (half centuries) 1600-1800. Included are all male individuals aged 23-62 for whom marital and occupational status were available. On the exclusion of cases see Table 4.3. Control group=person from Germany, surveyed in census period 1750, aged 48 years. S. Italy stands for Southern Italy. Sampling weights are calculated according to the urbanization rates of the countries. Urbanization rates were not available for Uruguay. Marginal effects are reported. Sources: See Table 4.1.

To determine whether the differences in the number of offspring are statistically significant, we implement the "number of children" as the dependent variable in a number of regressions. The results of the Negative Binomial regressions including all individuals are shown in Table 4.5. In the regressions that contain all of the observations, we differentiate between models including all of the countries and those including only the European countries. For models M1 (all of the countries) and M3 (the European countries), the unskilled and partly skilled groups are the joint reference category. Clearly, the number of children of the higher occupational groups, e.g., the professionals and the intermediates, differs significantly from the unskilled and partly skilled group. Given these findings, we agree with other authors who observe a positive correlation between the number of offspring and the income or social status for a static society such as that of the early modern population (Clark 2007; Cummins 2013; Hadeishi 2003).

However, the farmer coefficient has not only a significant and positive sign but also the largest value compared to all of the other occupational groups. For a farmer, the expected number of children was 0.63 children higher than in families from the unskilled and partly skilled groups of society, which results in a difference of 63 children per one hundred families (model M1). The difference between farmers and the other occupational groups becomes even more significant in models M2 (all of the countries) and M4 (the European countries), in which the professionals and intermediates are implemented as the joint reference category. Even when compared to the highest social groups, farmers still have a significantly higher number of children (0.40), whereas the groups three to five clearly had fewer offspring.

To verify whether our results hold under stronger assumptions, we perform different robustness tests. In the first step, we run a Negative Binomial regression in which "children up to the age of 12" is employed as the dependent variable. Models R1 to R4 in Table 4.5 confirm the results described above for the mean number of all children. When controlling for children who most likely still live in the family home (aged 0–12 years), we find that farmers again have the largest number of offspring in contrast to all other occupational groups. A farmer has 0.34 more children than a partly skilled or unskilled individual (model R1) and even 0.21 more children compared to the professional and intermediate group (model R2), both on a statistically significant level.

Table 4.6: Robustness Test: (Weighted) Zero Truncated Poisson Regression on the Number of Children up to 12 Years (Family Heads With Children)

ZTP, marginal effects	**R5**	**R6**	**R7**	**R8**
Dep. variable:	**Children up to 12 years**			
Included countries:	**All**		**European (weighted)**	
Professional	0.46***	ref	0.51***	ref
	(0.00)		(0.00)	
Intermediate	0.19***	ref	0.18***	ref
	(0.00)		(0.00)	
Skilled	0.12***	-0.14***	0.10***	-0.16***
	(0.00)	(0.00)	(0.00)	(0.00)
Partly skilled	ref	-0.19***	ref	-0.19***
		(0.00)		(0.00)
Unskilled	ref	-0.29***	ref	-0.29***
		(0.00)		(0.00)
Farmer	0.34***	0.08***	0.32***	0.06**
	(0.00)	(0.01)	(0.00)	(0.05)
Austria	0.27***	0.32***	0.28***	0.33***
	(0.00)	(0.00)	(0.00)	(0.00)
S. Italy	0.04	0.07	0.06	0.08
	(0.36)	(0.23)	(0.28)	(0.17)
Spain	0.01	0.02	-0.01	-0.01
	(0.85)	(0.78)	(0.85)	(0.91)
Germany	ref	ref	ref	ref
Denmark	0.11***	0.12***	0.10***	0.12***
	(0.00)	(0.00)	(0.00)	(0.00)
Uruguay	0.84***	1.01***	-	-
	(0.00)	(0.00)		
Age included?	yes	yes	yes	yes
Time dummies included?	yes	yes	yes	yes
Chi² (p-val.)	0.00	0.00	0.00	0.00
Pseudo R^2	0.023	0.022	-	-
Observations (households)	26,783	26,783	26,262	26,262

Note: Robust p-values in parentheses. ***, **, * indicate significance on the 1%-, 5%- and 10%-level. “ref” indicates the reference category. Time dummy variables are census periods (half centuries) 1600-1800. Included are all male married heads of families aged 23-62 with children. Control group=family head from Germany, surveyed in census period 1750, aged 48 years (occupational group indicated by “ref”). The Pseudo R^2 is not displayed for weighted Zero Truncated Poisson Regressions. S. Italy stands for Southern Italy. Sampling weights are calculated according to the urbanization rates of the countries. Marginal effects are reported. Sources: See Table 4.1.

In the next step, we exclude all individuals without children and those who are not married. We thereby make sure that the results are not biased because of persons to whom no children were assigned but in fact simply lived temporarily in another place. For this modified dataset, we perform a ZTP regression. The results of these regressions confirm the findings of the previous analysis (Table 4.6). Again, the farmers display the highest numbers of descendants (up to 12 years) compared to the two lowest and the average of the two highest groups of society (models R5–R8).

Table 4.7: Farmer Coefficients of (Weighted) Regressions by Country; Reference Groups: Partly Skilled and Unskilled; Professional and Intermediate

Included country	Model no.	Regression model		Dependent variable	Farmer coefficient vs. reference group: partly skill. & unskill.	No. of obs.
Austria	M1a	Weight.	Neg. Bin.	Children	1.30***	5,402
	R1a		ZTP		1.27***	2,414
	R2a		Neg. Bin.	Children up to 12	0.81***	4,968
	R3a		ZTP		0.61***	2,011
S. Italy	M1b	Weight.	Neg. Bin.	Children	-0.03	3,142
	R1b		ZTP		-0.08	2,553
	R2b		Neg. Bin.	Children up to 12	-0.05	2,776
	R3b		ZTP		-0.10	2,199
Spain	M1c	Weight.	Neg. Bin.	Children	0.45***	6,225
	R1c		ZTP		0.56***	4,229
	R2c		Neg. Bin.	Children up to 12	0.24***	4,483
	R3c		ZTP		0.35***	2,904
Germany	M1d	Weight.	Neg. Bin.	Children	0.82***	28,915
	R1d		ZTP		0.90***	17,116
	R2d		Neg. Bin.	Children up to 12	0.40***	26,570
	R3d		ZTP		0.40***	14,964
Denmark	M1e	Weight.	Neg. Bin.	Children	0.51***	9,651
	R1e		ZTP		0.51***	4,869
	R2e		Neg. Bin.	Children up to 12	0.27***	8,876
	R3e		ZTP		0.19***	4,184
Uruguay	M1f		Neg. Bin.	Children	1.35***	1,727
	R1f		ZTP		1.05***	727
	R2f		Neg. Bin.	Children up to 12	1.33***	1,526
	R3f		ZTP		1.05***	536
					Farmer coefficient vs. reference group: prof. & interm.	
Austria	M2a	Weight.	Neg. Bin.	Children	0.93***	5,402
S. Italy	M2b	Weight.	Neg. Bin.	Children	-0.30**	3,142
Spain	M2c	Weight.	Neg. Bin.	Children	0.38***	6,225
Germany	M2d	Weight.	Neg. Bin.	Children	0.53***	28,915
Denmark	M2e	Weight.	Neg. Bin.	Children	0.24***	9,651
Uruguay	M2f		Neg. Bin.	Children	-0.08	1,727

Note: ***, **, * indicate significance on the 1%-, 5%- and 10%-level. Included are male individuals aged 23-62. Time dummy variables are census periods (half centuries) 1600-1800. On the exclusion of cases see Table 4.3. The ZTP models include only married family heads with children, the Negative Binomial models include all individuals. Time dummy variables are not included if only one census period was available. Included are the same cases as in the models with all of the countries. In all types of regression models, it is controlled for provinces. Sampling weights are the corresponding urbanization weights of the countries. For controls of the individual countries see individual regression tables (Appendix A.4). Urbanization rates were not available for Uruguay. S. Italy stands for Southern Italy. Marginal effects are reported. Sources: See Table 4.1.

We performed both the Negative Binomial and the Zero Truncated Poisson models for each of the countries in the dataset (Table 4.7, upper part).[120] For almost all of the countries, the results are very similar to the regressions including all of the countries. Farmers have a significantly higher number of children than the partly skilled and unskilled people taken together in most of the countries. The only exception is Southern Italy, where the number of children in the farming group is not significantly higher than that for the reference group.[121] Table 4.7 (lower part) shows that, in Austria, Spain, Germany, and Denmark, farmers also have a significant advantage over the highest two groups of society, the professionals and intermediates, with regard to their number of children.[122]

Although the previous regression analysis represents one possibility of testing the reproductive differences between occupational groups, there is another measure related to only the reproductive success of males: the male net reproduction rate (MNRR). The female net reproduction rate may be used more commonly, but Myers (1941) argues that the reproduction rate for males can also be implemented to analyze reproductive differences. Alter and Clark (2010, p. 44) define the net reproduction rate as “the average number of daughters that would be born through their lifetime by the average female born in each decade”. If this index takes the value one, then the female population replaces itself over the period of interest. The net reproduction rate is influenced by the birth and death rates of a population. We proceed in a way similar to Alter and Clark (2010), but instead of calculating the female net reproduction rate, we use the observed average number of sons who are born to the average male in each occupational group because fertility by occupation is not available for pre-1800 Europe.[123] Therefore, we designate the rate the “census-based male reproduction rate”

[120] See Appendix A.4 for the complete regression models of each country.
[121] For Italy, there are relatively small differences among all of the occupational groups.
[122] Exceptions are Southern Italy and Uruguay for which the coefficient is negative (but insignificant for Uruguay).
[123] Consequently, we calculate a male net reproduction rate that is slightly adjusted to our data because we can only include the observed male children. The reproduction rate is calculated for two time periods in Austria (birth decades until 1650 and after 1650) because we are addressing a very long time span in the Austrian data. For the other countries, we calculate the reproduction rate over the given period for males between 23 and 62 years of age. In our dataset, we observe parents and their children who survived until the day of the survey and live in the same household, but we do not observe the total number of sons born

(MRR). Nevertheless, the importance of the (census-based) MRR in our analysis lies in studying the differentials between the occupational groups, which is independent of the formula used for the calculation of the index.

Table 4.8: (Weighted) Male Reproduction Rate (Census-Based) by Country

	Austria1	Austria2	S. Italy	Spain	Germany	Denmark	Uruguay
Professional	0.93	0.79	0.83	0.81	0.82	0.91	1.16
Intermediate	0.81	0.78	1.01	0.85	0.92	0.81	0.80
Skilled	0.87	0.67	1.10	0.97	0.68	0.72	0.45
Partly skilled	0.16	0.54	1.09	0.63	0.81	0.46	0.06
Unskilled		0.06	0.42	0.77	0.52	0.41	
Farmers	1.43	1.25	1.10	1.13	1.27	1.05	1.26

Note: The table shows the change in the occupational composition between the first and the second generation of males in the dataset. The first generation is composed of all male individuals aged 23-62 who can be classified into an occupational group, except those indicated as "children". The second generation is composed of all male children who are indicated as such, classified into their fathers' occupational group. The age range of the children is 1-47 (47 years is the maximum age range for the children because in this case the oldest father was 15 years at the birth of the son). Excluded are the families with identifiable children of former marriages because we cannot control if the children are genetic children of the mother or father. Austria1 indicates the early period of Austrian data (half centuries 1600-1650), Austria2 indicates the later period (half centuries 1700-1750). S. Italy stands for Southern Italy. Excluded are regions or places for which individual information on the children is not provided: Soria (Spain), Rhineland-Palatinate (Germany), Cerrillos and Maldonado and Districts (Uruguay). Excluded are also slaves in Uruguay because potential children of the slaves are not indicated. The values of similar groups (partly skilled & unskilled) are aggregated observation numbers were N<30. The underlying number of observed sons in Austria1 for partly skilled and unskilled was 21. The European observations are weighted by their respective urbanization weights. Urbanization rates were not available for Urguay in the respective time period. Sources: See Table 4.1.

In almost all of the countries, the farmers are once again the group with the highest share of male reproduction (Table 4.8). The exception is Southern Italy, where the farmers' share is equal to that of the skilled. The male reproduction rate of farmers exceeds the value of one in all of the countries. The previous results identify farmers as one of the most reproductive groups of society in the early modern period. However, from where do these large differences between farmers and the other occupational groups derive?

Certainly, there are several factors that we must consider, such as differences in fertility, the mortality rates of infants, and women's age at marriage. Because studies related to these differences between occupational groups for the early modern period across Europe are scarce, we refer to somewhat later periods in time. Van Bavel and Kok (2004, p. 133) find that farmers in 19th-century Holland had significantly shorter birth intervals in contrast to other occupational groups, particularly the unskilled. They

to a male. Hence, the reproduction rate calculated for our data may be downward biased.

argue that farmers in Holland could afford to replace the workforce of the wife by a servant when she had to take care of a newborn child.

We assume that a very similar mechanism led to the high numbers of children of farmers in our data. This assumption may also imply that farmers with large plots of land had more children than smallholders. In our dataset, we are able to identify two main groups of farmers by their respective terms, medium-sized (and larger) farmers representing approximately 65%, and smallholders who correspond to approximately 33% of the whole entire farmer group (Table 4.9).[124]

Table 4.9: Numbers of Observations
and Compositional Percentages of the Farmer Subcategories by Country

		Austria	**S. Italy**	**Spain**	**Germany**	**Denmark**	**Uruguay**	**Total**
		Obs.	Obs.	Obs.	Obs.	Obs.	Obs.	Obs.
1	Medium-sized/ larger farmer	1,092	173	1226	4,073	1,070	446	8,080
2	Smallholder	227	1,579	-	1,950	335	54	4,145
3	Other/mixed	3	-	-	230	14	-	247
	Total	1,322	1,752	1,226	6,253	1,419	500	12,472
		%	%	%	%	%	%	%
1	Medium-sized/ larger farmer	82.6	9.9	100.0	65.1	75.4	89.2	64.8
2	Smallholder	17.2	90.1	-	31.2	23.6	10.8	33.2
3	Other/mixed	0.2	-	-	3.7	1.0	-	2.0
	Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Note: Displayed are male individuals aged 23-62. These observations are relevant for the analysis of the number of children. On the exclusion of observations see Table 4.3. The three different groups contain the following labels: Austria: 1=*Bauer*, 2=*Hauesler*, 3=someone who lives of farming, but cannot clearly be aggregated to one of the first two groups. Southern Italy (S. Italy): 1=*massaro*, 2=*bracciale*. Spain: 1=*labrador*. Germany: 1=*Hufner, Partial Hufner*, property with land & agriculture, *Bauer, Colonus, Landmann, Landwirt, Ackersmann, Parcelist*, 2=*Kaetner, Koetter, Haeusler*, leaseholder or owner of a small piece of land, 3=someone who lives of farming, but cannot clearly be aggregated to one of the first two groups. Denmark: 1=*Hufner*, *Bohlsmann* (farmer in Sleswick), 2=*Kaetner*, 3=someone who lives of farming, but cannot clearly be aggregated to one of the first two groups. Uruguay: 1=*labrador*, 2=c*hacarero*. Sources: See Table 4.1.

Moreover, the medium-sized farmers frequently reported employing servants: while more than 53% of the medium-sized farmers had at least one servant, only approximately 17% of the small farmers reported the same information (see Appendix A.4). Hence, it is most likely that this large group of prosperous medium-sized or larger farmers had access to high-quality nutrition that increased their fertility and the means to provide for their large families.

[124] The numbers refer to individuals between 23 and 62 year of age in the farmer group. The rest of the approximately 9% are “others” who live off farming but cannot clearly be aggregated to one of the main groups of farmers. In the Spanish dataset, there is only one definition of a farmer: *labrador*.

Another decisive factor leading to differences in the number of descendants is the mortality rate of infants by occupational group. Woods (2000, p. 267) finds that, for 19th-century England and Wales, mortality rates were high (low) for infants of lower (higher) social groups. Surprisingly, the infant mortality rate of agricultural workers, who are considered the lowest group of this time in England, is not significantly higher than that of the young children of professionals. Woods ascribes this finding to the less dangerous environment to which children of rural agricultural workers were exposed in contrast to those of other occupational groups, including the professionals. The finding of a higher life expectancy among higher social groups and farmers is closely connected to this phenomenon.

Szreter (1996) analyses the relationship between fertility, women's age at marriage, and the occupational group of the husband in Great Britain during the 19th and early 20th centuries. The author shows that, still in times of decreasing fertility rates for higher social classes, farmers displayed a relatively high fertility.[125] Moreover, they belonged to groups that delayed marriage but nonetheless reached high fertility levels when marrying at an older age.[126]

4.5 The Heterogeneity of the Farmer Group

Because we classify farmers into one single category, one could object that farmers are a fairly heterogeneous group, with small-scale subsistence farmers on the one hand and large farms with a high number of farm hands on the other. Furthermore, the large number of children in farming families could be associated with the workforce need at small farms for which the income was not sufficient to hire external workers. Thus, if the dataset contained only subsistence farming families, then the variation in the number of offspring between farmers and other groups of society could be caused by the sheer need for more hands to work the land.

[125] Farmers were ranked 104 out of 195, with 195 representing the highest fertility rate of all occupational groups (Szreter 1996, Appendix C).

[126] Farmers in this category ranked 58 out of 195, with number 195 representing the group with the lowest proportion marrying at an older age (Szreter 1996, p. 336 and Appendix C). Haines (1979), who finds variation in the marriage patterns and the number of surviving children of different social groups, is also in line with these findings. Because the time period in Haines' study is composed of data from the 19th and 20th centuries, the fertility decline is already ongoing. Consequently, the high-status groups of society have lower fertility, whereas less skilled people have many births in this later period. The fertility differentials between the groups are significant. The fact that the differentials still exist, even after they are standardized to the marriage patterns of the female population, is revealing.

To assess these potential objections, we take a closer look at the terms used for farmers in the different countries of the dataset.[127] For almost all of the countries in the dataset, we were able to differentiate between medium-sized or larger farmers on the one hand and smallholders on the other. While in some of the countries in our dataset, several terms were used to indicate a farmer, for others, there was only one label used for a farmer. To adequately analyze the different categories of farmers, we formed subcategories following the relevant terms (see Table 4.9).

In the Austrian dataset, we have two main subcategories: approximately 83% of the Austrian farmer group consists of those for whom the term *Bauer* is used, denoting medium-sized or larger farmers. The subcategory of smallholders (*Haeusler*, *Halbbauer*) corresponds to approximately 17% of the Austrian farming group (on the labels see Heinsius 1840 p. 270).

In Germany, there are a few terms that indicate a farmer. The most prominent terms for farmers in Northern Germany (Holstein), from which most of the German data derive, differentiate between smallholders (*Kaetner*) and medium-sized or larger farmers (*Hufner*) (Lorenzen-Schmidt 1996, entry "Hufner"; Heinsius 1840, pp. 426–427).[128] We decided to include the individuals with at least half of a *Hufe* in the medium-sized or larger farmer group and the individuals with smaller pieces of land in the smallholder group. In Western and Southwestern Germany, several terms designate persons with larger or medium-sized farms (*Ackersmann*, *Landwirt*, *Bauer*, *Colonus*). We contrast these with a group of smallholders (*Kaetner*, *Casettarius*) (Heinsius 1840, p. 626).[129] In total, we identify approximately 65% of the German farming group as medium-sized or larger farmers and approximately 31% as smallholders. For approximately 4% of the German farmers, it is not entirely clear whether the individuals with farming occupations belong to the medium-sized farmer or smallholder group.[130]

The largest part of the Danish (Sleswick) farming group consists of the medium-sized or larger farmers (*Hufner*, *Bohlsmann*) accounting for approximately 75% of all farmers in Denmark. The smallholders (*Kaetner*) correspond to approximately 24% of the Danish farmer group.

[127] On the description of the farmer group see also chapter three, section five of this thesis.
[128] The *Hufner* is denoted by the size of the land he owns or rents, the *Hufe* (=30 to 42 acres in most areas), see also Heinsius (1840, pp. 426–427).
[129] *Colonus*, *Casettarius*: Latin for *Bauer* (medium-sized farmer), *Kaetner* (smallholder).
[130] For more information on the farmer subcategories in Germany see Appendix B.4.

In the Uruguayan data, the medium-sized or larger farmers, *labradores*, amount to nearly 89.2%. The group of smallholders, *chacareros*, accounts for only 10.8% because the inhabitants of this Latin American country were often able to gain access to medium-sized or larger farms. In Spain, the only term indicating a farmer is *labrador*. He may be the owner of a larger, medium-sized or smaller farm. There was no specific term for smaller farmers in Spain in the census.

The differentiation between farmer subcategories in Southern Italy is more complicated, particularly because of the land tenure structure in this region. On the one hand, there were a limited number of very wealthy landowners owning a large share of the land. By contrast, the smallholders were relatively poor (Galt 1986, pp. 432, 437–439). In our dataset, we are able to identify two terms that can classify a farmer: *massaro* and *bracciale*. The former describes a yeoman, whereas the latter relates to a smallholder.[131] However, the differentiation between these two terms does not necessarily reflect the actual position or wealth of the person. The only clear difference is that, by definition, a *bracciale* did not have herd animals whereas a *massaro* generally did. Although the differentiation between the two subcategories is less clear-cut than in the other countries, we assume that the term *bracciale* means smallholder, representing about 90% of the farmers, and that a *massaro* is a farmer with slightly more land, corresponding to approximately 10% of the Southern Italian farmers.

In general, we observe a strong relationship between the medium-sized or larger farmers and the presence of servants in the household. Approximately 84% of all servants in the farming group worked on farms of medium or larger size, whereas only 14.4% reported living in smallholder households (see Appendix A.4). This finding confirms the assumption that there is a correlation between the terms for the medium-sized or larger farmers and the existence of capital in their households. Further evidence is provided by Shaw-Taylor (2005, p. 175), who works on the relationship between the size of farms or holdings and the number of servants (or laborers) hired to work the land in mid-19th-century England. This author states that approximately 15% of the farmers with holdings between 20 and 100 acres did not report hiring laborers whereas the remaining share did. Considering the generally higher capitalization of agriculture in England, the implication is that our classification of farming groups can be assumed to

[131] In the 20th century, the word *bracciale* indicated an agricultural laborer who controlled some land. Nonetheless, referring to the evidence on income and the land tenure structure described by Galt (1986, pp. 432, 437–439), we assume that the term *bracciale* in 18th-century Southern Italy indicates a smallholder.

be relatively valid, given the shares of servants in the subcategories. Naturally, there are exceptional cases, such as the Southern Italian farmers, which also address very different preconditions.[132]

Table 4.10: Negative Binomial Regressions on the Number of Children of Farmers by Country

Neg. Bin. Marginal effects	**F1**	**F2**	**F3**	**F4**	**F5**
Dep. variable:	**No. of Children**				
Included country	**Austria**	**S. Italy**	**Germany**	**Denmark**	**Uruguay**
Medium-sized/ larger farmer	ref	ref	ref	ref	ref
Smallholder	-1.73***	-0.16	-0.42***	-0.50***	-0.25
	(0.00)	(0.26)	(0.00)	(0.00)	(0.49)
Marital status included?	yes	yes	yes	yes	yes
Time dummies included?	yes	yes	yes	yes	yes
Province dummies included?	yes	yes	yes	-	-
Chi² (p-val.)	0.00	0.00	0.00	0.00	0.00
Pseudo R²	0.059	0.017	0.049	0.066	0.062
Observations	1,312	1,752	6,023	1,405	500

Note: Robust p-values in parentheses. ***, **, * indicate significance on the 1%-, 5%- and 10%-level. “ref” indicates the reference category. Included are males aged 23-62. Time dummy variables are census periods (half centuries). Control group=person surveyed in census period 1750 (Germany/Austria) and 1800 (Italy), aged 48 years and married. S. Italy stands for Southern Italy. On the exclusion of cases see Table 4.3. It is not controlled for period in Denmark because the number of observations in some categories is N<30. The category “other” is excluded. Marginal effects are reported.
Sources: See Table 4.1.

In the following, we compare the number of children among farmer subcategories in regression models. The results in Table 4.10 reveal that the smallholders have a smaller number of children up to 12 years of age than the medium-sized or larger farmers in three out of five countries for which we find different designations for farmers: in Austria, Germany, and Denmark, the smallholders have a significantly smaller number of children up to 12 years of age than the group of the medium-sized or larger farmers. In Uruguay and Southern Italy, the smallholders’ coefficients also show a negative sign but not on a significant level.[133]

[132] However, we must bear in mind that England’s agriculture was generally more capitalized than in most of the other European countries.
[133] See Appendix A.4 for robustness tests on the number of children up to 12 years of age as the dependent variable. The results are relatively stable.

As noted in the previous section, we also find a strong relationship between medium-sized or larger farmers and the presence of servants in the household for the countries in our dataset, with the exception of Southern Italy.[134] Moreover, when assuming a positive relationship between the workforce need and the number of offspring, smallholders should be the group with a high number of children. However, as our results show, this assumption is not met. On the contrary: we find that the medium-sized farmers who could afford to pay (or at least to board and lodge) extra-familial labor were those who had a significantly higher number of children in relation to the farming individuals with smaller holdings. We conclude from this finding that it was mainly the large group of prosperous medium-sized and larger farmers who had a significant reproductive advantage over other groups of society.

4.6 Social Mobility in the Early Modern Period

Based on the previous results, a number of important conclusions can be drawn. Because the variation in the number of offspring between the different occupational or socioeconomic groups is fairly strong and statistically significant, we are interested in the effect of this mechanism in later generations. When we consider a high number of descendants in farming families, it is likely that these descendants have also been able to successfully reproduce, if certain skills were passed from parents to their children. Given the positive growth rate in each of the later generations of farmers and the negative growth rate of the partly skilled and unskilled groups, we can assume that the farmers' offspring would represent a larger part of society in subsequent decades.

It is apparent that not all of the farmers' sons had the opportunity to become farmers because the oldest son often inherited the family property in impartible inheritance areas (Duplessis 1997, pp. 163, 183; Herrigel 1996).[135] However, because not all of the siblings had this opportunity, many adult children of farmers were forced to leave their home and search for work as agricultural laborers. There may have been exceptional cases in which the descendants had the opportunity to undertake an apprenticeship and become a craftsman or a higher skilled person. The situation in areas

[134] In Southern Italy, neither the medium-sized farmers nor the smallholders had servants living in their households (there are a total of four farmer households that report servants).

[135] We assume that the farmers' daughters often married and left their parents' home. The inheritance patterns depended on the inheritance laws and regional customs. We assume here that the oldest son often inherited the family's property.

in which people partitioned their inherited land was also unfavorable because a growing share of the population lived on small holdings (Herrigel 1996, p. 35).

The mechanism of downward mobility in early modern society has been described for England by Clark (2007) and more recently by Boberg-Fazlic et al. (2011). While Clark argues on the basis of the inheritance of "middle class values", Boberg-Fazlic et al. suggest that a "demonstration effect" of the wealthy descendants' behavior led to the spread of "middle class values" in the poorer occupational groups to which they moved. However, in both of these approaches, one of the large population groups of early modern society was not considered: farmers. Farmers represented a relatively large share of society, they were provided with favorable human capital, and their numbers of descendants were among the highest compared to other groups in early modern society (on England, see Boberg-Fazlic et al. 2011; on farmers' human capital of other European countries, see Tollnek and Baten 2017).

To identify potential mobility between social groups in the descendants' generation, we compare the relative size of each of the occupational groups across two generations. Therefore, we consider the 23- to 62-year-old working men as the first generation and their male children as the second.[136] Because we aim to model the composition of the second generation as realistically as possible, we calculate the size of the occupational groups by weighting the observations by their respective urbanization rate (Table 4.11). Thus, we ensure that urban samples do not have a higher influence because of a higher number of observations.

Table 4.11: Change in the Size
of Occupational Groups From One Generation to the Next

<table>
<tr><th></th><th>Austria1</th><th>Austria2</th><th>S. Italy</th><th>Spain</th><th>Germany</th><th>Denmark</th><th>Uruguay</th></tr>
<tr><td></td><td colspan="7">(Weighted) percentage change in the size of occupational groups</td></tr>
<tr><td>Professional</td><td>0.1</td><td>0.4</td><td>-1.8</td><td>-0.4</td><td>0.1</td><td>1.2</td><td>6.4</td></tr>
<tr><td>Intermediate</td><td>-1.7</td><td>0.9</td><td>-0.1</td><td>-0.2</td><td>2.0</td><td>2.8</td><td>3.3</td></tr>
<tr><td>Skilled</td><td>-1.7</td><td>-1.5</td><td>1.0</td><td>2.8</td><td>-3.4</td><td>2.2</td><td>-4.0</td></tr>
<tr><td>Partly skilled</td><td rowspan="2">-14.8</td><td>-0.7</td><td>0.4</td><td>-2.6</td><td>0.2</td><td>-4.1</td><td rowspan="2">-36.4</td></tr>
<tr><td>Unskilled</td><td>-24.7</td><td>-2.0</td><td>-4.3</td><td>-10.9</td><td>-10.7</td></tr>
<tr><td>Farmer</td><td>18.1</td><td>25.5</td><td>2.4</td><td>4.7</td><td>12.1</td><td>8.6</td><td>30.7</td></tr>
</table>

Note: The table shows the change in the relative size of the occupational groups between the first and the second generation of males in the dataset. For example: the professional group in the first generation of Danish males represented 3.4% of the occupational groups, and their sons (assigned to the occupational

[136] Because we do not observe all of the children born to each man but only those living in the same household, the absolute numbers may be slightly downward biased. The relative shifts in the occupational groups, however, are assumed to be constant. The male children are classified into their fathers' occupational group.

group of their fathers) represented 4.6%. Consequently, this group increased its size by 1.2 percentage points. The first generation is composed of all male individuals aged 23-62 who can be classified into an occupational group, except those indicated as "children". The second generation is composed of all male children who are indicated as such, classified into their fathers' occupational group. The age range of the children is 1-47 (47 years is the maximum age range for the children because in this case the oldest father was 15 years at the birth of the son). Excluded are the families with identifiable children of former marriages because we cannot control if the children are genetic children of the mother or father. Austria1 indicates the early period of Austrian data (half centuries 1600-1650), Austria2 indicates the later period (half centuries 1700-1750). S. Italy stands for Southern Italy. Excluded are regions or places for which individual information on the children is not provided: Soria (Spain), Rhineland-Palatinate (Germany), Cerrillos and Maldonado and Districts (Uruguay). Excluded are also slaves in Uruguay because potential children of the slaves are not indicated. The values of similar groups (partly skilled & unskilled) are aggregated observation numbers were N<30. The underlying number of observed sons in Austria1 in partly skilled and unskilled was 21. The European observations are weighted by their respective urbanization weights. Urbanization rates were not available for Urguay in the respective time period. On the underlying numbers of observations see Appendix A.4. Sources: See Table 4.1.

The results in Table 4.11 reveal that the farmers are the only group with a substantial increase in their relative size from the first generation to the second. The increase in the proportion of the farmer group reaches from nearly 5 percentage points in Spain to more than 25 percentage points in the second period in Austria. It is only in Southern Italy that the increase in the farmers' relative size was relatively small, approximately 2.4 percentage points, which is likely due to the mainly smallholder composition of the group in Southern Italy. While the professional and the intermediate groups moderately increase their relative frequency in most of the countries, the skilled occupations vary in their success. The relative frequency of the partly skilled tends to decrease in most of the countries. By contrast, the unskilled group must take a significant loss in its percentage share from the first to the second generation, reaching from only -2 percentage points in Southern Italy to -36.4 percentage points in Uruguay.[137]

Table 4.12: Inflow Mobility of Occupational Groups of the Sons (Column Percentages)

Occup. group of the father (%)	Occup. group of the son (%)						
	Prof.	**Interm.**	**Skilled**	**Partly skill.**	**Unskill.**	**Farmer**	**Total**
Professional	50.0	21.1	4.9	1.9	1.9	0.2	5.8
Intermediate	17.9	30.5	16.0	5.9	1.5	0.9	9.7
Skilled	19.1	27.4	55.7	26.2	15.7	3.3	31.6
Partly skilled	4.9	5.3	6.0	30.2	9.3	3.2	9.1
Unskilled	0.0	3.2	8.6	4.9	23.2	0.9	8.1
Farmer	8.0	12.6	8.9	30.9	48.5	91.6	35.7
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Note: The table shows the "inflow mobility" of the son's occupational group. Percentages sum up to 100% by columns. The father's occupational group is composed of all male individuals indicated as fathers (aged 30-72) who can be classified into an occupational group. Fathers may be widowed or

[137] Partly skilled and unskilled groups are aggregated in Uruguay because the number of observations for the partly skilled was less than 30. See Appendix A.4 for the numbers of observations.

married. The son's occupational group is composed of the male individuals indicated as "children" for whom an occupation was reported (aged 15-50). The age range differs from other calculations to guarantee a sufficient number of father-son pairs. The age range is chosen so that the youngest father was at least 15 at the birth of the son; accordingly, the oldest father's distance to the oldest son is also at least 15 years. On the underlying numbers of observations see Appendix A.4. Sources: See Table 4.1.

Moreover, we are able to provide further evidence of the mobility of farmers' children. Therefore, we take into account the sons who are observable in their parents' household and for whom an occupation is reported. Table 4.12 yields the results of the "inflow mobility" and hence the mobility from the sons' perspective: which occupational group did the father belong to if the son was a farmer?[138]

The group of farmers seemed to have nearly no inflow mobility: only about 8% of the sons indicated as farmers, had a father with a different occupational background. The large group of unskilled workers, on the other hand, represented an enormous amount of inflow mobility: while only about 23% of the unskilled sons had a father who was also an unskilled worker, approximately 49% of the unskilled laborers stemmed from fathers whose occupation was indicated as farmer. The partly skilled group also represented a high share of inflow mobility, with about 31% of sons whose fathers were farmers. In conclusion, it is most likely that the farmers who successfully reproduced and provided their offspring with beneficial human capital skills managed to spread their human capital among the other groups of early modern society.

4.7 Conclusion

Clark has famously argued that the well-educated, wealthier strata of Western European society had more children than poor and uneducated people. He argues that this phenomenon was the driving factor for the Industrial Revolution. He describes this group as typically capitalistic and mercantile; hence, most people imagine that the group consists of merchants and people of similar social strata. However, what about the large group of farmers?

[138] On inflow mobility and the implemented illustration, see Boberg-Fazlic et al. (2011, p. 383). Note that the largest number of observations of sons who are farmers in Table 4.12 stem from Southern Italy and are indicated as farmers. Therefore, we provide an additional table without those sons who are indicated as *bracciale* (see Appendix A.4). Although the number of observations for sons who are farmers becomes relatively low then (32 observations), the results are very similar. Moreover, for our purposes, it was important to show that a large number of farmers' sons move to the unskilled group (for which we have a stable number of observations). Because we had to find father-son pairs where both reported an occupation for this analysis, we considered fathers between 30 and 72 years of age and sons between 15 and 50. On the underlying number of observations see Appendix A.4.

With a new and large dataset containing several countries and more than 298,000 observations, we demonstrated that the number of offspring was strongly influenced by the socioeconomic background in the early modern period. People with high incomes had a significantly higher number of children compared to poorer families, and they were only exceeded by the large group of farmers who reproduced more successfully than or on a level similar to the professional and intermediate groups.[139] The poorer families had to deal with negative effects of malnutrition and physically demanding work, which most likely reduced their fertility and consequently their reproductive success (Gray 1983, pp. 116–120; Standing 1983, p. 431). However, given that these highest groups represented only a small share of early modern society, it seems unlikely that their impact had a major influence.

Moreover, farmers were able to count, and they substantially contributed to the increase in human capital in 18th- and early 19th-century Europe, as shown by Tollnek and Baten (2017). However, how did they achieve this substantial contribution? It seems likely that farmers taught their large offspring how to process basic numerical tasks by intergenerational transmission (see, for example, Haveman and Wolfe 1995). Through the favorable provision of high-quality nutrition, the children of the farmers had most likely an advantage in adapting and learning these skills. Furthermore, the evidence provided in this study leads to the conclusion that, while there was nearly no selection *into* the farmer occupation, a considerable share of the descendants of the farmers had to move *down* to the lower skilled groups of society (see also Boberg-Fazlic et al. 2011, p. 383). As the downward moving individuals were provided with beneficial human capital skills, they may have spread these skills among other parts of society, reinforcing the increase in human capital in early modern Europe.

[139] Southern Italy, however, is the great exception because of the particular circumstances and land tenure structure of this region. The Uruguayan and Danish farmers had only a slightly lower mean number of children compared to the professionals. In the regression models, the farmers from five out of six countries have a significantly larger number of children compared to the other occupational groups.

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Appendix A.4: Additional Tables and Figures

Table A.4.1: Distribution of Occupational Groups: Weighted European Percentages

	Austria1	**Austria2**	**S. Italy**	**Spain**	**Germany**	**Denmark**	**Total**
European weighted percentages (all male individuals aged 23-62)							
	%	%	%	%	%	%	%
Professional	6.2	4.1	7.3	5.4	3.6	3.5	4.1
Intermediate	14.3	8.9	2.6	7.8	12.7	13.6	11.4
Skilled	28.7	23.8	21.3	23.8	24.5	28.5	25.0
Partly skilled	4.4	3.1	11.9	9.4	9.1	13.0	9.4
Unskilled	13.7	27.1	1.5	27.2	29.3	26.2	26.4
Farmer	32.8	33.1	55.4	26.3	20.8	15.2	23.7
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0
European weighted percentages (male family heads with children aged 23-62)							
	%	%	%	%	%	%	%
Professional	7.4	4.9	5.6	4.7	3.3	4.2	4.0
Intermediate	15.1	12.3	2.5	7.2	14.4	16.0	12.6
Skilled	27.9	23.4	21.4	24.5	20.9	29.8	23.1
Partly skilled	2.8	2.9	12.4	9.3	10.1	9.2	9.5
Unskilled	1.9	3.0	1.5	26.6	23.6	19.6	19.9
Farmer	44.9	53.4	56.7	27.6	27.7	21.2	31.0
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Note: Displayed are the weighted percentages of all male individuals aged 23-62 and those who are married family heads with children. These observations are relevant for the regression analysis of the number of children. Austria1 indicates the early period of Austrian data (half centuries1600-1650). Austria2 indicates the later period (half centuries1700-1750). S. Italy stands for Southern Italy. On the exclusion of observations see Table 4.3. The weighted percentages indicate the shares of the occupational groups when weighted by urbanization weights (only available for Europe). Sources: See Table 4.1.

Table A.4.2: Urbanization Rate
of the Data Compared to the Actual Urbanization Rate of 1750

	Urbanization Rate Data (overall)	**Actual Urbanization Rate**
Austria	27.8	8.9
Italy	18.2	19.4
Spain	31.9	14.0
Denmark	8.0	5.7
Germany	6.6	10.8

Note: The places counted as “urban” in the data are Salzburg (Austria), Monteleone (Southern Italy), Toledo and Granada (Spain), Kiel and Ludwigsburg (Germany) and Husum (Denmark/Sleswick). The actual urbanization rates are based on estimates for urban centers with 5,000 or more inhabitants in 1750 (Malanima 2010, p. 262). For Denmark, we use the Scandinavian urbanization rate approximately. For Uruguay, there is no urbanization rate available for the respective time period. Our data for Switzerland contain only rural areas and therefore are not weighted by urban shares. Sources: See Table 4.1 on the data and Malanima (2010) on the actual urbanization rates as well as Bairoch et al. (1988) for Austria.

Table A.4.3: Weighted Negative Binomial and Zero Truncated Poisson Regressions, Austria

Austria	**M1**	**M2**	**R1**	**M3**	**M4**	**R2**
Marg. effects	**Weighted Neg. Bin.**			**Weighted ZTP**		
Dep. variable:	**No. of children**		**Children up to 12**	**No. of children**		**Children up to 12**
Professional	0.66***	ref	0.56***	0.82***	ref	0.68***
	(0.00)		(0.00)	(0.00)		(0.00)
Intermediate	0.26*	ref	0.19	0.53***	ref	0.37**
	(0.06)		(0.12)	(0.01)		(0.05)
Skilled	0.56***	0.18*	0.32***	0.68***	0.06	0.32*
	(0.00)	(0.07)	(0.01)	(0.00)	(0.65)	(0.07)
Partly skilled	ref	-0.24	ref	ref	-0.42*	ref
		(0.18)			(0.09)	
Unskilled	ref	-0.50***	ref	ref	-0.85***	ref
		(0.00)			(0.00)	
Farmer	1.30***	0.93***	0.81***	1.27***	0.65***	0.61***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Married	ref	ref	ref	-	-	-
Single	-1.53***	-1.90***	-1.23***	-	-	-
	(0.00)	(0.00)	(0.00)			
Widowed	-0.15	-0.17	-0.40**	-	-	-
	(0.30)	(0.35)	(0.01)			
Carinthia	-0.47***	-0.59***	-0.35***	-0.53***	-0.70***	-0.39***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Lower Austria	0.21**	0.25**	0.21**	0.04	0.04	0.12
	(0.03)	(0.04)	(0.02)	(0.75)	(0.79)	(0.30)
Upper Austria	0.27**	0.34**	0.25**	0.01	0.04	0.09
	(0.02)	(0.02)	(0.02)	(0.95)	(0.85)	(0.49)
Salzburg	ref	ref	ref	ref	ref	ref
Tirol	0.21**	0.25**	0.26***	0.34***	0.45***	0.54***
	(0.03)	(0.03)	(0.00)	(0.00)	(0.00)	(0.00)
Age included?	yes	yes	yes	yes	yes	yes
Time dummies included?	yes	yes	yes	yes	yes	yes
Chi² (p-val.)	0.00	0.00	0.00	0.00	0.00	0.00
Pseudo R^2	0.242	0.242	0.260	-	-	-
Observations	5,402	5,402	4,968	2,414	2,414	2,011

Note: Robust p-values in parentheses. ***, **, * indicate significance on the 1%-, 5%- and 10%-level. “ref” indicates the reference category. Included are males aged 23-62. Time dummy variables are census periods (half centuries) 1600-1750. Control group (ZTP)=family head surveyed in census period 1750, aged 48 years. Control group (Neg. Bin.)=person surveyed in census period 1750, aged 48 years and married (occupational group indicated by “ref”). On the exclusion of cases see Table 4.3. The ZTP models include only married family heads with children, the Neg. Bin. models include all individuals. Sampling weights are calculated according to the Austrian urbanization rates in the 18th century. Marginal effects are reported. The Pseudo R^2 is not displayed for weighted ZTP regressions. Sources: See Table 4.1.

Table A.4.4: Weighted Negative Binomial and Zero Truncated Poisson Regressions, Southern Italy

Southern Italy Marg. effects	M1	M2	R1	M3	M4	R2
	Weighted Neg. Bin.			Weighted ZTP		
Dep. variable:	No. of children		Children up to 12	No. of children		Children up to 12
Professional	0.42**	ref	0.32**	0.51***	ref	0.41**
	(0.02)		(0.05)	(0.01)		(0.02)
Intermediate	-0.08	ref	0.07	0.19	ref	0.40*
	(0.74)		(0.73)	(0.42)		(0.09)
Skilled	0.22*	-0.05	0.10	0.36***	-0.06	0.22**
	(0.07)	(0.76)	(0.29)	(0.00)	(0.70)	(0.05)
Partly skilled	ref	-0.22	ref	ref	-0.37**	ref
		(0.18)			(0.03)	
Unskilled	ref	-0.65**	ref	ref	-0.83**	ref
		(0.03)			(0.01)	
Farmer	-0.03	-0.30**	-0.05	-0.08	-0.50***	-0.10
	(0.75)	(0.04)	(0.53)	(0.40)	(0.00)	(0.27)
Married	ref	ref	ref	-	-	-
Single	-2.58***	-2.84***	-1.89***	-	-	-
	(0.00)	(0.00)	(0.00)			
Widowed	-0.93***	-0.99***	-0.53	-	-	-
	(0.00)	(0.00)	(0.43)			
Brindisi	0.94***	1.11***	0.47***	0.90***	1.12***	0.39**
	(0.00)	(0.00)	(0.01)	(0.00)	(0.00)	(0.03)
Cosenza	0.35***	0.39***	0.25***	0.46***	0.53***	0.37***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Napoli	0.58***	0.67***	0.44***	0.43*	0.52**	0.30
	(0.00)	(0.00)	(0.01)	(0.06)	(0.04)	(0.10)
Vibo Valentia	ref	ref	ref	ref	ref	ref
Age included?	yes	yes	yes	yes	yes	yes
Time dummies included?	yes	yes	yes	yes	yes	yes
Chi² (p-val.)	0.00	0.00	0.00	0.00	0.00	0.00
Pseudo R^2	0.071	0.071	0.044	-	-	-
Observations	3,142	3,142	2,776	2,553	2,553	2,199

Note: Robust p-values in parentheses. ***, **, * indicate significance on the 1%-, 5%- and 10%-level. "ref" indicates the reference category. Included are males aged 23-62. Time dummy variables are census periods (half centuries) 1700-1750. Control group (ZTP)=family head surveyed in census period 1750, aged 48 years. Control group (Neg. Bin.)=person surveyed in census period 1750, aged 48 years and married (occupational group indicated by "ref"). On the exclusion of cases see Table 4.3. The ZTP models include only married family heads with children, the Neg. Bin. models include all individuals. Sampling weights are calculated according to the Italian urbanization rates in the 18th century. The Pseudo R^2 is not displayed for weighted Zero Truncated Poisson regressions. Marginal effects are reported. Sources: See Table 4.1.

Table A.4.5: Weighted Negative Binomial and Zero Truncated Poisson Regressions, Spain

Spain	**M1**	**M2**	**R1**	**M3**	**M4**	**R2**
Marg. effects	**Weighted Neg. Bin.**			**Weighted ZTP**		
Dep. variable:	**No. of children**		**Children up to 12**	**No. of children**		**Children up to 12**
Professional	-0.03	ref	-0.05	0.06	ref	0.20
	(0.81)		(0.68)	(0.72)		(0.20)
Intermediate	0.13	ref	0.03	0.52***	ref	0.33***
	(0.24)		(0.77)	(0.00)		(0.01)
Skilled	0.37***	0.30***	0.20***	0.47***	0.13	0.29***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.27)	(0.00)
Partly skilled	ref	-0.13	ref	ref	-0.38**	ref
		(0.30)			(0.02)	
Unskilled	ref	-0.04	ref	ref	-0.32***	ref
		(0.64)			(0.01)	
Farmer	0.45***	0.38***	0.24***	0.56***	0.22*	0.35***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.09)	(0.00)
Married	ref	ref	ref	-	-	-
Single	-2.22***	-2.28***	-1.72***	-	-	-
	(0.00)	(0.00)	(0.00)			
Widowed	-0.69***	-0.71***	-0.63***	-	-	-
	(0.00)	(0.00)	(0.00)			
Granada	ref	ref	ref	ref	ref	ref
Guadalajara	-0.10	-0.10	0.01	-0.27***	-0.30***	-0.04
	(0.21)	(0.23)	(0.83)	(0.00)	(0.00)	(0.67)
Malaga	0.48***	0.51***	0.28**	0.33*	0.40*	0.16
	(0.00)	(0.00)	(0.03)	(0.08)	(0.07)	(0.33)
Soria	-0.37***	-0.37***	-	-0.41***	-0.45***	-
	(0.00)	(0.00)		(0.00)	(0.00)	
Toledo	-0.42***	-0.42***	-0.31***	-0.35***	-0.39***	-0.19***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Age included?	yes	yes	yes	yes	yes	yes
Time dummies included?	yes	yes	yes	yes	yes	yes
Chi² (p-val.)	0.00	0.00	0.00	0.00	0.00	0.00
Pseudo R²	0.068	0.068	0.075	-	-	-
Observations	6,225	6,225	4,483	4,229	4,229	2,904

Note: Robust p-values in parentheses. ***, **, * indicate significance on the 1%-, 5%- and 10%-level. "ref" indicates the reference category. Included are males aged 23-62. Control group (ZTP)=family head aged 48 years. Control group (Neg. Bin.)=person aged 48 years and married (occupational group indicated by "ref"). On the exclusion of cases see Table 4.3. The ZTP models include only married family heads with children, the Neg. Bin. models include all individuals. The number of children up to 12 years could not be calculated for Soria because of missing age information of children in this province. Time dummy variables are not included because there is only one census period (half century 1750). Sampling weights are calculated according to the Spanish urbanization rates in the 18th century. The Pseudo R^2 is not displayed for weighted Zero Truncated Poisson regressions. Marginal effects are reported. Sources: See Table 4.1.

Table A.4.6: Weighted Negative Binomial and Zero Truncated Poisson Regressions, Germany

Germany	**M1**	**M2**	**R1**	**M3**	**M4**	**R2**
Marg. effects	**Weighted Neg. Bin.**			**Weighted ZTP**		
Dep. variable:	**No. of children**		**Children up to 12**	**No. of children**		**Children up to 12**
Professional	0.55***	ref	0.29***	0.97***	ref	0.57***
	(0.00)		(0.00)	(0.00)		(0.00)
Intermediate	0.23***	ref	0.10***	0.33***	ref	0.17***
	(0.00)		(0.00)	(0.00)		(0.00)
Skilled	0.09***	-0.20***	-0.00	0.18***	-0.27***	0.05
	(0.01)	(0.00)	(0.88)	(0.00)	(0.00)	(0.15)
Partly skilled	ref	-0.17***	ref	ref	-0.33***	ref
		(0.00)			(0.00)	
Unskilled	ref	-0.34***	ref	ref	-0.50***	ref
		(0.00)			(0.00)	
Farmer	0.82***	0.53***	0.40***	0.90***	0.45***	0.40***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Married	ref	ref	ref	-	-	-
Single	-2.01***	-2.29***	-1.50***	-	-	-
	(0.00)	(0.00)	(0.00)			
Widowed	-0.53***	-0.60***	-0.55***	-	-	-
	(0.00)	(0.00)	(0.00)			
Baden-Wuerttemberg	ref	ref	ref	ref	ref	ref
Holstein	0.10	0.13	0.27***	0.01	0.02	0.25**
	(0.26)	(0.20)	(0.00)	(0.93)	(0.87)	(0.02)
North Rine-Westphalia	-0.07	-0.07	0.16*	-0.14	-0.16	0.23**
	(0.44)	(0.51)	(0.05)	(0.20)	(0.23)	(0.04)
Rhineland-Palatinate	0.08	0.12	0.18**	-0.11	-0.11	0.04
	(0.43)	(0.30)	(0.04)	(0.30)	(0.39)	(0.74)
Age included?	yes	yes	yes	yes	yes	yes
Time dummies included?	yes	yes	yes	yes	yes	yes
Chi² (p-val.)	0.00	0.00	0.00	0.00	0.00	0.00
Pseudo R^2	0.182	0.182	0.193	-	-	-
Observations	28,915	28,915	26,570	17,116	17,116	14,964

Note: Robust p-values in parentheses. ***, **, * indicate significance on the 1%-, 5%- and 10%-level. “ref” indicates the reference category. Included are males aged 23-62. Time dummy variables are census periods (half centuries) 1700-1800. Control group (ZTP)=family head surveyed in census period 1750, aged 48 years. Control group (Neg. Bin.)=person surveyed in census period 1750, aged 48 years and married (occupational group indicated by “ref”). On the exclusion of cases see Table 4.3. The ZTP models include only married family heads with children, the Neg. Bin. models include all individuals. Sampling weights are calculated according to the German urbanization rates in the 18th century.The Pseudo R^2 is not displayed for weighted Zero Truncated Poisson regressions. Marginal effects are reported. Sources: See Table 4.1.

Table A.4.7: Weighted Negative Binomial
and Zero Truncated Poisson Regressions, Denmark (Sleswick)

Denmark	**M1**	**M2**	**R1**	**M3**	**M4**	**R2**
Marg. effects	**Weighted Neg. Bin.**			**Weighted ZTP**		
Dep. variable:	**No. of children**		**Children up to 12**	**No. of children**		**Children up to 12**
Professional	0.66***	ref	0.53***	0.77***	ref	0.66***
	(0.00)		(0.00)	(0.00)		(0.00)
Intermediate	0.18***	ref	0.10*	0.35***	ref	0.24***
	(0.01)		(0.10)	(0.00)		(0.00)
Skilled	0.28***	0.01	0.11**	0.30***	-0.14*	0.08
	(0.00)	(0.88)	(0.01)	(0.00)	(0.09)	(0.21)
Partly skilled	ref	-0.27***	ref	ref	-0.37***	ref
		(0.00)			(0.00)	
Unskilled	ref	-0.27***	ref	ref	-0.47***	ref
		(0.00)			(0.00)	
Farmer	0.51***	0.24***	0.27***	0.51***	0.07	0.19***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.40)	(0.01)
Married	ref	ref	ref	-	-	-
	-1.78***	-2.05***	-1.47***			
Single	(0.00)	(0.00)	(0.00)	-	-	-
	-0.47***	-0.55***	-0.60***			
Widowed	(0.00)	(0.00)	(0.00)	-	-	-
	(0.00)	(0.00)	(0.00)			
Age included?	yes	yes	yes	yes	yes	yes
Time dummies included?	yes	yes	yes	yes	yes	yes
Chi² (p-val.)	0.00	0.00	0.00	0.00	0.00	0.00
Pseudo R²	0.209	0.209	0.226	-	-	-
Observations	9,651	9,651	8,876	4,869	4,869	4,184

Note: Robust p-values in parentheses. ***, **, * indicate significance on the 1%-, 5%- and 10%-level. “ref” indicates the reference category. Included are males aged 23-62. Time dummy variables are census periods (half centuries) 1750-1800. Control group (ZTP)=family head surveyed in census period 1750, aged 48 years. Control group (Neg. Bin.)=person surveyed in census period 1800, aged 48 years and married (occupational group indicated by “ref”). On the exclusion of cases see Table 4.3. The ZTP models include only married family heads with children, the Neg. Bin. models include all individuals. Sampling weights are calculated according to the Scandinavian urbanization rates in the 18th century. The Pseudo R² is not displayed for weighted Zero Truncated Poisson regressions. Marginal effects are reported. Sources: See Table 4.1.

Table A.4.8: Negative Binomial and Zero Truncated Poisson Regressions, Uruguay

Uruguay	**M1**	**M2**	**R1**	**M3**	**M4**	**R2**
Marg. effects		**Neg. Bin.**			**ZTP**	
Dep. variable:	**No. of children**		**Children up to 12**	**No. of children**		**Children up to 12**
Professional	1.88***	ref	1.42***	0.99***	ref	0.52
	(0.00)		(0.00)	(0.00)		(0.11)
Intermediate	1.01***	ref	0.90***	0.52*	ref	0.50
	(0.00)		(0.00)	(0.10)		(0.13)
Skilled	1.04***	-0.38	1.06***	0.64**	-0.12	0.84***
	(0.00)	(0.14)	(0.00)	(0.02)	(0.57)	(0.00)
Partly skilled	ref	-1.01*	ref	ref	-0.62	ref
		(0.09)			(0.28)	
Unskilled	ref	-1.49***	ref	ref	-0.78**	ref
		(0.00)			(0.01)	
Farmer	1.35***	-0.08	1.33***	1.05***	0.29	1.05***
	(0.00)	(0.74)	(0.00)	(0.00)	(0.18)	(0.00)
Married	ref	ref	ref	-	-	-
Single	-1.41***	-2.82***	-0.85***	-	-	-
	(0.00)	(0.00)	(0.00)			
Widowed	-0.58***	-1.21***	-0.50***	-	-	-
	(0.00)	(0.00)	(0.00)			
Canelones	0.01	0.49	-0.04	0.81	1.41**	0.54
	(0.97)	(0.48)	(0.87)	(0.13)	(0.05)	(0.37)
Maldonado	ref	ref	ref	ref	ref	ref
Montevideo	0.33***	0.66***	0.22***	0.83***	1.11***	0.55***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Age included?	yes	yes	yes	yes	yes	yes
Time dummies included?	yes	yes	yes	yes	yes	yes
Chi² (p-val.)	0.00	0.00	0.00	0.00	0.00	0.00
Pseudo R^2	0.233	0.232	0.248	-	-	-
Observations	1,727	1,727	1,526	712	712	521

Note: Robust p-values in parentheses. ***, **, * indicate significance on the 1%-, 5%- and 10%-level. "ref" indicates the reference category. Included are males aged 23-62. Time dummy variables are census periods (half centuries) 1750-1800. Control group (ZTP)=family head surveyed in census period 1750, aged 48 years. Control group (Neg. Bin.)=person surveyed in census period 1750, aged 48 years and married (occupational group indicated by "ref"). The time dummy variable has been omitted because Maldonado is the only province containing data from the census period 1750. On the exclusion of cases see Table 4.3. The ZTP models include only married family heads with children, the Neg. Bin. models include all individuals. The Pseudo R^2 is not displayed for weighted Zero Truncated Poisson regressions. Marginal effects are reported. Sources: See Table 4.1.

Table A.4.9: Percentages of Farming Households With/Without Servants (Row Percentages)

	Farmer hh with Servants	**Farmer hh without Servants**	**Total Farmer hh**	**% of total Farmer hh with Servants**	**% of total Farmer hh without Servants**	**% Total Farmer hh**
	Obs.	Obs.	Obs.	%	%	%
Medium-sized/larger farmer	4,282	3,777	8,059	53.1	46.9	100.0
Smallholder	735	3,398	4,133	17.8	82.2	100.0
Other	78	167	245	31.8	68.2	100.0

Note: Included are males aged 23-62. “hh” stands for household. Percentages are row percentages. Sources: See Table 4.1.

Table A.4.10: Distribution of All Servants in Farming Households (Column Percentages)

	Obs.	**%**
Medium-sized/ larger farmer	4,282	84.0
Smallholder	735	14.4
Other	78	1.5
Total	5,095	100.0

Note: Included are male farmers aged 23-62 who had servants. Sources: See Table 4.1.

Table A.4.11: Negative Binomial Regressions on the Number of Children up to 12 Years of Farmers by Country

Neg. Bin., marg. effects Dep. variable:	**F1a**	**F2a**	**F3a**	**F4a**
	Children up to 12 years			
Included country	**Austria**	**S. Italy**	**Germany**	**Denmark**
Medium-sized/ larger farmer	ref	ref	ref	ref
Smallholder	-1.21***	0.01	-0.16***	-0.12
	(0.00)	(0.96)	(0.00)	(0.21)
Marital status included?	yes	no	yes	no
Time dummies included?	yes	yes	yes	yes
Province dummies included?	yes	yes	yes	-
Chi² (p-val.)	0.00	0.00	0.00	0.02
Pseudo R^2	0.052	0.017	0.040	0.002
Observations	1,150	1,544	5,326	1,244

Note: Robust p-values in parentheses. ***, **, * indicate significance on the 1%-, 5%- and 10%-level. “ref” indicates the reference category. Included are males aged 23-62. On the exclusion of observations see Table 4.3. Time dummy variables are census periods (half centuries). Control group=person surveyed in census period 1750 (Germany/Austria) and 1800 (Italy), aged 48 years and married. It is not controlled for period in Denmark because the number of observations in some categories is N<30. For Uruguay, the number of individuals with children under 12 was N<30 in some categories and is therefore not provided. It is not controlled for marital status in Italy and Denmark because overall significance was not given. The category “other” is dropped. Marginal effects are reported. Sources: See Table 4.1.

Table A.4.12: Farming Family Heads With Children (aged 23–62)

		Austria	S. Italy	Germany	Denmark	Uruguayy	Total
		Obs.	Obs.	Obs.	Obs.	Obs.	Obs.
1	Medium-sized/ larger farmer	879	149	3,239	750	304	5,321
2	Smallholder	135	1,309	1,517	238	32	3,231
	Total	1,014	1,458	4,756	988	336	8,552

Sources: See Table 4.1.

Table A.4.13: Numbers of Observations in the 1st and 2nd Generation of Males for the (Census-Based) Male Net Reproduction Rate and the Change in the Size of Occupational Groups

	Austria1	Austria2	S. Italy	Spain	Germany	Denmark	Uruguay	Total
	First generation: fathers aged 23-62 (unweighted no. of obs.)							
Professional	110	257	358	425	898	327	96	2,471
Intermediate	197	435	91	610	3,407	1,346	117	6,203
Skilled	318	1,248	866	1,578	6,447	2,625	415	13,497
Partly skilled	96	213	485	536	2,577	1,204	42	5,153
Unskilled	140	1,069	132	1,736	9,045	2,647	655	15,424
Farmer	198	1,150	2,186	630	6,001	1,428	393	11,986
Total	1,059	4,372	4,118	5,515	28,375	9,577	1,718	54,734
	Second generation: sons aged 0-47 (unweighted no. of obs.)							
Professional	97	185	297	310	768	301	111	2,069
Intermediate	145	326	92	499	3,140	1,085	94	5,381
Skilled	244	616	953	1,352	4,474	1,885	187	9,711
Partly skilled	57	80	529	335	2,111	550	39	3,701
Unskilled		76	56	1,247	4,695	1,091		7,165
Farmer	283	1,438	2,404	699	7,646	1,495	497	14,462
Total	826	2,721	4,331	4,442	22,834	6,407	928	42,489

Note: The table shows the number observations for the intergenerational change in occupational group compositions and for the male net reproduction rate. The first generation is composed of all male individuals aged 23-62 who can be classified into an occupational group, except those indicated as "children". The second generation is composed of all male children who are indicated as such, classified into their fathers' occupational group. The age range of the children is 1-47 (47 years is the maximum age range for the children because in this case the oldest father was 15 years at the birth of the son). Excluded are the families with identifiable children of former marriages because we cannot control if the children are genetic children of the mother or father. Austria1 indicates the early period of Austrian data (half centuries 1600-1650), Austria2 indicates the later period (half centuries 1700-1750). Excluded are regions or places for which individual information on the children is not provided: Soria (Spain), Rhineland-Palatinate (Germany), Cerrillos and Maldonado and Districts (Uruguay). Excluded are also slaves in Uruguay because potential children of the slaves are not indicated. The values of similar groups (partly skilled & unskilled) are aggregated observation numbers were N<30. The underlying number of observed sons in Austria1 in partly skilled and unskilled was 21. The European observations are weighted by their respective urbanization rates. Urbanization rates were not available for Urguay in the respective time period. Sources: See Table 4.1.

Table A.4.14: Robustness Test for Inflow Mobility of Occupational Groups of the Sons (Column Percentages): Excluding *Bracciali*

Occup. group of the father (%)	**Occup. group of the son (%)**						
	Prof.	**Interm.**	**Skilled**	**Partly skilled**	**Unskill.**	**Farmer**	**Total**
Professional	50.0	21.1	4.9	1.9	1.9	3.1	7.3
Intermediate	17.9	30.5	16.0	5.9	1.5	9.4	12.0
Skilled	19.1	27.4	55.7	26.2	15.7	0.0	38.8
Partly skilled	4.9	5.3	6.0	30.2	9.3	0.0	10.6
Unskilled	0.0	3.2	8.6	4.9	23.2	0.0	9.9
Farmer	8.0	12.6	8.9	30.9	48.5	87.5	21.4
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Note: The table shows the “inflow mobility” of the son’s occupational group. Percentages sum up to 100% by columns. This is the robustness check of inflow mobility excluding the sons for whom the occupation bracciale is indicated. The father’s occupational group is composed of all male individuals indicated as fathers (aged 30-72) who can be classified into an occupational group. Fathers may be widowed or married. The son’s occupational group is composed of the male individuals indicated as “children” for whom an occupation was reported (aged 15-50). The age range differs from other calculations to guarantee a sufficient number of father-son pairs. The age range is chosen so that the youngest father was at least 15 at the birth of the son; accordingly, the oldest father’s distance to the oldest son is also at least 15 years. Sources: See Table 4.1.

Table A.4.15: Numbers of Observations on Inflow Mobility of Occupational Groups of the Sons

Occup. group of the father (obs.)	**Occup. group of the son (obs.)**						
	Prof.	**Interm.**	**Skilled**	**Partly skilled**	**Unskill.**	**Farmer**	**Total**
Professional	81	20	63	8	9	1	182
Intermediate	29	29	207	25	7	6	303
Skilled	31	26	724	112	76	22	991
Partly skilled	8	5	78	129	45	21	286
Unskilled	0	3	111	21	112	6	253
Farmer	13	12	115	132	234	610	1,116
Total	162	95	1,298	427	483	666	3,131

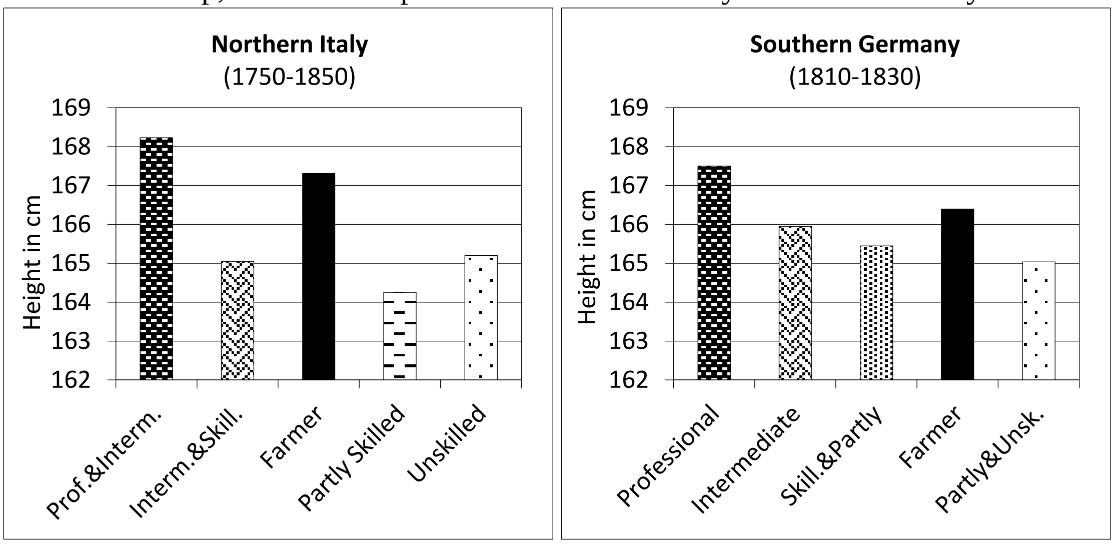
Note: The table shows the “inflow mobility” of the son’s occupational group. The father’s occupational group is composed of all male individuals indicated as fathers (aged 30-72) who can be classified into an occupational group. Fathers may be widowed or married. The son’s occupational group is composed of the male individuals indicated as “children” for whom an occupation was reported (aged 15-50). The age range differs from other calculations to guarantee a sufficient number of father-son pairs. The age range is chosen so that the youngest father was at least 15 at the birth of the son; accordingly, the oldest father’s distance to the oldest son is also at least 15 years. Sources: See Table 4.1.

Table A.4.16: Numbers of Observations
on Inflow Mobility of Occupational Groups of the Sons: Excluding *Bracciali*

Occup. group of the father (obs.)	Occup. group of the son (obs.)						
	Prof.	**Interm.**	**Skilled**	**Partly skilled**	**Unskill.**	**Farmer**	**Total**
Professional	81	20	63	8	9	1	182
Intermediate	29	29	207	25	7	3	300
Skilled	31	26	723	112	76	0	969
Partly skilled	8	5	78	129	45	0	265
Unskilled	0	3	111	21	112	0	247
Farmer	13	12	115	132	234	28	534
Total	162	95	1,297	427	483	32	2,497

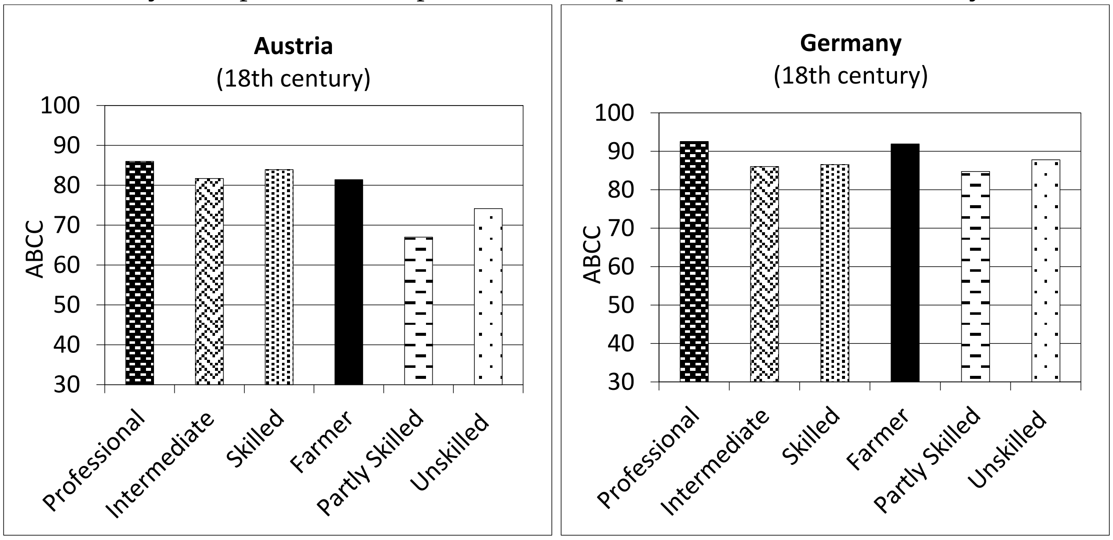
Note: The table shows the "inflow mobility" of the son's occupational group. This is the number of observations on the robustness check of inflow mobility excluding the sons for whom the occupation bracciale is indicated. The father's occupational group is composed of all male individuals indicated as fathers (aged 30-72) who can be classified into an occupational group. Fathers may be widowed or married. The son's occupational group is composed of the male individuals indicated as "children" for whom an occupation was reported (aged 15-50). The age range differs from other calculations to guarantee a sufficient number of father-son pairs. The age range is chosen so that the youngest father was at least 15 at the birth of the son; accordingly, the oldest father's distance to the oldest son is also at least 15 years. Sources: See Table 4.1.

Figures A.4.1.1–A.4.1.2: Height by Occupational
Group, for the Examples of Southern Germany and Northern Italy



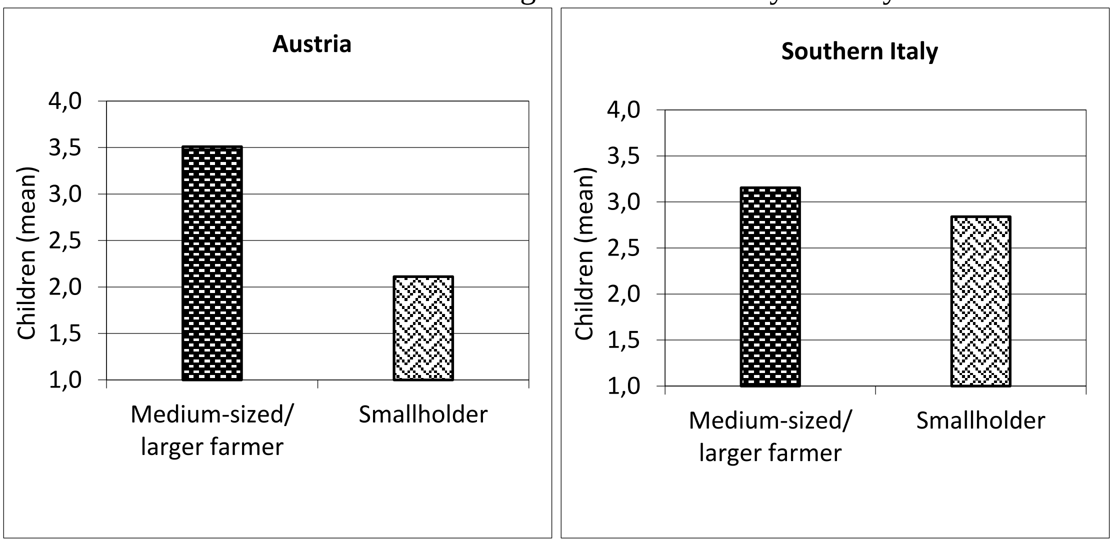
Sources: A'Hearn (2003), Baten (2000). For the Italian data, the intermediate professions were not separately listed but instead partly included in the professional group, and partly among the skilled. For Southern Germany, the partly skilled were not separately listed, but partly included among the skilled, and partly among the unskilled. For similar evidence on Austria-Hungary, see Komlos (1987).

Figures A.4.2.1–A.4.2.2: ABCC Values
by Occupational Group, for the Examples of Austria and Germany

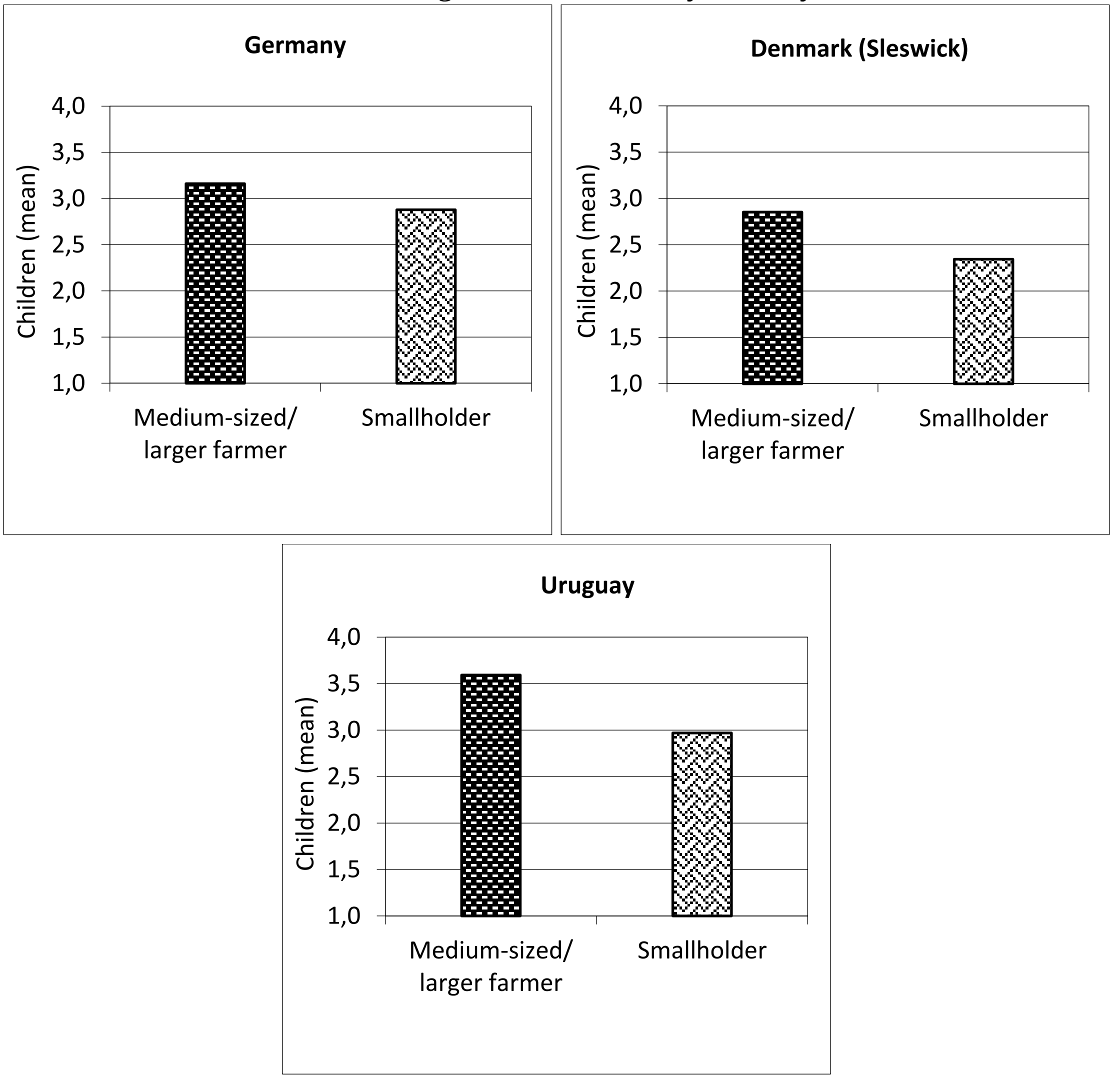


Note: Figures stem from Tollnek and Baten (2017, Figures 4.1 and 4.3). Included are only individuals aged 23 to 62. The data are weighted: sampling weights are calculated such that the urban observations correspond to the actual urbanization rates of the countries. The German sample contains the four German federal entities shown in Figure 4.1; the sample of Holstein is based on a 12% sample of the original dataset. Sources: See Table 4.1.

Figures A.4.3.1–A.4.3.5: Mean Numbers
of Children for Subcategories of Farmers by Country



Figures A.4.3.1–A.4.3.5: Mean Numbers of Children for Subcategories of Farmers by Country – Continued



Note: Included are male farming family heads with children, aged 23-62 years. For the numbers of observations see Table A.4.12. Sources and time periods: See Table 4.1.

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Appendix B.4: Farmer Subcategories[140]

For the analysis of the farmer group, we build two main categories of farmers: the medium-sized or larger farmers and the smallholders. In some of the regions in the dataset, we find a certain variety of labels that define medium-sized farmers or smallholders, especially in those regions from which we have a large amount of data.[141]

This is the case for Holstein, Germany, for example: while a first group (*Hufner*/*Vollhufner*) represents approximately 45% of the whole farmer group in Holstein, a second group (*Halbhufner*, *Dreiviertelhufner*, etc.) stands for approximately 24%.[142] While a *Hufner* is a person who owns a piece of land as large as *Hufe*, a *Halbhufner* owns half of a *Hufe* and a *Dreiviertelhufner* owns three quarters of a *Hufe*.This person is also a member of the village community (Lorenzen-Schmidt 1996). Heinsius (1840) notes that the *Hufe* consisted of 30 to 42 acres of land in most regions. The group with the smallest holdings (*Kaetner*, *Boedner*) represents approximately 17% of the farmer group in Holstein.[143] While the division between *Kaetner* and *Hufner* in smallholders and medium-sized to larger farmers is clear by the definition of Lorenzen-Schmidt (1996) and Heinsius (1840), our source also contains a number of *Hufner* for whom only parts of a *Hufe* are mentioned, varying between 3/4 and 1/48 of a *Hufe*. We decided to include the individuals with at least 1/2 of a *Hufe* (representing approximately 8% of the farming group in Holstein) in the medium-sized or larger farmer group and the ones with smaller pieces of land (approximately 14%) in the smallholder group. Because the division of partial *Hufner* is less clear-cut, we additionally control for different farmer groupings by including the individuals with at least 1/12 of a *Hufe* in the medium-sized or larger farmer group. Another very small group of medium-sized farmers consists of *Hufner* for whom an additional occupational title is provided (e.g. craftsman, 3%). Furthermore, there is another occupational title in the census records that could indicate both, a smallholder or a larger farmer ("lives of land or agriculture/farming") (Lorenzen-Schmidt 1996). This subcategory represents approximately 1.5% of the farmers in Holstein. Because this group is not clearly

[140] This Appendix is based on Tollnek and Baten (2017, Internet Appendix E, which equals Appendix D.3 in this thesis). Note that the distribution (percentage shares) of farmers among the subcategories is different.
[141] Considered are the male individuals aged 23-62 indicated as farmers (this sample is the basis of the analysis).
[142] A small share of these partial *Hufne*r reported an additional occupational title (e.g. craftsman).
[143] A small share of the smallholders reported an additional occupational title (e.g. craftsman), and all of those smallholders stated to have land at their disposal.

described, it is classified as "others", for the analysis.[144] The remaining 13% consist of medium-sized farmers as well as smallholders for whom other labels are indicated (e.g. *Hollaender, Bauer*, "has property and land"). However, the division of these observations is clear by the indicated term.

In Rhineland-Palatinate (Southwest Germany) we are able to differentiate between two terms that both designate persons with larger or medium-sized farms (*Ackersmann*, approximately 45%, and *Landwirt*, circa 55%). Furthermore, the medium-sized farmers (*Bauer*/*Colonus*, *Hofbesitzer*), correspond to roughly 95% in Baden-Wuerttemberg and 69% in North Rhine-Westphalia, while the minor subcategory, which contains smallholders (*Kaetner*/*Koetter*/*Casettarius*), stands for approximately 5% in Baden-Wuerttemberg and 31% in North Rhine-Westphalia (on the definition of the farmer terms see Heinsius 1840 and Lorenzen-Schmidt 1996).
In summary, 65.2% of the male German farmers in the underlying data are medium-sized or larger farmers, 31.1% are smallholders, and the remaining 3.8% are considered as "others".

In general, we observe a strong relationship between the medium-sized or larger farmers and the presence of servants in the households. More than 84% of all servants in the farming group worked on farms of medium or larger size, whereas the remaining share was reported to live in the households of smallholders (Appendix A.4). This finding strengthens the assumption that there is a correlation between the terms for the medium-sized or larger farmers and the existence of capital in their households. Further evidence is provided by Shaw-Taylor (2005, p. 175) who worked on the relationship between the size of farms or holdings and the number of servants (or laborers) hired to work the land in mid-19th century England. The author states that around 15 to 20% of the farmers with holdings between 20 and 100 acres did not report to hire laborers, wherase the remaining share did. By implication, this means that our classification of farming groups can be assumed to be relatively valid, considering the shares of servants in the subcategories. Of course, there are exceptional cases such as the Southern Italian farmers, which also deal with very different preconditions.

[144] The group "others" refers to all types of farmers who cannot clearly be assigned to one of the two main groups. However, this group is fairly small, corresponding to approximately 1.5%.

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5 Was There a "Rivalry for Resources"? Determinants of Height in Early 19th-Century Bavaria With a Focus on Family Size and Birth Order Effects

Abstract:

In this study, I assess the impact on height of three important determinants: (1) socioeconomic background, (2) living conditions, and (3) the number of siblings. While I can generally confirm the results of other studies related to socioeconomic background and living conditions, the effect of family size has not been subject to many studies in this field. Research on family size (and birth order) related to the 20th and 21st centuries mainly suggests a negative relationship between larger family size and child outcome. Considering the harsh living conditions of the early 19th century, one might assume a similar situation with the competitive environment and struggle for the allocation of resources among siblings. However, the underlying data suggest a positive relationship between a large number of siblings and height.

5.1 Introduction

Height is now a well-established proxy indicator for health and net nutritional status, particularly in developing countries and in time periods before the Industrial Revolution, for which other indicators of welfare are not available (see, for example, Komlos 1985; Steckel 1995; Baten and Blum 2014). In this study, I will explore three important determinants of individual height in early 19th-century Lower and Upper Bavaria: (1) socioeconomic background, which is approximated by occupational group; (2) living conditions, approximated by the region in which the individuals live; and (3) family size. Because family size might be closely related to birth order effects, birth order also receives particular attention in this study. While the first two indicators have been widely discussed by several authors whose findings I can mostly confirm, this study delivers new and important insights on the effects of family size.

Of course, the largest impact on height differences among individuals results from genetic variation. However, there is still substantial variation across populations that can be traced back to other determinants (see, for example, A'Hearn 2003, p. 354). One of the driving factors of height growth is the procurement of protein from dairy products, particularly milk. Thus, we can assume that individuals living in regions with a large number of cattle have better access to protein, which is reflected in a higher average height in those regions (Baten 1999, p. 116; Baten and Blum 2014, p. 145). Another important factor for the procurement of protein is a sufficiently high income to purchase high-quality foodstuffs at markets, particularly in urban areas. Because data on real monetary income are mostly unavailable for the early 19th century, occupational group can be used as a proxy for social status and give some indication of income level, assuming a positive relationship between highly skilled groups and income (A'Hearn 2003, p. 368; Case and Paxson 2008, p. 500). Several scholars, among them Komlos (1987), Baten (2000, 1999), A'Hearn (2003), and Stolz, Baten, and Reis (2013), assessed the influence of occupational and regional differences on height and detected a strong relationship between the two factors. As these two factors are crucial to understanding height differences within a society, I will include them in my analyses. The dataset analyzed contains the heights of 19-year-old conscripts and provides information about their regions of origin and the occupation of their fathers, both necessary to this study.[145]

[145] The year recorded on the list was 1815, and the birth year of the conscripts was 1797. In the "Law of

Moreover, this comprehensive dataset contains information about the ages of the parents, the number of (older/younger) siblings and whether they were sisters or brothers, whether the mother or father had died (and whether a stepparent lived in the household), and other household-specific variables.[146] This information provides the possibility to further assess height determinants. Central to this study, these data can address the role of family size (i.e., the number of children) and birth order among siblings to reveal differences in the outcomes of individuals. Most of the scholars working in this field employ educational attainment or human capital as the outcome variable (Rosenzweig and Wolpin 1980; Black, Deveraux and Salvanes 2005; Booth and Kee 2009; De Haan, Plug and Rosero 2014; Lehmann, Nuevo-Chiquero, and Vidal 2014). If we think in terms of Becker (1960), who laid the foundation for research on the theory of the quantity-quality trade-off in children, we might interpret the outcome variable as "quality" in children. Because height delivers information on net nutrition and health, it can also be implemented to measure the "quality" of children (see also Li and Power 2004; Hatton and Martin 2010; Black, Deveraux, and Salvanes 2015).

When analyzing the effects of family size on outcome, we have to consider the situation in the early 19th century. The early modern period had terminated shortly before, and the population found itself on the verge of modern times. However, the fertility transition had not yet begun, and hence the population was still trapped in the Malthusian equilibrium with high birth and death rates that balanced each other out, preventing the population from continuous growth (Galor and Weil 1999, p. 150; Lee 2003, pp. 168–169). Contraceptives were not available, and the only effective methods of limiting fertility were abstinence or the delay of marriage. Indeed, the delay of marriage was practiced in Western Europe, where marriage age for women reached an average of approximately 25 years (Lee 2003, p. 169).[147] Because infant death rates were high, the vast majority of married couples had a large number of children, allowing them to "replace" potentially deceasing (or already deceased) children.

Conscription of 1812" (Ger. *Conscriptions-Gesetz von 1812*), it is determined that conscripts should have completed the 19th year of their lives. From their completed 19th to their completed 23rd year of life, they were obligated to serve in the military, provided that they were healthy and met the minimum height requirement (Doellinger 1838, p. 24). The dataset was collected and provided by Joerg Baten. The list is in the Bavarian National Archive, Division War Archives (*Bayerisches Hauptstaatsarchiv, Abteilung Kriegsarchiv*).

[146] In approximately 95% of all cases, the place of birth and residence are the same. This is important for the regional analysis because heights are largely influenced by nutrition in early childhood (Stolz et al. 2013, p. 557). See Appendix A.5 for a list of places and regions.

[147] The delay of marriages limited the number of children at population average. However, it did not limit marital fertility, which is the subject of the analysis (Lee 2003, p. 169).

Incentives to reduce birth rates were not given before death rates significantly decreased (Lee 2003, pp. 173–174). In Western Europe, the decline of death rates and the resulting decrease of marital fertility rates that lead to the demographic transition did not start before the end of the 19th century in most European countries (Coale and Treadway 1986).[148] Knodel (1988, p. 45) states that infant mortality rates in the German villages he studied were fairly high during the first half of the 19th century, and they decreased only slightly in the second half of that century. By implication, family size was not – or was only in very rare cases – due to the endogenous decision of couples on a "perfect" number of children. Rather, it was the result of trying to adjust to the adverse circumstances of high infant death rates. Thus, family size can be regarded as the "reproductive success"[149] of couples that was largely influenced by exogenous factors at the beginning of the 19th century.[150]

By contrast, the authors who assess family size effects in more recent periods assume the number of children to be chosen endogenously. It is possible that parents aim for a certain number of children or a gender balance, for example. Endogeneity poses a problem that should be considered because family size could correlate with unobserved factors and thus bias the estimation results (Black et al. 2005, p. 676). Several scholars tried to solve this problem by including twin births in their analysis. Multiple births are not planned and thus simulate an exogenous shock, requiring the reallocation of parental resources (Rosenzweig and Wolpin 1980, p. 233; Hatton and Martin 2010, p. 162).

Because of the aforementioned issues facing early 19th-century society, endogeneity is not assumed to be a serious issue for the data under analysis. On the one hand, this is an advantage because I am able to estimate child outcome without bias. On the other hand, I cannot trace the "true" fertility, which is due to parental decisions as it is in modern times, but I instead must assess the allocation of resources across families with different levels of reproductive success as a result of high birth and death rates. Nevertheless, we still gain interesting insights into a controversial topic.

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[148] France was the great exception and first European country to limit fertility (see, for example, Lee 2003, p. 170).

[149] Note that the dataset does not include completed fertility but only the children being reported on the day the information about the conscripts was collected. For a more detailed discussion of the data, see section three of this article.

[150] On the definition of reproductive success see, for example, Clark (2007, p. 73).

Moreover, when analyzing the effects of family size, there are two other important issues to consider: First, it is necessary to control for birth order effects because these two effects can otherwise be confused (Black et al. 2005, p. 676). Second, to find the effects of family size or birth order on an outcome, it is necessary to consider scarcity in the household in terms of financial means, nutritional resources or parental time (see, for example, Hatton and Martin 2010, p. 162). I am able to control for those effects related to the birth order because the number of older and younger siblings is provided. Furthermore, scarcity of nutrition was omnipresent in the early 19th century. Of course, there were regions and social groups that were more affected by food scarcity than others, but these will be controlled for.

While the basic assumptions about the endogeneity of family size in this study are different from other studies in this field, this is still a valuable contribution concerning the relationship between family size and height in an earlier time period. Because of the scarcity of resources in early 19th century, I would expect that there would be rivalry among siblings, resulting in a negative effect of child outcome. Surprisingly, this is not the case; on the contrary, the results of the analysis suggest that having a large number of siblings has a strong and positive impact on height.[151]

5.2 Literature Review

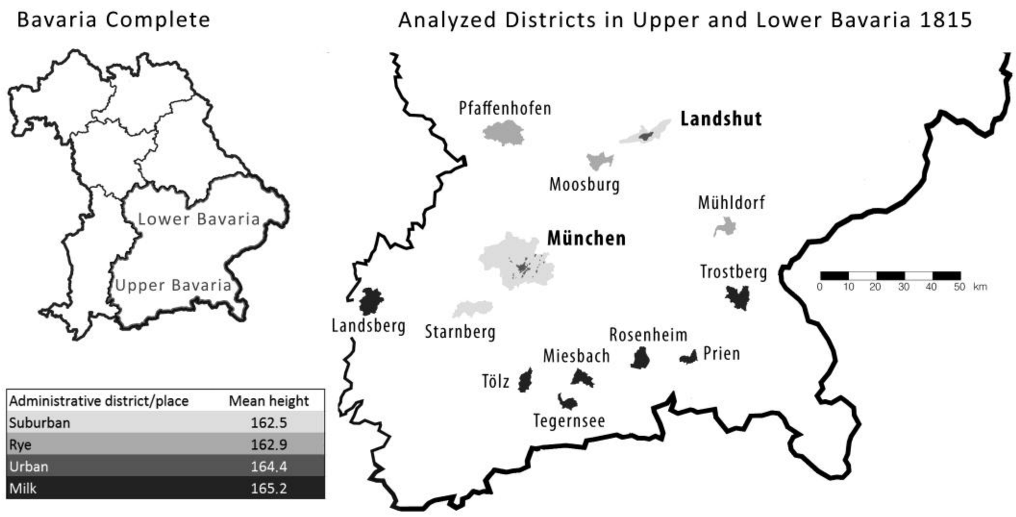
Whether a person is able to reach his or her genetic ideal depends largely on his or her environment and on the availability of nutritional resources. Baten (1999, pp. 113–139) studied regional differences in height development during the 19th century in Bavaria. He classified the regions that he studied into urban, suburban, milk-producing, and rye-producing according to their specific properties.[152] Baten's regional classification also serves as a basis for this study. A place is considered urban if it had more than 5,000 inhabitants. In the 19th century, these places had to import the largest share of foodstuffs because keeping animals was expensive and agricultural space was limited in these densely populated cities. Because there was no cooling system for the transport of milk in this time period, cities were often subject to an "urban penalty", meaning that people living in cities tended to be shorter because of their disadvantages in acquiring protein-

[151] See section five of this study.
[152] The basis for the regional differentiation is provided by the so-called *Landgerichte* (administrative districts). Several *Landgerichte* are aggregated into a regional unit (Baten 1999, p. 119).

rich nutrition (A'Hearn 2003, p. 355; Baten 1999, pp. 114–115). The suburban area is defined as the surroundings of cities within a distance of 20 to 55 kilometers.[153] People in suburban areas often struggled with a relatively low standard of living due to hard work from an early age and nutrition that was low in protein because they sold a large share of their products on the urban markets (Baten 1999, p. 116). The regions producing milk and meat were mainly located in the Alpine foreland and the Alps, where the number of cattle per capita was among the highest in Bavaria. The farmers specialized in the production of clarified butter, which they sold on the urban markets. Curdled milk was a by-product of this process and had a large quantity of protein that could not be transported because of the lack of refrigeration. Because the farmers regarded it as "left over", it was affordable also for poorer population groups and therefore became a good source of protein for the people living in this area (Baten 1999, p. 117). Mokyr and Ó Gráda (1994, pp. 56–58) observe a similar effect for Ireland, where the population was relatively poor but tall in the 19th century. They produced butter for British markets and consumed the left over skimmed milk, which, alongside potatoes, provided healthy nutrition. The last type of region is the rye area in which people cultivated rye and other types of grain. Additionally, they specialized in pig farming. These regions were conveniently located in contrast to the milk-producing areas, allowing people to sell a larger amount of their production (Baten 1999, p. 117). As a consequence, it is possible that the nutritional situation was less favorable for people living in the rye-producing area. Figure 5.1 provides an overview over the regions and districts the conscripts lived in and the respective mean height in the regions (on the numbers of observations see Appendix A.5).

[153] The radius depends on the size of the city. The suburban area of Munich reaches a radius of 55 kilometers (Baten 1999, p. 115).

Figure 5.1: Map of Analyzed Bavarian Districts



Note: Gray shadings indicate mean height by type of region. For Munich and Landshut, the urban and suburban areas are analyzed and illustrated. Sources: Own illustration on basis of maps from *Statistisches Landesamt Bayern* (2014a: general map on Bavaria; 2014b and 2014c: base map of administrative districts in Lower and Upper Bavaria) and *Landeshauptstadt München* (2016) (historical map of Munich 1812). Data source: Bavarian conscript list of 1815.

When examining occupational groups, I assume that height is positively correlated with higher social status. Hence, professional and skilled individuals are expected to be taller than partly or unskilled persons. The mechanism leading to such variation could work via different channels. Case and Paxson (2008, pp. 500, 503) argue that height is positively related with cognitive skills, which lead to higher income in the labor market. On the one hand, it is possible that taller people select themselves into more highly skilled occupations. On the other hand, people in more highly skilled groups tend to have higher incomes and thus are able to afford higher quality and protein-rich nutrition, which they can then provide to their children. Consequently, their children may grow taller than others and develop favorable cognitive skills on the basis of this high-quality nutrition. Several authors verified a positive relationship of height and occupational group of the father, such as Komlos (1987, p. 903) for the United States, A’Hearn (2003, p. 368) for Northern Italy and Baten (1999, 2000) for Southern Germany. However, there is one large group that has received little specific attention so far: farmers. Stolz et al. (2013, p. 552), for example, classify farmers in the same category as unskilled individuals, assuming a relatively low skill level. However, Tollnek and Baten (2017) show that farmers had fairly high numeracy and that their contribution to human capital formation during the early modern period was larger than generally perceived. Farmers had access to high-quality nutrition, which promoted the development of human capital and presumably height growth.

Most of the authors who assess the relationship of family size to children's outcome – usually approximated by education – conclude that an increasing number of children or a higher birth order within the family has a negative impact (see, for example, Black et al. 2005; Booth and Kee 2009). However, the results related to birth order differ. Black et al. (2005, p. 683) find a strong negative impact of family size on education in Norway, but once they include birth order as a control variable, the size of the effect becomes minor (though the coefficient remains significant). One potential bias in the study of Black et al. (2005) is that they do not control for parental income, which can affect child quality. As parents' income is likely to increase over time, a greater investment in the education of later born children is possible (De Haan et al. 2014, p. 373). In their study on British households, Booth and Kee (2009, p. 393) analyze the effect of family size on two indicators of child outcome: "highest level of qualification and years of schooling". They control for income, family size, and birth order.[154] While the results of Booth and Kee (2009, p. 391) indicate that birth order generally has a negative effect on years of education, the pattern is not as consistent as in Black et al. (2005, p. 679) because not all of the birth order dummy variables are significant. However, Booth and Kee (2009, p. 393) find that there is a strong negative impact of increasing family size on children's educational attainment. This effect remains substantial even after controlling for birth order.[155]

Hatton and Martin (2010, p. 181) explore the effect of family size and birth order on heights of mainly poor British children in the 1930s. While also controlling for household income, they find a significant and negative impact of both family size and birth order on height. This finding is in line with Li and Power (2004) as well as Black et al. (2015), who also detect the same negative relationship between these indicators and height.

[154] Related to birth order, they consider that effects on child outcome might work in two directions. On the one hand, parents could expect older children to help with younger siblings, resulting in more responsible behavior and consequently better performance in school. On the other hand, they could be urged to drop out of school early to work and increase family income, which would lead to lower levels of education (Booth and Kee 2009, p. 370).

[155] Today, it is even possible to find effects of "strategic parenting", meaning that parents try to influence their children's performance in school by implementing disciplinary methods (Hotz and Pantano 2015, pp. 911–912). Disciplinary methods may be stricter for later-born children due to insufficient school performance of earlier-born siblings.

It is most likely that scarcity of resources in households leads to limited resources devoted to each child with respect to financial means, nutrition or parental quality time, which is also important for the positive development of child outcome. Hence, resources become scarcer over time and decrease with increasing numbers of children. Nevertheless, there is another potential direction of causality. De Haan et al. (2014, p. 360) find a positive impact of birth order on children's human capital in Ecuador. They argue that in developing countries, many families are not able to provide the necessary financial resources or invest time for childcare in earlier-born children because they have to work to a large extent outside home. Once families managed to achieve a certain income due to hard work and presumably with the help of older children, their later-born children received a larger share of resources than their earlier-born children. However, the effect of family size, which they add as a control variable, is negative (De Haan et al. 2014, pp. 369, 371). Ejrnæs and Pörtner (2004) find that birth order in the Philippines is also positively related to education, though the birth order effect is weaker in families in which parents have a higher education.

As all these studies refer to the 20th or 21st century, the following question arises: in which ways did fertility affect child outcome in earlier periods, i.e., before the Industrial Revolution? In this study, I will try to answer this question and shed some light on the influence of family size on height right after the end of the early modern period in Lower and Upper Bavaria.

5.3 Data Description and Estimation Strategy

5.3.1 The Data: Issues, Source, and Description

Table 5.1: Descriptive Statistics of Included Variables, Including Conscripts of All and Living Biological Parents

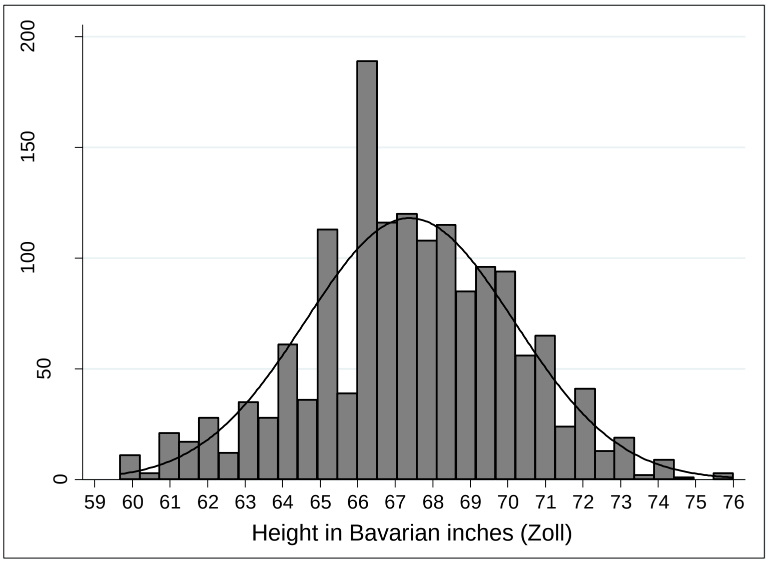
Variables	No. of obs.	Mean	Std. Dev.	Min.	Max.	No. of obs.	Mean	Std. Dev.	Min.	Max.
Sample	**A: All parents**					**B: Living biological parents**				
Height	1,560	163.89	6.75	145.1	184.9	939	163.83	6.68	146.0	184.9
Total siblings	1,560	3.24	2.23	0	12	939	3.46	2.22	0	11
Older siblings	1,560	1.28	1.54	0	11	939	1.20	1.46	0	8
Younger siblings	1,560	1.95	1.89	0	9	939	2.26	1.92	0	9
Total brothers	1,560	1.55	1.39	0	8	939	1.67	1.39	0	7
Older brothers	1,560	0.64	0.98	0	7	939	0.62	0.94	0	6
Younger brothers	1,560	0.91	1.10	0	6	939	1.05	1.14	0	6
Total sisters	1,560	1.69	1.48	0	8	939	1.80	1.50	0	8
Older sisters	1,560	0.64	0.94	0	6	939	0.58	0.87	0	5
Younger sisters	1,560	1.04	1.25	0	7	939	1.21	1.31	0	7
Birth order	1,382	2.45	1.56	1	12	857	2.32	1.48	1	9
Father's age at birth	1,203	35.68	7.87	15	67	939	35.67	7.01	15	53
Mother's age at birth	1,248	32.00	6.37	16	45	939	31.59	6.28	16	45
Mother's age at 1st birth	1,232	28.24	6.11	15	45	920	28.06	6.09	15	45
(Step)father numerate	1,184	0.74	0.44	0	1	939	0.74	0.44	0	1
Father died	1,560	0.22	0.41	0	1					
Mother died	1,560	0.16	0.37	0	1					
Stepfather	1,560	0.04	0.20	0	1					
Stepmother	1,560	0.01	0.10	0	1					

Note: Only children are excluded from birth order. "Mother's age at 1st birth" relates to the age at birth of the first-born child, "mother's age at birth" to the age at birth of the conscript (which may also be the first-born child). There are few cases in which "mother's age at 1st birth" was smaller than 15; these are set to missing. Source: Bavarian conscript list of 1815.

The dataset used in this study provides information on the height of 1,560 conscripts in 1815 (Table 5.1, A). When working with height data from conscript lists for military purposes, there are some issues to address. Baten (1999, p. 119) summarizes that many height distributions for military recruitment were truncated because conscripts were expected to meet minimum height requirements, which was 5 feet 4 inches (155.6 cm) in Bavaria at that time.[156]

[156] Note that the measure in this study generally refers to Bavarian feet of the respective time period. On the minimum height requirement see Barth (1831, p. 9250).

Figure 5.2: Histogram of Heights



Note: The most frequent value appears around 5 (Bavarian) feet and 6 inches (= 66 inches, plus lines; the most frequent value of lines is 0) or approximately 160.5 cm. It is most likely that the individuals who measured the heights rounded to the nearest number of inches (see also Komlos 1994, p. 97). Source: See Table 5.1.

As we can observe in Figure 5.2, the underlying height distribution is not truncated. However, there is an extremely large number of individuals who seem to be approximately 5 feet 6 inches (or 66 inches, approximately 160 cm) tall. This result is likely due to a rounding pattern on the nearest number of inches, which is often observed in height distributions (Komlos 1994, p. 97; Baten 1999, p. 120; A'Hearn 2003, p. 359). Because a heaping behavior might not be the only explanation for the high frequency around a certain value, we also have to think of other options. It is theoretically possible that the minimum height requirement in the previous period had been 5 feet 6 inches; therefore, particularly patriotic recruits might have persuaded the measuring personnel to note this exact number (rounding slightly up or down) to ensure their entry into military service. Generally, the accumulation of observations around one specific height can lead to non-normality of the distribution, which could cause heteroscedasticity.[157] To rule out potential heteroscedasticity issues in the regression models, I implement robust standard errors.

While the data were collected for military purposes, the list has the character of a soul register (Ger. *Seelenregister*).[158] Soul registers were drawn by the church and

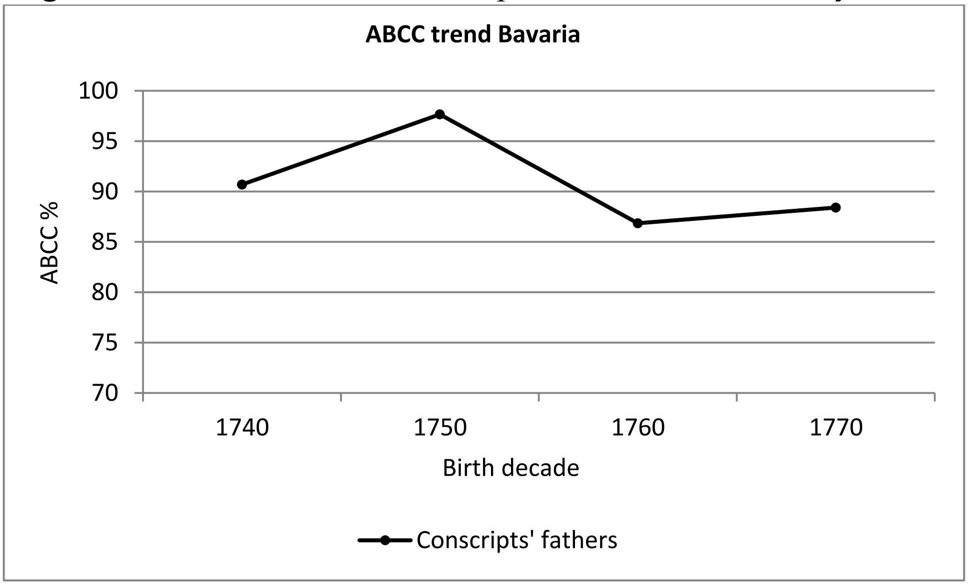
[157] The skewness-kurtosis test rejects the normality of the height distribution at the 5%- but not the 1%-significance level. I also tested the residuals, and they proved to be homoscedastic. For a reduced sample including only the conscripts whose mothers were not older than 28 years at the birth of their first child, the skewness-kurtosis test does not reject normality.

[158] Personal communication with Joerg Baten.

typically contained detailed information about the household members, their number of children, and other persons living with them. When creating a soul register, the priest mostly went from house to house and surveyed the church members. The procedure for the collection of the conscript lists were based on the "Law of Conscription of 1812" (Ger. *Conscriptions-Gesetz von 1812*). Following this law, the conscript's parents had to give their consent for the registration of their son, and they were coerced to cooperate in the conscription process (Barth 1831, p. 9224). Thus, when trying to reconstruct the procedures for the collection of the conscript list, it seems likely that household members answered the question by themselves, at least in the case of the parents. For most of the information in the data, it is of little importance whether the conscript or the family member himself or herself answered the question about personnel information, with the exception of age statements. Age statements can be employed to approximate the basic education of the father and its influence on height. The proxy for numeracy is based on the concept of "age heaping": in the case that people did not know their precise age, they tended to round their ages to multiples of five. On the basis of this age-heaping behavior, we are able to calculate the so-called "ABCC" index that ranges between 0 and 100 and represents the share of the population able to report their ages exactly (A'Hearn, Baten, and Crayen 2009, pp. 787–788).[159]

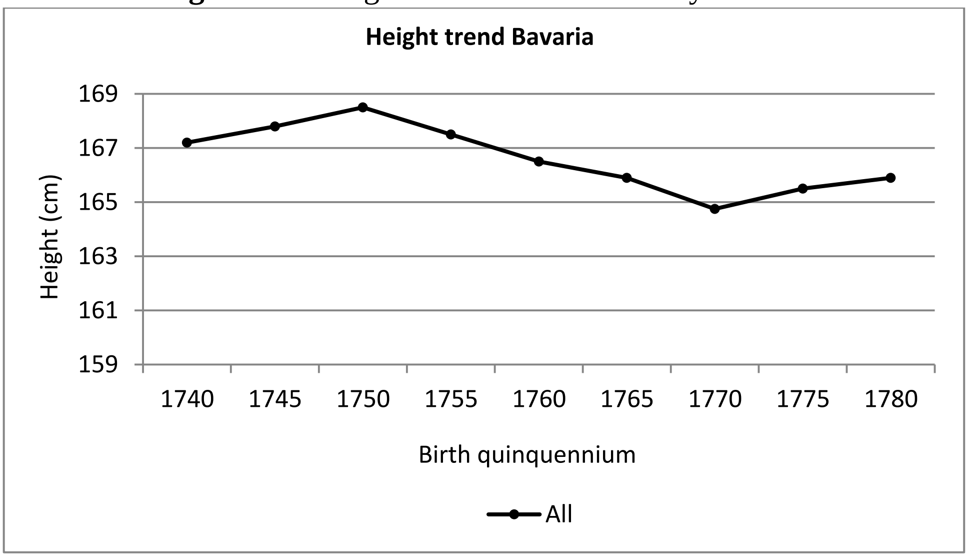
[159] The ABCC is a transformation of the Whipple index. For a detailed discussion of its use, implementation, and biases, see Tollnek and Baten (2016; 2017, section IV) or chapter two, section two, and chapter three, section four, of this thesis.

Figure 5.3: ABCC Trends of Conscripts' Fathers in 18th-Century Bavaria



Note: For observation numbers see Appendix A.5. Source: See Table 5.1.

Figure 5.4: Height Trends in 18th-Century Bavaria



Source: Baten (1999, p. 70, Figure 4.8). Note: The original figure in Baten includes the time period from 1730-1790; displayed height range is 162-172 cm.

The ABCC trend in Figure 5.3 is based on the age statements of the conscripts' fathers who were aged between 34 and 72. I allocated them to their age groups and calculated their birth decades so that we can observe an ABCC trend for 18th-century Bavaria. The trend line provides a potential hint in favor of the self-reporting of age statements because it follows nearly the same pattern as the height trends for the period from the 1740s to the 1780s (Figure 5.4).[160] In fact, the two trend lines take exactly the same path

[160] The time periods for the ABCC trend indicate birth cohorts in 10-year-intervals, whereas the height trend is based on birth quinquennials. However, this is not supposed to cause any problems in comparison.

between 1740 and 1760 with an increase until 1750 and a decrease in the 1760s. The subsequent trend is slightly different, as the ABCC index recovers slightly towards the 1770s, whereas the heights increase again only after the 1770s. However, the similarities of the two trends suggest that the fathers most likely reported their ages by themselves because the increase and subsequent decrease of height and numeracy were presumably driven by exogenous factors that influenced both indicators, such as temporary shortages in food. Baten (1999, p. 70) states for 1770–1774 that grain production per capita declined strongly during the birth quinquennium of 1770–1774.

Furthermore, the similarity of the two trends suggests that height and human capital are closely related. This finding is not surprising when we bear in mind that protein-rich nutrition favors both an increase in height and the development of cognitive skills, particularly during early childhood. The findings of Magnusson, Rasmussen and Gyllensten (2006, p. 659) support this assumption: they detect that the height of 18-year old Swedish conscripts is a good forecasting indicator of the education that the individuals will achieve in the course of their life.

Table 5.2: Observation Numbers and Percentages for Occupational Groups and Regions, Including Conscripts of All and Living Biological Parents

Sample:	**A: All parents**		**B: Living biological parents**	
1: Occupational group	Obs.	%	Obs.	%
Professional & intermediate	92	6.1	49	5.2
Skilled	439	29.3	272	29.1
Farmer	637	42.6	404	43.3
Partly skilled	62	4.1	40	4.3
Unskilled	266	17.8	169	18.1
Total	1,496	100	934	100
2: Farmer subcategory	Obs.	%	Obs.	%
Smallholder	342	53.7	207	51.2
Larger/medium-sized farmer	281	44.1	189	46.8
Mixed	14	2.2	8	2.0
Total	637	100.0	404	100.0
3: Region	Obs.	%	Obs.	%
Milk	622	39.9	382	40.7
Rye	426	27.3	251	26.7
Urban	175	11.2	86	9.2
Suburban	337	21.6	220	23.4
Total	1,560	100	939	100

Note: The "mixed" farmer group contains individuals who could not clearly be aggregated to one of the two groups. Source: See Table 5.1.

The occupational groups of the fathers used to approximate the socioeconomic background are arranged according to Alan Armstrong (1972, pp. 215–223) and include six categories (Table 5.2).[161] The first group consists of professionals with a high degree of education (doctors, lawyers), followed by the semi-professional or intermediate individuals who are also educated, but on a slightly lower level than the first group (administrators, higher clerks). Because the number of observations of these two groups is fairly low, they are aggregated for the analyses and represent approximately 6% of the occupation groups (Table 5.2, A1).[162] In the following, this group will be referred to as professional. The skilled group, representing approximately 29% of all occupations, consists mainly of craftsmen who accomplished several years of apprenticeship. The partly skilled category contains occupations such as carriage drivers and herdsmen (not owning animals) and the unskilled group consists of persons without any degree of formal education (mainly day laborers). These two groups include approximately 4% and 18% of the occupational categories. Moreover, the individuals with farming occupations are allocated to their own category, which represents approximately 43% of all occupations (Table 5.2, A1). The farming group consists of smallholders (53.7%) and medium-sized or larger farmers (44.1%) (Table 5.2, A2), but is treated as one group for most of the analyses for convenience and because their preconditions were not as different as one might assume (Tollnek and Baten, 2017, section V).[163]

The four regions included in the data are represented by a sufficient number of observations (Table 5.2, A3). The milk region accounts for approximately 40%, the rye region accounts for approximately 27%, and the suburban area accounts for approximately 22% of the data. The urban share of the data is approximately 11%. As the urbanization rate for early modern Germany was approximately 10.8%, this value can be regarded as representative (Malanima 2010, p. 262). Consequently, it is not necessary to weight the observations.

[161] Armstrong considers not only the skills of an individual needed to fulfill a certain task, but also allocates the groups by their relative social position. On the description of the Armstrong scheme see also chapter three, section three, and chapter four, section three.
[162] For most of the analyses, I use a restricted sample, limited to the conscripts whose biological parents were still alive. The occupational composition differs slightly for this restricted sample: the shares are 5% for the professionals, 29% for the skilled, 43% for the farming group, 4% for the partly skilled, and 18% for the unskilled group (Table 5.2, B1).
[163] The division into smallholders and medium-sized or larger farmers is based (1) on the term indicating a farming person. The most common term for a medium-sized farmer was *Bauer*, a small group of smallholders was denoted by *Gaertner*. The large group of *Bauern* were further differentiated by (2) the size of their farm or land, which was also reported in the conscript list. In case they owned at least half of a *Hof* or *Gut* (Engl. farm) or if they owned land (Ger. *Grundbesitz*), they were categorized as medium-sized or larger farmers.

5.3.2 Sample Restrictions, Methodology, and Estimation

As mentioned above, the sample includes conscripts whose fathers or mothers had died. This sample is assumed not to cause problems when estimating the influence of regions on heights. However, the sample is an issue when analyzing the effects of occupational groups or family size. Related to the occupational groups of the deceased fathers, we do not know at what age each father died and thus whether the father's socioeconomic status influenced the son. It is possible that the family fell into poverty once the head of the household had become deceased. In the case of fertility, it is even more important to consider "complete" married couples. If the father or mother died after the birth of the first child (and the widow/widower did not remarry), we analyze truncated fertility. For that reason, most of the analyses concerning family size and birth order are limited to a sample that includes only conscripts living with their biological parents, which restricts the sample to 939 observations (Table 5.1, B).[164]

Another concern might be that we observe the conscripts and their families only at one point in time. Although it is most likely that we observe surviving children by family until the day the conscript list was made, we cannot be sure whether all surviving children are mentioned or only those who were still living in their parents' household.[165] It is theoretically possible that older siblings had already left the household and that younger ones were not born yet. By limiting the sample to living biological parents, I account for this potential bias to a certain degree.[166] Hatton and Martin (2010, p. 173), who observe only the children currently living in the household, argue that this issue might not be of major importance when analyzing family size and birth order effects on health status (in contrast to education) because individual height is considerably

[164] The age of the mother at the birth of the conscript is restricted to a minimum of 15 and maximum of 45 years. In the case that the age of the mother at birth is below 15 or above 45, the age at birth is set to missing. For the restricted sample, the necessary control variables can be included (in contrast to the full sample that contains missing values for several variables, such as the ages of the parents).

[165] Knodel (1988, p. 355) reports the mean number of surviving children until the age of 5 in several Bavarian villages to be 4.99 in the period from 1800–1824. Hence, there is a good chance that the underlying data also contain the mean number of surviving siblings (or children if we add one child, namely the conscript) up until the day of the survey (see Table 5.1). However, this issue should be of minor importance for the analysis of family size because we would still gain useful insights on the average number of siblings, even when observing only those children living in their parents' household. Additionally, I analyze mean numbers of children by different categories. The differences between categories are assumed to be similar whether observing children in the household or children who survived.

[166] Referring to birth order, I also assume that a potential bias is not particularly large because we observe the conscripts at the age of 19. Hence, there is a good chance that they are among the former-born children (considered categories are the first- to fourth-born children and an aggregated category of fifth- or higher-borns).

influenced by living conditions in the respective time period. Nevertheless, I perform robustness checks in which I include only conscripts whose mothers had their first child at a maximum age of 28 years. In doing so, I can rule out a large part of the potential bias of older children having left the household, as most of the women had married by approximately 25 years and presumably had their first child within the first years of marriage (Lee 2003, p. 169). Another limitation of the underlying sample could be that the heights of only young male adults are included, which means that we do not observe female heights. Additionally, there is a potential residual growth rate for 19-year-olds from which the descendants of the lower occupational groups might particularly benefit.[167] Nonetheless, we would presumably still observe the same differences for this cohort in higher ages, but on a more moderate level. Furthermore, we do not observe intra-household allocation of resources but only allocation across households because we know the height of only one child (the conscript). However, this is not assumed to be an issue.[168]

In the first step of analysis, I perform descriptive statistics of height by regions, occupational groups of the fathers, the number of siblings, and the birth order, for which I use mainly the restricted sample of living biological parents. In the next step, I conduct several Ordinary Least Squares (OLS) regressions to test whether influences of the determinants on height are significant using the complete and the reduced sample. Height is implemented as the dependent variable, while the occupational groups of the fathers, the regions, and the total number of siblings serve as control variables. Occupational groups and regions are not included in the same regression because of high correlations between the farming group and the milk regions and between the skilled group and the urban area. By doing so, multicollinearity issues can be ruled out. Furthermore, I control for the basic education of the father by including the binary variable "numerate" that takes on a value of one if a precise age is reported and a value of zero otherwise. A higher education level of the parents might have a positive effect on child outcome.

Moreover, I conduct descriptive and regression analyses, including categorical variables for the number of total, younger, and older siblings, as well as sisters and brothers to test whether sex composition or parental gender preferences could play a

[167] The children of poorer families are assumed to suffer more from malnutrition and work from relatively early ages, which leads to slower growth in their youth. This is partially compensated in early adulthood.
[168] On the contrary, it could rule out some of the endogeneity issues when analyzing birth order effects among siblings within the same household.

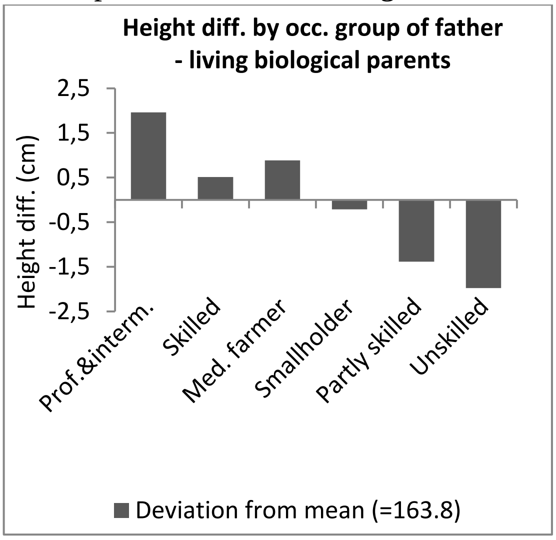
role. Additionally, I control for family background characteristics via occupational groups, regions, and the ages of the parents.[169] It is possible that younger mothers have healthier babies with a greater birth weight who might grow taller. However, older parents tend to be more patient and have more experience in childcare and the prevention of diseases (see, for example, Booth and Kee 2009, p. 375). In a separate section, I test for potential influences of birth order.

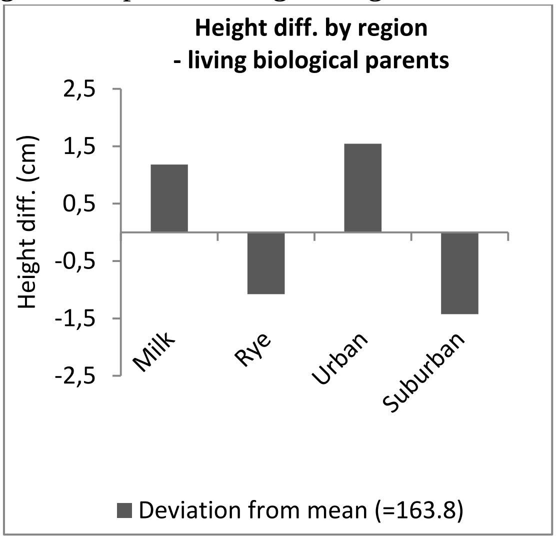
5.4 Descriptive and Regression Results

5.4.1 The Impact of Socioeconomic Background and Region on Height

We can assume that a higher socioeconomic status, approximated by the occupational group of the father, and living in a milk-producing region are positively correlated with height (A'Hearn 2003; Baten 1999).

Figures 5.5.1–5.5.2: Height Differences of Conscripts by Occupational Group of the Father and Region, Including Conscripts of Living Biological Parents





Note: Height refers always to the height of the conscripts. Additionally it is described, which sample is included for the calculation. Living biological parents refers to conscripts whose parents are both still alive and not listed as being stepmother or -father. See Appendix A.5 for figures including the complete height range and the full sample. For the number of observations, see Table 5.2. Source: See Table 5.1.

Figures 5.5.1 and 5.5.2 show the height differences of conscripts with living biological parents compared to the mean of occupational groups.[170] The occupational differences reflect the expected pattern: the sons of the aggregated professional/intermediate group

[169] I control for the age of the mother at the birth of the first child, the age of the mother at birth of the recruit or the age of the father at the birth of the recruit in different models.

[170] Farmers are placed behind the skilled group, following Tollnek and Baten (2017, section V). In the full sample (Appendix A.5), the smallholders' sons are slightly taller than in the limited sample.

are the tallest by an advantage of approximately 2 cm. While the sons of the medium-sized or larger farmers represent the second tallest group with a difference of almost 1 cm, the descendants of the smallholders are a little shorter than the mean (-0.2 cm). The sons of the skilled are in the third position with an advantage of approximately 0.5 cm. As expected, the conscripts born into the partly skilled or unskilled classes are clearly shorter than the ones born into other occupational groups (approximately -1.4 and -2 cm). These findings are in line with A'Hearn (2003), Baten (2000), and Komlos (1987). Case and Paxson (2008, p. 519) also find very similar results for 20th-century Britain, except for the farmers who are shorter than the mean in that time period.

Related to region, which serves as a proxy for living circumstances and protein provisions, we observe that the conscripts living in a milk-producing region are approximately 1.2 cm taller than the mean of all regions, whereas individuals from rye-producing or suburban areas have a height disadvantage of approximately -1.1 and -1.4 cm. Because there is usually an "urban penalty" for cities, it is slightly unexpected that the urban conscripts represent the tallest of all groups with an advantage of 1.5 cm. However, this "urban penalty" does not apply to Munich, where most of the urban observations originate. Munich is situated relatively close to the Alpine foreland and was thus fairly well provided with milk and meat. These results are similar to those of Baten (1999, pp. 125, 130–132).[171]

Table 5.3: OLS-Regression of Height on Occupational Group of the Father, Regions, and Total/Older/Younger Siblings/Sisters/Brothers, Including Conscripts of All Parents, Living Biological Parents, and Stepfathers

OLS	**1a**	**2a**	**3a**	**4a**	**5a**	**6a**	**7a**
Dep. var.:	**Height of conscripts**						
Sample	**All parents**		**Living biological parents**				**Stepfath. in family**
Professional	3.22***		3.68***		3.80***		
	(0.00)		(0.00)		(0.00)		
Skilled	1.48***		2.23***		2.35***		
	(0.00)		(0.00)		(0.00)		
Farmer	2.01***		2.01***		2.13***		
	(0.00)		(0.00)		(0.00)		
Partly skilled	ref		ref		ref		
Unskilled	ref		ref		ref		

171 In the sample including the conscripts with all parents, the individuals from milk-producing regions are slightly taller than the ones from urban areas (see Appendix A.5)

Table 5.3: OLS-Regression of Height on Occupational Group of the Father, Regions, and Total/Older/Younger Siblings/Sisters/Brothers, Including Conscripts of All Parents, Living Biological Parents, and Stepfathers – Continued

OLS	**1a**	**2a**	**3a**	**4a**	**5a**	**6a**	**7a**
Dep. var.:	**Height of conscripts**						
Sample	**All parents**		**Living biological parents**				**Stepfath. in family**
Milk		2.19***		2.24***		2.21***	
		(0.00)		(0.00)		(0.00)	
Rye		ref		ref		ref	
Suburban		-0.37		-0.30		-0.25	
		(0.44)		(0.61)		(0.68)	
Urban		1.46**		2.64***		2.78***	
		(0.02)		(0.00)		(0.00)	
(Step)father numerate			0.76				-3.57*
			(0.13)				(0.05)
Older siblings	0.19*						
	(0.10)						
Older sisters		0.32*					
		(0.07)					
Total siblings			0.22**				
			(0.03)				
Total sisters				0.30**			0.68*
				(0.04)			(0.10)
Total brothers					0.30*		
					(0.05)		
Younger siblings						0.29**	
						(0.02)	
Constant	162.15***	162.75***	160.79***	160.74***	160.30***	160.43***	164.11***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Adj. R^2	0.017	0.028	0.028	0.037	0.025	0.036	0.058
F-Test (p-val.)	0.00	0.00	0.00	0.00	0.00	0.00	0.07
Observations	1,496	1,560	934	939	934	939	59

Note: Robust p-values in parentheses. ***, **, * indicate significance on the 1%-, 5%- and 10%-level. "ref" indicates the reference category. Professional & intermediate are condensed to professional. It is also controlled for "father died", "stepfather in family", "father's age at birth", "mother's age at birth". None of these controls is significant (see also robustness test in Appendix A.5). Source: See Table 5.1.

Table 5.3 shows that the regression results correspond to the descriptive analysis. The sons of the professionals, the skilled, and the farmers turn out to be significantly taller than the ones born into the partly skilled or unskilled groups, which represent the pooled reference category (models 1a/3a/6a).[172] The coefficients are statistically highly

[172] I also ran the regression with the farming group divided into subcategories, which shows that the smallholders are not significantly different from the medium-sized or larger farmers (the reference

significant and of substantial size, implying that the upper groups of society as well as the farmers are more than 2 cm taller than the two lowest groups. There is a slight difference between the samples including the conscripts with all parents (model 1a) and those with living biological parents (limited sample, models 3a/5a). In model 1a, the farmers have a slight height advantage over the skilled group, while they are in the third position in the limited sample of conscripts with living biological parents.[173]

Concerning the regional differences, the persons living in milk-producing and urban regions are significantly taller than the ones living in rye areas, while there is no significant difference between the suburban and rye-producing regions (Table 5.3, models 2a/4a/6a). Again, we observe a slight difference between the full (model 2a) and limited samples (models 4a/6a) for which the urban individuals have a slight advantage over the ones living in milk regions.[174]

The influence of the fathers' numeracy is not significant in the sample with living biological parents, although the coefficient is positive and the p-value is fairly small (Table 5.3, model 3a). However, the coefficient of the stepfather's numeracy on the height of the conscript is negative and significant (model 7a). Theoretically, it is possible that a stepfather might give preference to his own biological children and regard a stepson as a potential rival. However, we have to consider (and potentially prefer) other possible explanations. For example, the families whose head of household had deceased were poorer and lived in adverse circumstances so that the conscripts of these families were shorter and the stepfathers were likely to be negatively selected.[175]

category). Additionally, the professionals are not significantly different from the medium-sized farmers (Appendix A.5). The robustness test shows also the additional control variables (see note on Table 5.3).

[173] The figures including the full sample deliver similar results (Appendix A.5). This result would mean that if the father, who was a farmer, died, then the son tended to grow taller than if the father did not die; for the sons of the skilled individuals, it appears to be the other way around. This may be due to regional effects because many farmers came from milk regions while a large share of the skilled lived in the city. It is possible that children who lived in the city and lost their father had a great disadvantage because of stigmatization, decreasing family income, and malnutrition. By contrast, the sons of deceased fathers who were farmers were likely to take over the family farm as the new head of household and increase their relative socioeconomic position.

[174] As mentioned in the previous footnote, it is possible that the conscripts living in the city and whose father had become deceased had a great disadvantage, while it was the other way around for farmers' sons.

[175] The sample size of families with a stepfather is fairly small (including 59 observations). As a robustness test, I performed the regressions additionally with "bootstrapped" standard errors. These regressions are useful in cases with low sample sizes and an unclear underlying distribution. However, the results are almost the same as those in Table 5.3.

5.4.2 The Influence of Family Size on Height

Table 5.3 provides the first hint concerning the influence of family size on height. An increasing number of siblings seem to have a positive influence on height throughout all samples and modifications. In the sample of conscripts with living biological parents, we observe a general advantage of having a larger number of siblings, sisters, and brothers as well as younger siblings. In the sample including all observations, we can additionally observe a very moderate effect of having older siblings or sisters.[176]

Because the coefficients of the total number of siblings are relatively small (with an effect of less than half a centimeter), I categorize the number of siblings into zero to one, two to three, and four or more siblings.[177] In doing so, we are able to determine whether a large number of siblings have a larger impact than a small number of siblings. The same method is used for brothers and sisters because it is possible that the sex composition of children also affects their outcome. Rosenberg (1965, pp. 112–126) states that when boys are in the minority among sisters, they have a particularly high self-esteem and an implicit self-acceptance because of the special role they receive within the family. Conley (2000, p. 445), on the other hand, concludes that having a larger number of siblings of the opposite sex reduces the educational outcome of children significantly. For early 19th-century Bavaria, one might also consider that scarcity of nutritional resources causes rivalry among siblings, particularly among brothers, which would lead to smaller height in families with a large number of sons. Furthermore, I control for older and younger siblings, sisters, and brothers to test potential effects of age composition.[178]

Table 5.4 shows that all of the categories contain representative numbers of observations. The most important categories, including the number of total, older, and younger siblings, are each represented by a minimum of 152 individuals (Table 5.4, column 1).

[176] This effect is most likely due to the truncated fertility observed in the full sample, which also contains conscripts whose fathers or mothers deceased. Therefore, their number of younger siblings is limited, while their number of older siblings might be slightly higher. However, the effects of the older siblings and sisters are significant at only the 10%-level. See Appendix A.5 for results of total siblings and sisters of the full sample.

[177] The categories are assigned following similar patterns: for example, the height of those having zero to one sibling is similar, and so on.

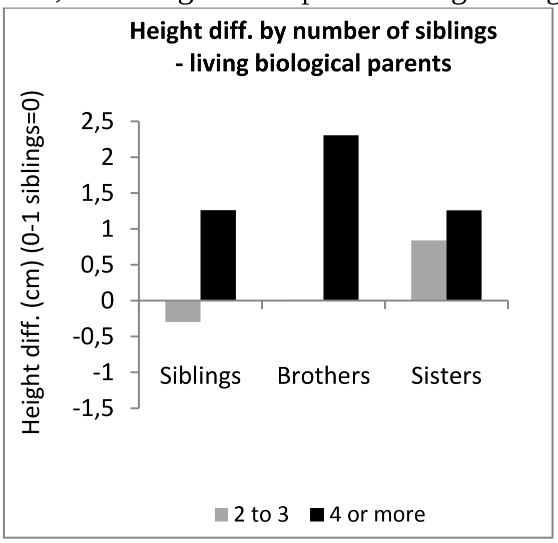
[178] The categories of the older and younger siblings, sisters, and brothers are zero, one, two, and three or more siblings, etc. The categories are different from the total number of siblings because the number of younger and older siblings is generally lower than the overall numbers of siblings.

Table 5.4: Observation Numbers and Percentages for Total, Older, and Younger Siblings, Including Conscripts of Living Biological Parents

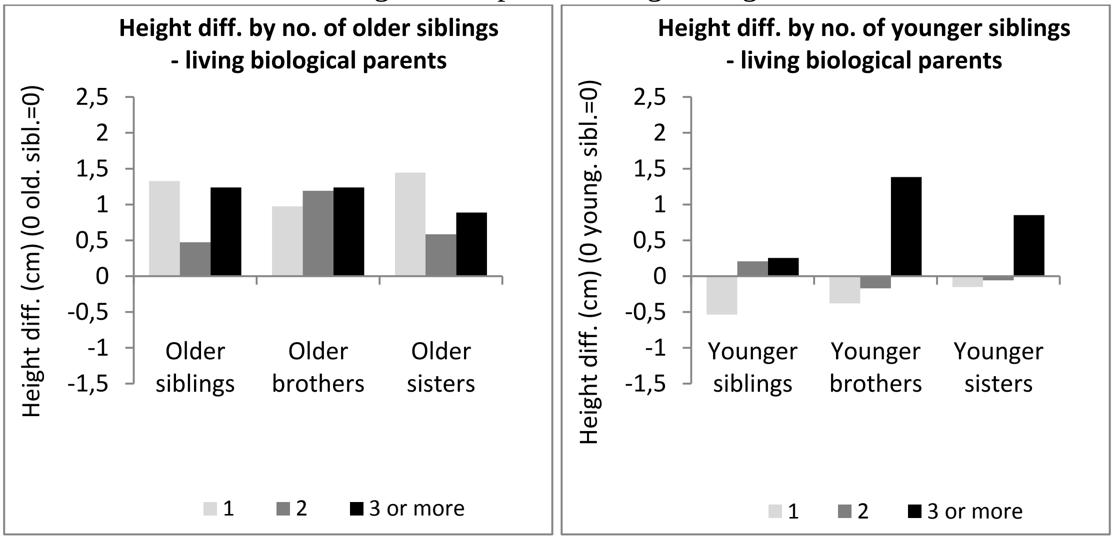
	Obs.	%	Obs.	%	Obs.	%
Total	**Siblings**		**Brothers**		**Sisters**	
0 to 1	187	19.9	476	50.7	449	47.8
2 to 3	326	34.7	360	38.3	364	38.8
4 or more	426	45.4	103	11.0	126	13.4
Total	939	100.0	939	100.0	939	100.0
Older	**Siblings**		**Brothers**		**Sisters**	
0	406	43.2	564	60.1	574	61.1
1	227	24.2	241	25.7	225	24.0
2	152	16.2	84	8.9	105	11.2
3 or more	154	16.4	50	5.3	35	3.7
Total	939	100.0	939	100.0	939	100.0
Younger	**Siblings**		**Brothers**		**Sisters**	
0	196	20.9	377	40.1	356	37.9
1	197	21.0	290	30.9	269	28.6
2	171	18.2	171	18.2	165	17.6
3 or more	375	39.9	101	10.8	149	15.9
Total	939	100.0	939	100.0	939	100.0

Source: See Table 5.1.

Figures 5.6.1–5.6.3: Height Differences of Conscripts by Number of Total/Older/Younger Siblings/ Brothers/Sisters, Including Conscripts of Living Biological Parents



Figures 5.6.1–5.6.3: Height Differences of Conscripts by Number of Total/Older/Younger Siblings/ Brothers/Sisters, Including Conscripts of Living Biological Parents – Continued



Note: The base categories are 0 to 1 total siblings/sisters/brothers and 0 older/younger siblings /sisters/brothers. The other categories are adjusted to the base category. See Table 5.4 for the number of observations and Appendix A.5 for absolute mean height figures. Source: See Table 5.1.

Figure 5.6.1 illustrates that the conscripts with four or more siblings have a clear height advantage of approximately 1.25 cm compared to those with zero or one and also to those with two to three siblings. Surprisingly, the height advantage for the conscripts with at least four brothers is particularly large with a difference of approximately 2.3 cm. Having a large number of sisters also seems to increase height, while a moderate number of two to three sisters also means a height advantage. Figure 5.6.2 reveals that having at least one older sibling, whether a brother or sister, always increases height compared to having no older sibling. A higher number of either younger sisters or younger brothers also seem to increase height (Figure 5.6.3).[179]

[179] The results of the reduced sample (conscripts whose mothers were not older than 28 years at their first birth, see Appendix A.5), are fairly similar although a moderate number of siblings has a stronger negative effect on height while having a modest number of sisters is almost equal to having zero to one sisters.

Table 5.5: OLS-Regression of Height on Categorized Siblings, Including Conscripts of Living Biological Parents

OLS	**1b**	**2b**	**3b**	**4b**	**5b**	**6b**
Dep. var.:	**Height of conscripts**					
Testing	**Siblings**		**Brothers**		**Sisters**	
Mother's age at 1st birth	0.05		0.03		0.03	
	(0.18)		(0.39)		(0.36)	
Father's age at birth		0.03		0.05*		0.04
		(0.32)		(0.10)		(0.22)
Father numerate	0.74	0.67	0.79	0.70	0.81	0.72
	(0.15)	(0.17)	(0.12)	(0.16)	(0.12)	(0.15)
0 to 1	ref		ref		ref	
2 to 3	ref		ref		0.59	
					(0.21)	
4 or more	1.36***		2.03***		1.35*	
	(0.00)		(0.00)		(0.05)	
No older		ref				ref
1 older		1.25**				1.07**
		(0.02)				(0.03)
2 older		0.36				0.00
		(0.58)				(1.00)
3 or more older		0.76				0.31
		(0.25)				(0.77)
0 to 2 younger				ref		
3 or more younger				1.45**		
				(0.03)		
Constant	159.61***	160.67***	160.41***	160.41***	160.19***	160.66***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Adj. R^2	0.028	0.037	0.028	0.038	0.023	0.036
F-Test (p-val.)	0.00	0.00	0.00	0.00	0.00	0.00
Observations	915	939	915	939	915	939

Note: Robust p-values in parentheses. ***, **, * indicate significance on the 1%-, 5%- and 10%-level. "ref" indicates the reference category. It is controlled for occupational groups (1b/3b/5b) or regions (2b/4b/6b) (see Appendix A.5). The lines are to be combined with the columns, e.g., "No older" (=line) "siblings" (=column). The gray highlightings help indicating the matching dummies. Source: See Table 5.1.

In the regressions shown in Table 5.5, I test whether the height advantages for conscripts with a large number of siblings is significant.[180] Compared to the pooled

[180] I also control for occupational groups (models 1b/3b/5b) and regions (2b/4b/6b), and the results are almost the same as those in Table 5.3 (see Appendix A.5 for the results). The results of the robustness tests including the reduced sample of conscripts whose mothers had a maximum age of 28 years at their first birth are very similar to those in Table 5.5 (see Appendix A.5).

reference category with zero to three siblings, the conscripts with at least four siblings were significantly taller.[181] Again, having a large number of brothers correlates with a particular and highly significant height advantage of more than 2 cm compared to having zero to three brothers. Having a large number of sisters yields only a moderate height advantage compared to having zero to one sisters, while a medium number of two to three sisters does not have a significant effect. These results support the findings of Conley (2000) that having siblings of the same sex tends to have a less negative effect on children's outcome than having siblings of the opposite sex. By contrast, a large number of brothers strongly increase the outcome of the conscripts. This finding is supported by the significant result of a large number of younger brothers (three or more, Table 5.5, model 4b).

Furthermore, there is a significant positive impact on height in the case that there is one older sibling or, in particular, one older sister present in the household (Table 5.5, models 2b/6b). This finding might be a hint for a parental sex preference toward boys. Such a preference would not be surprising because male descendants were often expected to provide financial support for their parents at older ages (Hank and Kohler 2003, p. 135).

The control for the basic education of the father ("numerate") again has a positive but insignificant influence (Table 5.5, models 1b–6b). The ages of the mother and the father also have a positive but mainly insignificant influence and are of minor size (models 1b/3b/5b and 2b/4b/6b).

5.4.3 Controlling for Effects of Birth Order on Height

It is important that the impact of family size is not confused with a potential effect of birth order (Black et al. 2005, p. 676). Consequently, I account for birth order by differentiating between five categories, one for each of the first- to fourth-born children and an aggregated group for fifth- or later-borns.

As shown in Table 5.6, the categories are represented by sufficient numbers of observations. Because I am mainly interested in birth order effects among siblings, only children are excluded from the analyses (see, for example, Black et al. 2015, p. 7).[182]

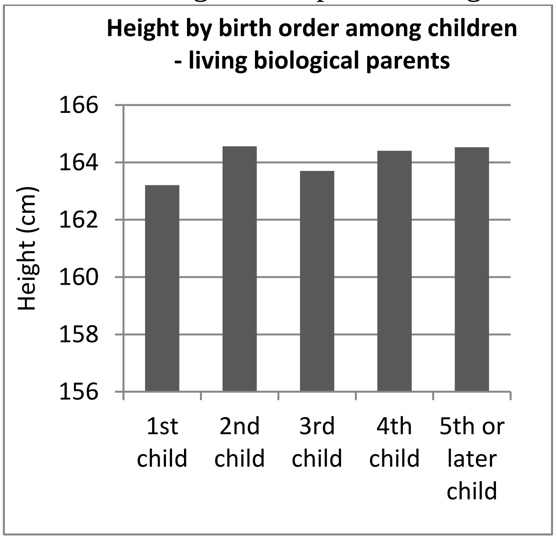
[181] The reference categories are based on the lowest categories in the figures.
[182] Including only children in the analysis yields nearly identical results.

Table 5.6: Observation Numbers and Percentages of Birth Order Among Children, Sons, and Second-Borns, Including Conscripts of Living Biological Parents

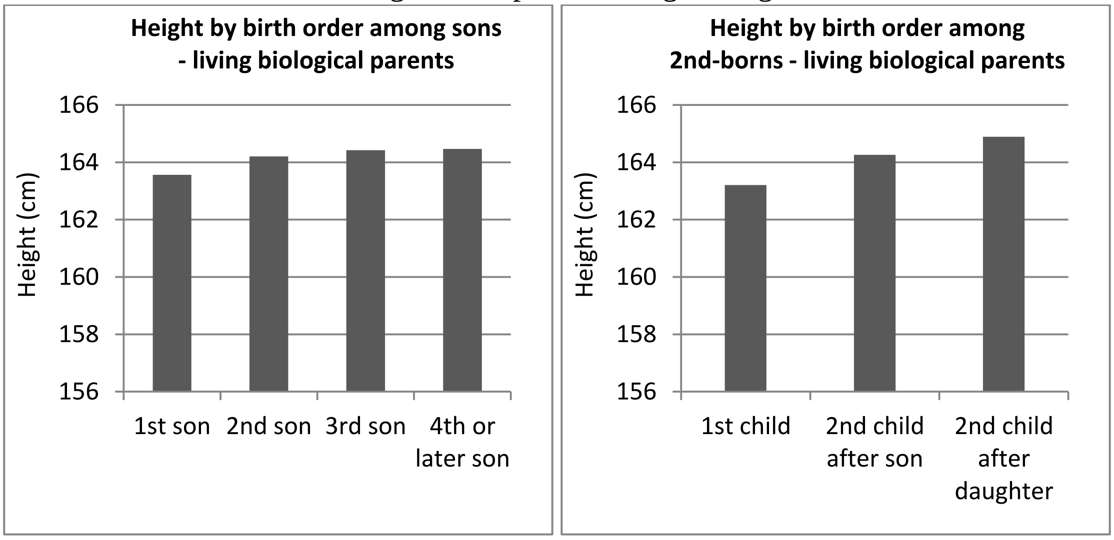
Birth order					
Children	**Obs.**	**Sons**	**Obs.**	**2nd child after son/daughter**	**Obs.**
1st child	324	1st son	482	1st child	324
2nd child	227	2nd son	241	2nd child after son	119
3rd child	152	3rd son	84	2nd child after daughter	108
4th child	77	4th or later son	50		
5th or later child	77				
Total	857		857		551
Children	**%**	**Sons**	**%**	**2nd child after son/daughter**	**%**
1st child	37.8	1st son	56.2	1st child	58.8
2nd child	26.5	2nd son	28.1	2nd child after son	21.6
3rd child	17.7	3rd son	9.8	2nd child after daughter	19.6
4th child	9.0	4th or later son	5.8		
5th or later child	9.0				
Total	100.0		100.0		100.0

Note: Only children are excluded for the calculation of birth order. Source: See Table 5.1.

Figures 5.7.1–5.7.3: Height Differences of Conscripts by Birth Order among Siblings, Brothers, and Second-Borns, Including Conscripts of Living Biological Parents



Figures 5.7.1–5.7.3: Height Differences of Conscripts by Birth Order among Siblings, Brothers, and Second-Borns, Including Conscripts of Living Biological Parents – Continued



Note: Only children are excluded when analyzing birth order. "First child" means that no other children were born before (but first child equals first son because there are only heights of male recruits in the sample); first son: may as well be the first child, but may also have older sisters in the birth order among sons. For the number of observations see Table 5.6. Source: See Table 5.1.

Figure 5.7.1 shows that the children born on a second or higher position have a moderate height advantage over first-borns. The second-borns seem to have a particular advantage because they are taller than not only the first-borns but also the third-borns. I also find a modest positive effect relating to the birth order among brothers compared to the first-borns but not a particularly large impact of being second-born (Figure 5.7.2). It is possible that if the second-born was the first boy, the parents allocated a large share of the resources to him. Therefore, I further differentiate between "second child after daughter" and "second child after son" (Figure 5.7.3). While the second-born after a son is still taller than the first-born, the second child after a daughter, who also equals the first son in the underlying data, has a substantial height advantage of approximately 1.7 cm.

When testing birth order effects in regression analysis, the authors of previous studies proceeded in different ways. Hatton and Martin (2010) include birth order and the number of children as continuous variables, whereas Behrman and Taubman (1986, p. 137) include birth order as binary variables. Black et al. (2005 and 2015) conduct several regressions including both dummy and continuous variables for family size and dummy variables for birth order effects. To avoid any bias that might result from testing either continuous or binary variables, I conduct separate regressions including birth order and the number of siblings as continuous and dummy variables. Additionally, it is important to control for family-specific properties because birth order effects might vanish completely once they are tested for family characteristics, as shown by Behrman and Taubman (1986, pp. 144–145). Therefore, I include "numerate", the fathers' occupational group, the type of region the family lives in, and the ages of the parents.[183]

Table 5.7: OLS-Regression of Height on the Number of Siblings and Birth Order, Including Conscripts of Living Biological Parents

OLS	**1c**	**2c**	**3c**	**4c**	**5c**
Dep. var.:			**Height of conscripts**		
Father numerate	1.02*	1.09**	0.92*	1.03*	0.69
	(0.06)	(0.05)	(0.08)	(0.05)	(0.29)
Total siblings	0.34**				
	(0.01)				
Birth order		0.03			
		(0.89)			
1 to 3 siblings		ref	ref	ref	ref
4 or more siblings		1.14**	1.41***	1.32***	1.69***
		(0.02)	(0.01)	(0.01)	(0.00)
1st child	ref		ref		
2nd child	1.11*		1.26**		
	(0.05)		(0.02)		
3rd child	0.28		0.24		
	(0.68)		(0.72)		
4th child	0.78		0.78		
	(0.31)		(0.32)		
5th or later child	0.16		0.05		
	(0.86)		(0.95)		
1st son				ref	
2nd son				0.40	
				(0.46)	
3rd son				0.22	
				(0.78)	
4th or later son				-0.53	
				(0.61)	
1st child					ref
2nd child after son					0.76
					(0.31)
2nd child after daughter					1.54**
					(0.02)

[183] On the choice of included variables, see, for example, Ejrnæs and Pörtner (2004, p. 1013) and Behrman and Taubman (1986, p. 135). See Appendix A.5 for the results of all control variables.

Table 5.7: OLS-Regression of Height on the Number of Siblings and Birth Order, Including Conscripts of Living Biological Parents – Continued

OLS	**1c**	**2c**	**3c**	**4c**	**5c**
Dep. variable:	**Height of conscripts**				
Constant	158.41***	159.60***	160.32***	160.40***	159.61***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Adj. R^2	0.030	0.029	0.049	0.045	0.051
F-test (p-val.)	0.00	0.00	0.00	0.00	0.00
Observations	835	835	838	838	549

Note: Robust p-values in parentheses. ***, **, * indicate significance on the 1%-, 5%- and 10%-level. "ref" indicates the reference category. It is controlled for occupational groups (1c/2c) or regions (3c/4c/5c) (see Appendix A.5). It is also controlled for "mother's age at 1st birth" (1c/3c) or "father's age at birth" (2c/4c/5c), none of which is significant. The gray highlightings help indicating the matching dummies. Only children are excluded when testing birth order. Source: See Table 5.1.

The effect of family size remains positive and significant throughout all of the regression models (Table 5.7). While the continuous variable "number of siblings" again yields a rather small effect on height with an increase of 0.34 cm for each additional sibling (model 1c), the advantage for conscripts with four or more siblings is still substantial (between approximately 1.1 and 1.7 cm in relation to those with zero to three siblings, models 2c–5c).

In model 2c (Table 5.7), I include birth order as a continuous variable, which is small and not significant. Including dummy variables for birth order yields a weakly positive but mainly insignificant effect of ascending birth order (models 1c/3c). However, there is a positive significant impact of the second-born child, who is slightly more than 1 cm taller compared to the first-born. Having a closer look at the second-borns strengthens the assumption I derived from the descriptives: being the second child after a son (hence, the second son) does not increase height significantly, whereas being born as the second child after a daughter (i.e., the first son) leads to a height advantage of 1.54 cm (model 5c). The birth order among sons does not yield any significant effect (model 4c).

Controlling for the father's numeracy yields a positive and significant impact on height in four out of five models (Table 5.7, 1c–4c).[184] It is most likely that better educated fathers had higher-skilled jobs and therefore could provide better for their children. Furthermore, they might be able to allocate potentially scarce resources within

[184] In the other regressions, numeracy is not significant, but has a fairly small p-value. The significant effect in Table 5.7 is probably due to the sample in which I exclude only children. It is possible that the numeracy effect has a stronger impact on height in families with a greater number of children because in large families the allocation of resources is particularly important. In the robustness checks, the numeracy effect disappears, which might be caused by the relatively small sample size (Appendix A.5).

the household more efficiently than fathers with very low basic education. The results of the occupational groups and the regions in Table 5.7 are very similar to those described in Table 5.3.

The regression results seem to support different theories. The very modest effect of positive birth order might point in the direction of De Haan et al. (2014), who suggest that poor families in developing countries increase their income over time and therefore are able to invest in later-born children. For example, De Moor and Zuijderduijn (2013) also find that groups with relatively low incomes, such as smallholders, indeed saved or invested capital in the early modern period. However, because the birth order results are not consistently significant, I can neither reject nor confirm the hypothesis of De Haan et al. (2014). Instead, I find that being second-born after a daughter has a strong impact, which might be a hint for the preference of boys because sons were supposed to have a greater "net utility" compared to daughters, as they were expected to help their parents and provide for them at older ages (Hank und Kohler 2003, p. 135). It is also possible that a boy (born after a girl as the first child) received a special position in the family, as described by Rosenberg (1965, pp. 112–126).[185] Looking at the results of birth order among boys seems to confirm this assumption, as none of the sons seems to have received a special role in the cases where brothers were present.

In summary, I can reject the assumption of a rivalry for resources, particularly among boys. It is likely that the parents with a greater number of sons had the means to provide for them and managed to allocate their resources evenly among the sons. Furthermore, the strong, positive impact of a large number of siblings on height remains unchanged even when controlling for birth order effects. This finding stands in contrast to those of several authors who conclude that family size had a negative impact on children's outcome, such as Li and Power (2004), Booth and Kee (2009), Hatton and Martin (2010), and Black et al. (2015).

[185] However, having a large number of sisters does not increase height as strongly as having a large number of brothers.

5.5 Socioeconomic Background and Family Size

A negative impact of family size on child outcome seems to be logical because family resources are limited and an increasing number of children mean a decrease in allocated resources for each additional child, implying a quantity-quality trade off (see Becker 1960). This relationship might hold for modern times and, in particular, for poorer families with a large number of siblings and very limited resources, such as in the study of Hatton and Martin (2010). Therefore, what are the reasons for the substantial positive impact of family size on height that stands in sharp contrast to the results of other studies?

When answering this question, we have to consider the specific fertility mechanisms of the early 19th century in which birth control was hardly available. Having a large number of children was regarded a good provision for parents' old age. Therefore, I suggest an explanation that is based on the theory that wealthy groups of early 19th-century society had a larger number of (surviving) children than poorer groups (Clark 2007, pp. 112–116). We already observed that the conscripts born into higher occupational groups had a significant height advantage over the ones born into lower occupational groups. The upper groups of society were most likely able to not only provide their children with a sufficient amount of protein-rich nutrition but also increase their fertility, which we measured indirectly through the height effect of conscripts with a large number of siblings. To test this assumption, I conducted an additional regression in which the total number of siblings is implemented as the dependent variable while the occupational groups serve as independent variables.[186]

[186] Because the number of siblings is a count variable that takes on small integer values, I ran a negative binomial regression model that accounts for potential overdispersion (meaning that the variance is larger than the mean). The marginal effects allow interpretation of the coefficients as unit changes (here: siblings).

Table 5.8: Negative Binomial Regression of the Number of Siblings

Negative Binomial Marginal effects	**1d**	**2d**
Dep. var.:	**Number of siblings**	
Sample	**All parents**	**Living biological parents**
Professional	0.67***	0.58*
	(0.01)	(0.08)
Skilled	0.69***	0.50***
	(0.00)	(0.01)
Farmer	1.22***	0.99***
	(0.00)	(0.00)
Partly skilled	ref	ref
Unskilled	ref	ref
Father's age at birth	-	0.02***
		(0.00)
Father numerate	-	0.15
		(0.27)
Pseudo R²	0.010	0.010
Chi² (p-val)	0.00	0.00
Observations	1,496	934

Note: Robust p-values in parentheses. ***, **, * indicate significance on the 1%-, 5%- and 10%-level. "ref" indicates the reference category. Marginal effects are reported. Source: See Table 5.1.

The results shown in Table 5.8 confirm the assumption of a large number of siblings in higher occupational groups for the underlying data. The professional and skilled individuals have a significantly larger number of children (or siblings) than the partly skilled or unskilled groups that build the pooled reference category, resulting in 0.67 more siblings per family (or 67 more siblings per one hundred families, model 1d). The conscripts in farmer families even have 1.22 siblings more than those of the least skilled groups of society.[187] These results are in line with Clark (2007, p. 116), who finds a similar mechanism in England. Hadeishi (2003, p. 504) confirms a similar pattern in terms of income for early modern France. This pattern results most likely from high infant mortality rates among poorer groups and a lower fertility due to malnutrition and worse hygienic conditions. The farmers who had the largest number of children had a proximity-advantage to high protein-rich nutrition. In times of high food prices and famine, they could keep a larger share of their products for their own families instead of selling a large share on the market (Tollnek and Baten 2017, section II).

[187] I also test for the father's age, which has a positive and significant influence. Of course, the number of children increases with age. Additionally, it was custom in the early 19th century to start a family once income was sufficiently high to provide for the family (Lee 2003, p. 169). Hence, older parents had a higher income and a larger number of children.

5.6 Conclusion

In this study, I assessed the influence of important determinants of conscripts' heights in early 19^{th}-century Bavaria. Being born into a family with a highly skilled head of household, living in a milk-producing or urban region, and having at least four siblings increased an individual's height substantially. Being born into a large farming family also significantly increased one's chances of growing tall, which was probably due to the availability of high-quality nutrition. Of course, these results have to be considered carefully, as they are based on data observing only males and households at a specific point in time. To see the full picture, it would be necessary to analyze a complete dataset including females' heights and households with completed fertility. However, such complete datasets are rare for the early 19^{th} century; thus, this introductory study provides valuable insights on the impact of socioeconomic status, living conditions, and family size on height.

The assumption of a potential rivalry among siblings or sons should be rejected for the data analyzed here. On the contrary, the more siblings – in particular brothers – a conscript had, the greater was his height advantage compared to those with zero or a moderate number of siblings. The strong family size effect remains even when controlling for birth order. Birth order, on the other hand, has a slight positive but insignificant influence on height with the exception of a second-born child – and hence first son – after a daughter. This finding might be a hint for parental preferences in the sex of their children because sons were expected to provide for their parents once they were old (Hank and Kohler 2003, p. 135).

We find potential reasons for the positive family size effect in the Malthusian world of early 19^{th}-century Bavaria: the fertility transition that later enabled the famous quantity-quality trade-off of children had not yet begun. Infant mortality rates were still high, which created incentives for high fertility rates (Galor and Weil 1999; Lee 2003). In this time period, the more skilled and thus wealthier groups of society as well as farming families seemed to have an advantage over the lower groups of society in every respect. They probably not only managed to decrease their infant mortality rate and increase their number of (surviving) children but also had the means to provide their descendants with a sufficient amount of high-quality foodstuffs (Tollnek and Baten 2017). Consequently, there was no rivalry for resources, and their children were presumably able to reach the maximum individual height that was possible under the harsh living conditions of the early 19^{th}-century.

5.7 References

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Appendix A.5: Additional Tables and Figures

Table A.5.1: Observation Numbers and Mean Height by Region and Place

Region	**Place**	**Mean height**	**No. of obs.**
Milk	Landsberg	164.4	168
Milk	Miesbach	165.7	129
Milk	Prien	167.2	52
Milk	Rosenheim	164.4	95
Milk	Tegernsee	164.8	9
Milk	Toelz	166.5	73
Milk	Trostberg	164.4	96
Rye	Moosburg	160.9	108
Rye	Muehldorf	163.6	191
Rye	Pfaffenhofen	163.6	127
Urban	Landshut (city)	164.9	41
Urban	Munich (city)	164.2	134
Suburban	Landshut	161.1	133
Suburban	Munich	163.9	138
Suburban	Starnberg	162.5	66
Total		163.9	1,560

Note: "Mean height total" displays the mean weighted by the underlying number of observations. Source: See Table 5.1.

Table A.5.2: Observation Numbers of the Fathers' ABCCs by Birth Decades

Birth Decade	**Conscripts' fathers**
1740	164
1750	535
1760	403
1770	82

Note: The fathers' ages start at 34; included is the age range between 34 and 72. Source: See Table 5.1.

Table A.5.3: Descriptive Statistics of Included Variables, Reduced Sample

Variable	No. of obs.	Mean	Std. Dev.	Min.	Max.
Sample	reduced sample				
Height	488	163.74	6.53	146.0	181.2
Total siblings	488	4.14	2.20	0	11
Older siblings	488	1.44	1.60	0	8
Younger siblings	488	2.70	2.03	0	9
Total brothers	488	2.04	1.44	0	7
Older brothers	488	0.76	1.04	0	6
Younger brothers	488	1.29	1.23	0	6
Total sisters	488	2.09	1.55	0	7
Older sisters	488	0.68	0.95	0	5
Younger sisters	488	1.41	1.39	0	7
Birth order	470	2.49	1.60	1	9
Father's age at birth	488	34.88	7.32	15	53
Mother's age at birth	488	28.15	5.44	16	45
Mother's age at 1st birth	488	23.45	3.50	15	28
Father numerate	488	0.75	0.43	0	1

Note: Only children are excluded from birth order. Reduced sample: included are conscripts whose mother's age at 1st birth<=28. Source: See Table 5.1.

Table A.5.4: Observation Numbers and Percentages by Occupational Group of the Father and Region, Reduced Sample

Reduced sample					
Occupational group:	obs.	%	Region:	obs.	%
Professional & interm.	33	6.8	Milk	171	35.0
Skilled	136	27.9	Rye	138	28.3
Farmer	222	45.6	Urban	58	11.9
Partly skill. & unskilled	96	19.7	Suburban	121	24.8
Total	487	100	Total	488	100

Note: Only children are excluded from birth order. Reduced sample: included are conscripts whose mother's age at 1st birth<=28. Source: See Table 5.1

Table A.5.5: Observation Numbers and Percentages by Farmer Subcategories, Conscripts of All Parents and Living Biological Parents

Sample:	**All parents**		**Living biological parents**	
Farmer subcategory:	Obs.	%	Obs.	%
Smallholder	342	53.7	207	51.2
Larger/medium-sized farmer	281	44.1	189	46.8
Mixed	14	2.2	8	2.0
Total	637	100.0	404	100.0

Note: The "mixed" farmer group contains individuals who could not clearly be aggregated to one of the two groups. Source: See Table 5.1.

Table A.5.6: Observation Numbers and Percentages for the Total Number of Siblings, Including Conscripts of All Parents and Reduced Sample

	Obs.	%	Obs.	%	Obs.	%
All parents	**Siblings**		**Brothers**		**Sisters**	
0 to 1	366	23.5	847	54.3	800	51.3
2 to 3	554	35.5	563	36.1	575	36.9
4 or more	640	41.0	150	9.6	185	11.9
Total	1,560	100.0	1,560	100.0	1,560	100.0
Reduced sample	**Siblings**		**Brothers**		**Sisters**	
0 to 1	54	11.1	190	38.9	195	40.0
2 to 3	152	31.1	223	45.7	201	41.2
4 or more	282	57.8	75	15.4	92	18.9
Total	488	100.0	488	100.0	488	100.0

Note: The reduced sample includes conscripts whose mother's age at 1st birth<=28. Source: See Table 5.1.

Table A.5.7: Observation Numbers and Percentages of Birth Order Among Children, Including Conscripts of All Parents and Reduced Sample

Birth order					
All parents	**obs.**	**%**	**Reduced sample**	**obs.**	**%**
1st child	473	34.2	1st child	160	34.0
2nd child	372	26.9	2nd child	121	25.7
3rd child	246	17.8	3rd child	89	18.9
4th child	146	10.6	4th child	46	9.8
5th or later child	145	10.5	5th or later child	54	11.5
Total	1,382	100.0	Total	470	100.0

Note: Only children are excluded when analyzing birth order. The reduced sample includes conscripts whose mother's age at 1st birth<=28. Source: See Table 5.1.

Table A.5.8: Robustness Test: OLS-Regression of Height on Occupational Group/Farming Group of the Father, Regions, and Siblings, Including Conscripts of All Parents, Living Biological Parents and Reduced Sample

OLS	**1a**	**2a**	**3a**	**4a**	**5a**	**6a**	**7a**
Dep. var.:	**Height of conscripts**						
Sample	**All parents**		**Liv. bio. parents**	**Reduced sample (mother's age at 1st birth<=28)**			
Professional			1.10	3.37**		3.49**	
			(0.30)	(0.02)		(0.01)	
Skilled			-0.33	1.95**		2.12***	
			(0.59)	(0.02)		(0.01)	
(Medium-sized) farmer			ref	1.54**		1.78**	
				(0.05)		(0.02)	
Smallholder			-1.12	-		-	
			(0.10)				
Partly skilled			-2.23**	ref		ref	
			(0.04)				
Unskilled			-2.68***	ref		ref	
			(0.00)				
Milk	2.24***	2.23***			2.88***		2.73***
	(0.00)	(0.00)			(0.00)		(0.00)
Rye	ref	ref			ref		ref
Suburban	-0.31	-0.33			-0.03		-0.06
	(0.52)	(0.50)			(0.97)		(0.93)
Urban	1.57**	1.51**			2.68**		2.77***
	(0.01)	(0.02)			(0.01)		(0.01)
Father died	-0.04						
	(0.93)						
Stepfather in family		-0.42					
		(0.61)					
Father's age at birth					-0.00		
					(0.98)		
Mother's age at birth						-0.02	0.05
						(0.77)	(0.41)
Father numerate				0.28			
				(0.68)			
Total sibl.	0.17**		0.21**	0.40***			
	(0.02)		(0.03)	(0.00)			
Total sist.		0.24**			0.39**		
		(0.04)			(0.03)		
Total bros.						0.53**	
						(0.01)	
Younger sibl.							0.39***
							(0.01)
Constant	162.34***	162.52***	163.97***	160.40***	161.65***	161.49***	160.06***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)

Table A.5.8: Robustness Test: OLS-Regression of Height on Occupational Group/Farming Group of the Father, Regions, and Siblings, Including Conscripts of All Parents, Living Biological Parents and Reduced Sample – Continued

OLS	**1a**	**2a**	**3a**	**4a**	**5a**	**6a**	**7a**
Dep. var.:	**Height of conscripts**						
Sample	**All parents**		**Liv. bio. parents**	**Reduced sample (mother's age at 1st birth<=28)**			
Adj. R^2	0.029	0.029	0.027	0.029	0.047	0.024	0.052
F-Test (p-val.)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Observations	1,560	1,560	934	487	488	487	488

Note: Robust p-values in parentheses. ***, **, * indicate significance on the 1%-, 5%- and 10%-level. "ref" indicates the reference category. Professional & intermediate are condensed to professional. In 3a the farming group is separated in medium-sized farmers and smallholders; in the other models, "farmer" stands for the whole farming group. Source: See Table 5.1.

Table A.5.9: Supplement to Table 5.5:
Results for Occupational Group of the Father and Regions

OLS	**1b**	**2b**	**3b**	**4b**	**5b**	**6b**
Dep. var.:	**Height of conscripts**					
Testing	**Siblings**		**Brothers**		**Sisters**	
Professional	3.66***		3.75***		3.68***	
	(0.00)		(0.00)		(0.00)	
Skilled	2.08***		2.18***		2.14***	
	(0.00)		(0.00)		(0.00)	
Farmer	1.87***		2.00***		1.92***	
	(0.00)		(0.00)		(0.00)	
Partly skilled	ref		ref		ref	
Unskilled	ref		ref		ref	
Milk		2.18***		2.12***		2.18***
		(0.00)		(0.00)		(0.00)
Rye		ref		ref		ref
Suburban		-0.39		-0.46		-0.45
		(0.51)		(0.44)		(0.45)
Urban		2.63***		2.58***		2.52***
		(0.00)		(0.00)		(0.00)
Constant	159.61***	160.67***	160.41***	160.41***	160.19***	160.66***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Adj. R^2	0.028	0.037	0.028	0.038	0.023	0.036
F-Test (p-val.)	0.00	0.00	0.00	0.00	0.00	0.00
Observations	915	939	915	939	915	939

Note: Robust p-values in parentheses. ***, **, * indicate significance on the 1%-, 5%- and 10%-level. "ref" indicates the reference category. This is the supplement to the main table controlling for categorized siblings. Source: See Table 5.1.

Table A.5.10: Robustness Test: OLS-Regression of Height on Categorized Siblings, Reduced Sample (Mother's Age at First Birth<=28)

OLS	**1b**	**2b**	**3b**	**4b**	**5b**	**6b**
Dep. var.:	**Height of conscripts**					
Testing	**Siblings**		**Brothers**		**Sisters**	
Professional	3.35**		3.59***		3.47**	
	(0.02)		(0.01)		(0.01)	
Skilled	1.97**		2.15***		2.12**	
	(0.02)		(0.01)		(0.01)	
Farmer	1.68**		1.84**		1.79**	
	(0.03)		(0.02)		(0.02)	
Partly skilled	ref		ref		ref	
Unskilled	ref		ref		ref	
Milk		2.96***		2.75***		2.99***
		(0.00)		(0.00)		(0.00)
Rye		ref		ref		ref
Suburban		-0.11		-0.15		-0.11
		(0.89)		(0.85)		(0.89)
Urban		2.66**		2.64**		2.56**
		(0.01)		(0.01)		(0.01)
Mother's age at 1st birth	-0.03		-0.03		-0.03	
	(0.76)		(0.72)		(0.71)	
Father's age at birth		-0.01		0.01		0.00
		(0.80)		(0.74)		(0.95)
Father numerate	0.28	0.00	0.31	0.04	0.37	0.14
	(0.70)	(1.00)	(0.66)	(0.96)	(0.60)	(0.83)
0 to 1	ref		ref		ref	
2 to 3	ref		ref		0.04	
					(0.95)	
4 or more	1.63***		2.48***		1.91**	
	(0.01)		(0.00)		(0.02)	
No older		ref				ref
1 older		1.83**				1.42**
		(0.02)				(0.04)
2 older		0.76				-0.70
		(0.37)				(0.37)
3 or more older		0.78				0.19
		(0.38)				(0.88)
0 to 2 younger				ref		
3 or more younger				1.55**		
				(0.04)		

Table A.5.10: Robustness Test: OLS-Regression of Height on Categorized Siblings, Reduced Sample (Mother's Age at First Birth<=28) –Continued

OLS	**1b**	**2b**	**3b**	**4b**	**5b**	**6b**
Dep. var.:	**Height of conscripts**					
Testing	**Siblings**		**Brothers**		**Sisters**	
Constant	161.70***	162.05***	162.21***	161.82***	162.25***	161.96***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Adj. R^2	0.025	0.044	0.029	0.044	0.021	0.044
F-Test (p-val.)	0.00	0.00	0.00	0.00	0.01	0.00
Observations	487	488	487	488	487	488

Note: Robust p-values in parentheses. ***, **, * indicate significance on the 1%-, 5%- and 10%-level. "ref" indicates the reference category. Prof. & interm. are condensed to prof. The lines have to be combined with the columns, e.g., "No older" (=line) "sibling" (=column). The gray highlightings help indicating the matching dummies. Ref. groups 0-2 younger brothers are condensed. Source: See Table 5.1.

Table A.5.11: Supplement to Table 5.7: Results for Occupational Groups and Regions

OLS	**1c**	**2c**	**3c**	**4c**	**5c**
Dep. var.:	**Height of conscripts**				
Professional	3.00***	3.01***			
	(0.01)	(0.01)			
Skilled	2.32***	2.31***			
	(0.00)	(0.00)			
Farmer	1.79***	1.85***			
	(0.00)	(0.00)			
Partly skilled	ref	ref			
Unskilled	ref	ref			
Milk			2.40***	2.36***	2.39***
			(0.00)	(0.00)	(0.00)
Rye			ref	ref	ref
Suburban			-0.05	-0.17	-0.17
			(0.93)	(0.78)	(0.82)
Urban			2.93***	2.78***	2.53**
			(0.00)	(0.00)	(0.03)
Mother's age at 1st birth	0.05		0.02		
	(0.25)		(0.67)		
Father's age at birth		0.03		0.02	0.04
		(0.33)		(0.51)	(0.32)
Constant	158.41***	159.60***	160.32***	160.40***	159.61***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Adj. R^2	0.030	0.029	0.049	0.045	0.051
F-test (p-val.)	0.00	0.00	0.00	0.00	0.00
Observations	835	835	838	838	549

Note: Robust p-values in parentheses. ***, **, * indicate significance on the 1%-, 5%- and 10%-level. "ref" indicates the reference category. This is the supplement to the main table controlling for siblings and birth order. Source: See Table 5.1.

Table A.5.12: Robustness Test: OLS-Regression of Height on the Number of Siblings and Birth Order, Reduced Sample (Mother's Age at First Birth<=28)

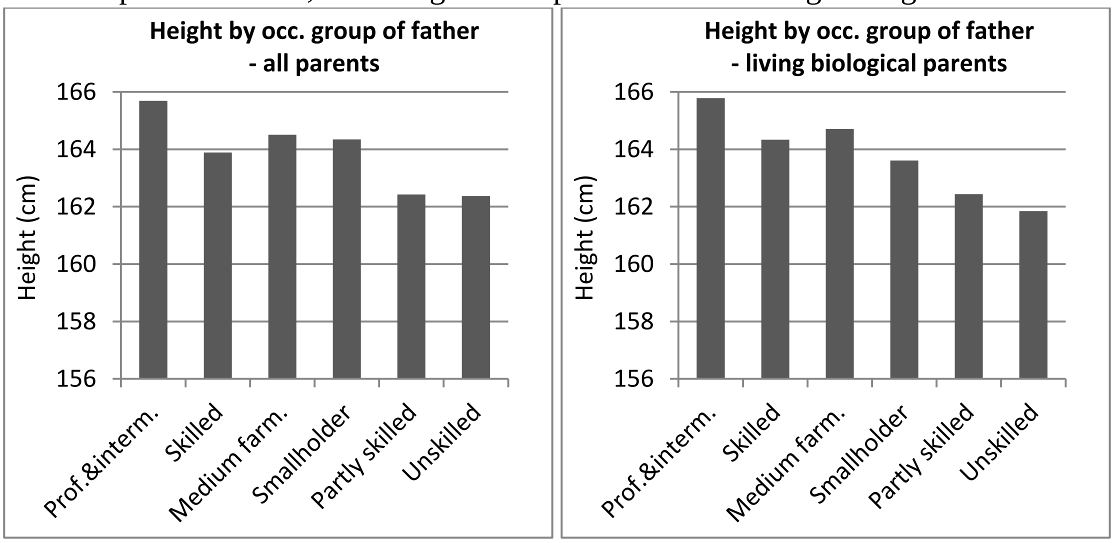
OLS	**1c**	**2c**	**3c**	**4c**	**5c**
Dep. var.:			**Height of conscripts**		
Professional	2.36*	2.57*			
	(0.09)	(0.07)			
Skilled	1.93**	1.98**			
	(0.02)	(0.02)			
Farmer	1.36*	1.62**			
	(0.08)	(0.04)			
Partly skilled	ref	ref			
Unskilled	ref	ref			
Milk			3.03***	2.95***	4.01***
			(0.00)	(0.00)	(0.00)
Rye			ref	ref	ref
Suburban			0.05	0.16	0.53
			(0.94)	(0.84)	(0.62)
Urban			2.49**	2.51**	2.08
			(0.02)	(0.02)	(0.16)
Mother's age at 1st birth	0.01		-0.05		
	(0.88)		(0.62)		
Father's age at birth		0.01		-0.02	-0.00
		(0.84)		(0.72)	(0.95)
Father numerate	0.15	0.25	-0.01	0.04	-0.34
	(0.84)	(0.72)	(0.99)	(0.96)	(0.71)
Total siblings	0.53***				
	(0.00)				
Birth order		-0.01			
		(0.97)			
1 to 3 siblings		ref	ref	ref	ref
4 or more siblings		1.69***	1.77***	1.54**	1.76**
		(0.01)	(0.01)	(0.01)	(0.03)
1st child	ref		ref		
2nd child	1.65**		1.80**		
	(0.04)		(0.02)		
3rd child	0.30		0.40		
	(0.72)		(0.63)		
4th child	0.13		-0.01		
	(0.90)		(0.99)		
5th or later child	-0.37		-0.07		
	(0.73)		(0.95)		

Table A.5.12: Robustness Test: OLS-Regression of Height on the Number of Siblings and Birth Order, Reduced Sample (Mother's Age at First Birth<=28) – Continued

OLS	**1c**	**2c**	**3c**	**4c**	**5c**
Dep. var.:	**Height of conscripts**				
1st son				ref	
2nd son				0.56	
				(0.43)	
3rd son				0.00	
				(1.00)	
4th or later son				0.80	
				(0.51)	
1st child					ref
2nd child after son					1.48
					(0.16)
2nd child after daughter					2.33**
					(0.02)
Constant	159.26***	160.81***	161.88***	161.76***	160.75***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Adj. R^2	0.028	0.018	0.058	0.048	0.074
F-test (p-val.)	0.01	0.02	0.00	0.00	0.00
Observations	469	469	470	470	281

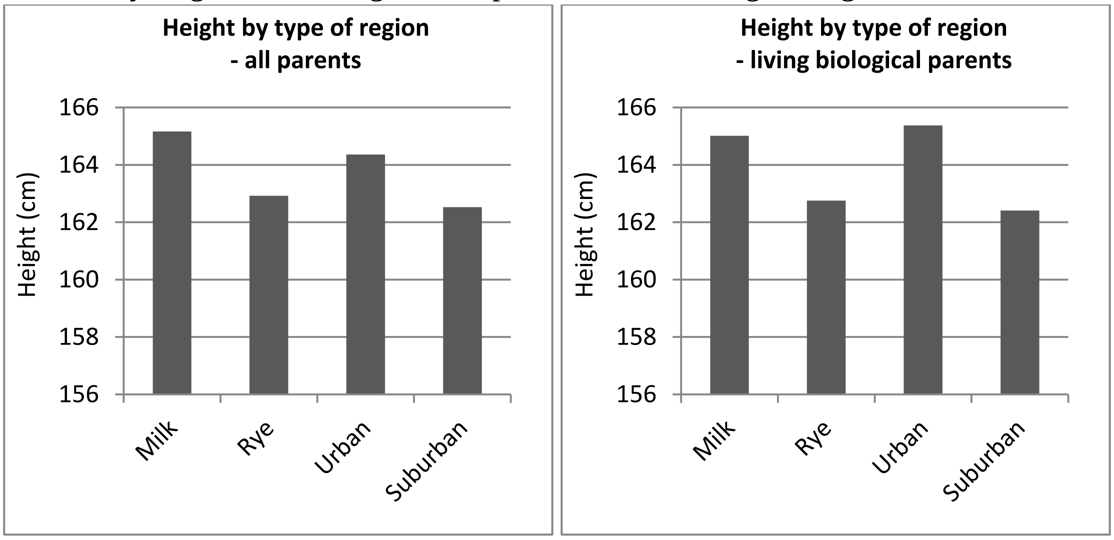
Note: Robust p-values in parentheses. ***, **, * indicate significance on the 1%-, 5%- and 10%-level. "ref" indicates the reference category. The gray highlightings help indicating the matching dummies. Only children are excluded when testing birth order. Only children are excluded when analyzing birth order. Source: See Table 5.1.

Figures A.5.1.1–A.5.1.2: Height of Conscripts by Occupational Group of the Father, Including Conscripts of All and Living Biological Parents



Note: Height refers always to the height of the conscripts. Additionally it is described, which sample is included for the calculation. Living biological parents refers to conscripts whose parents are still both alive and not listed as being stepmother or -father. For observation numbers see Table 5.2. Source: See Table 5.1.

Figures A.5.2.1–A.5.2.2: Height of Conscripts by Region, Including Conscripts of All and Living Biological Parents



Note: For observation numbers see Table 5.2. Source: See Table 5.1.

Figure A.5.3.1–A.5.3.6: Height of Conscripts by Number of Total/Older/Younger Siblings/Brothers/Sisters, Including Conscripts of All Parents, Living Biological Parents, and Reduced Sample

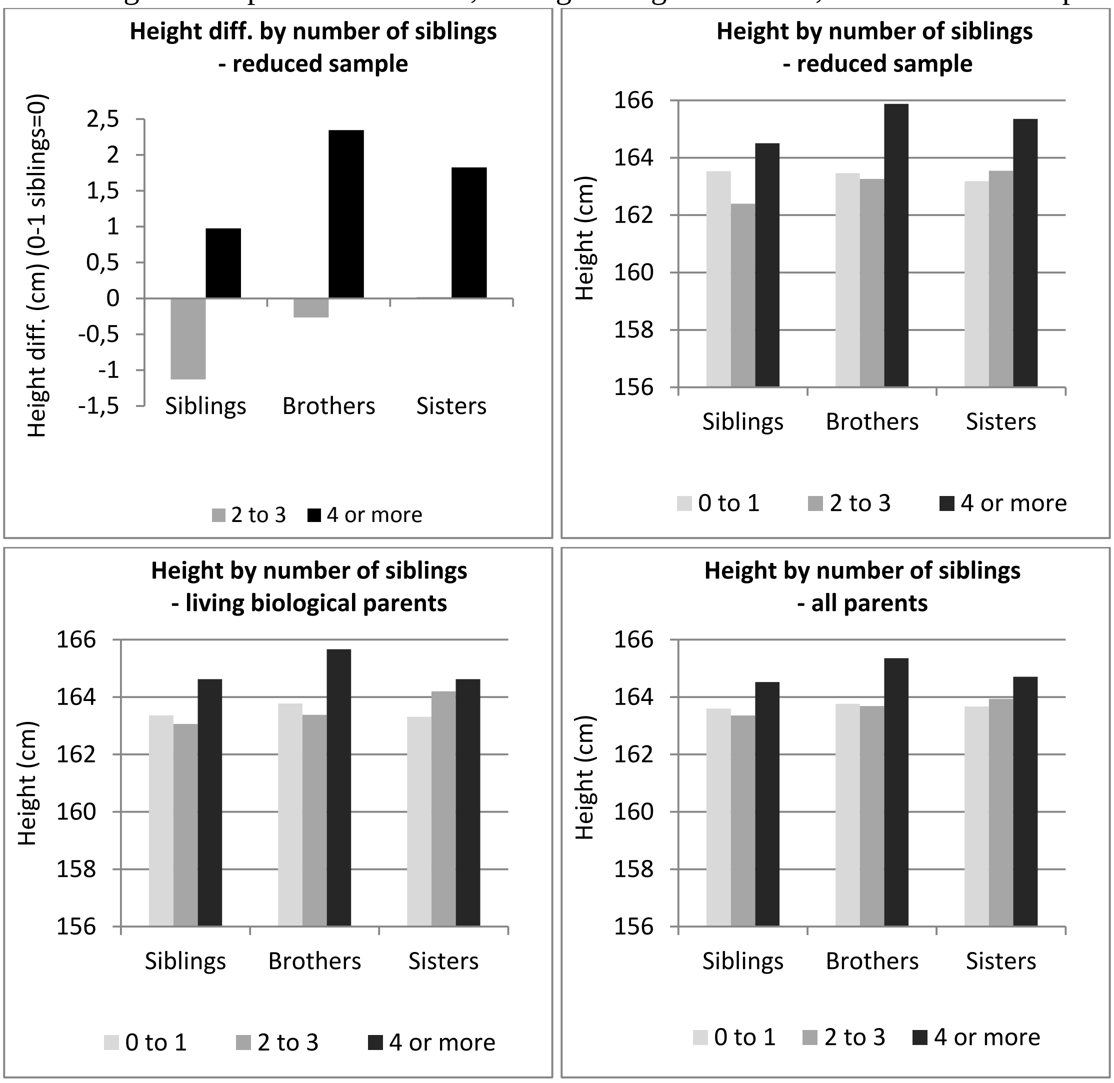
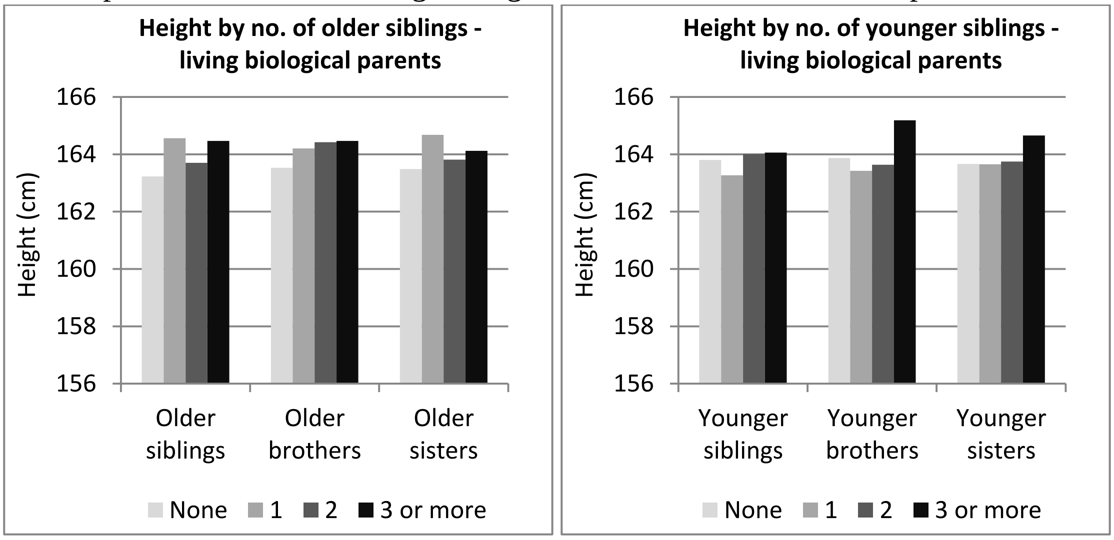
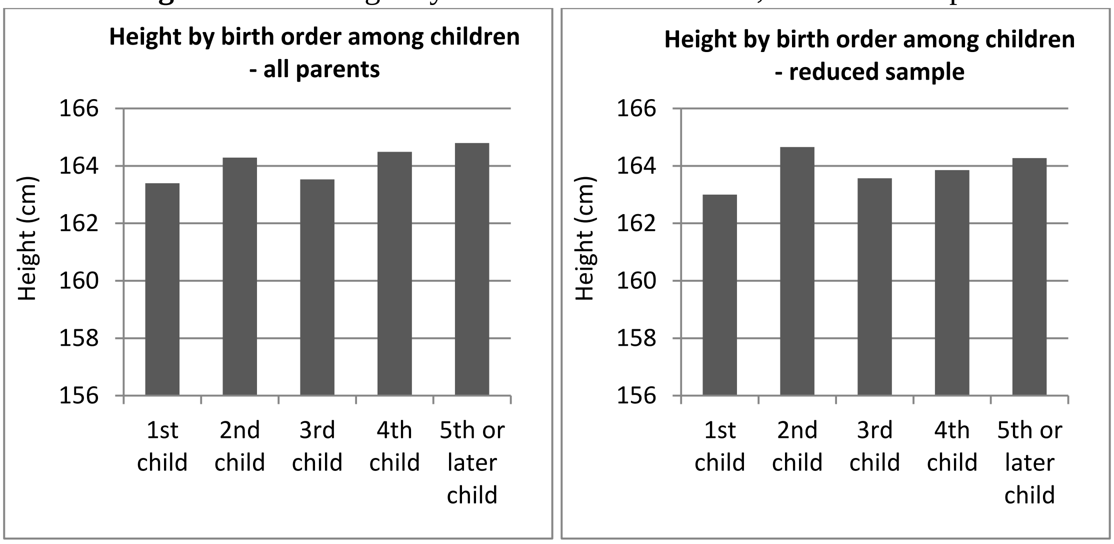


Figure A.5.3.1–A.5.3.6: Height of Conscripts by Number of Total/Older/Younger Siblings/Brothers/Sisters, Including Conscripts of All Parents, Living Biological Parents and Reduced Sample – Continued



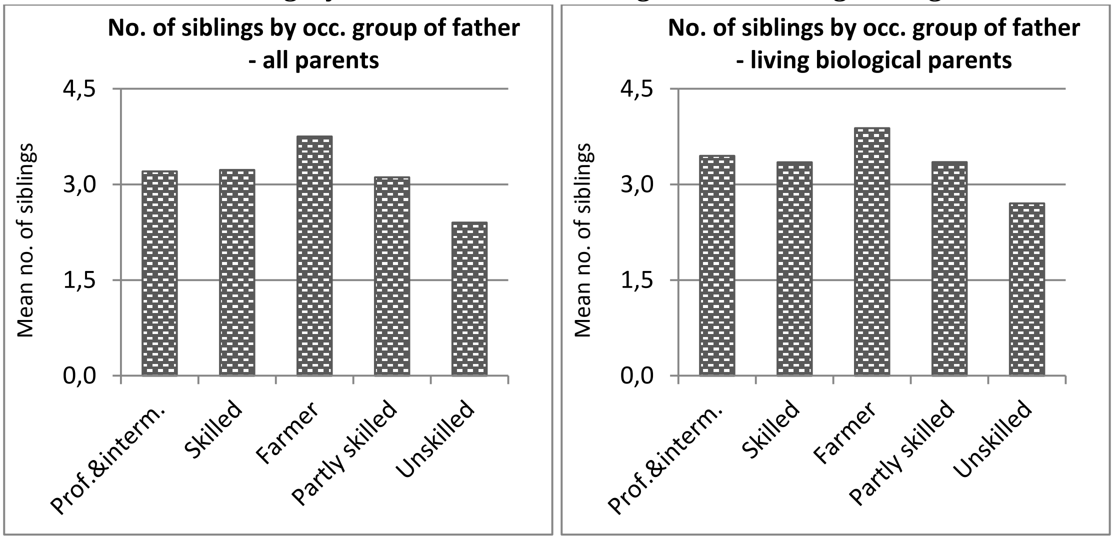
Note: The reduced sample includes conscripts whose mother's age at 1st birth<=28. The results for older and younger siblings of all parents and the reduced sample are very similar to those for the sample of living biological parents. For observation numbers see Tables 5.4 and A.5. Source: See Table 5.1.

Figure A.5.4: Height by Birth Order of Children, Reduced Sample



Note: The reduced sample includes conscripts whose mother's age at 1st birth<=28. Only children are excluded when analyzing birth order. The results of the full and reduced sample concerning birth order among sons and second borns are also very similar to those including living biological parents (Figures 5.7.1-5.7.3). Source: See Table 5.1.

Figures A.5.5.1–A.5.5.2: Number of Siblings by Occupational Group and Farmer Subcategory of the Father, Including All and Living Biological Parents



Note: The partly skilled seem to have a fairly high number of children but their number of observations is low which could lead to a slight upward bias for this group. For observation numbers see Table 5.2. Source: See Table 5.1.

6 What About Gender Equality in a Patriarchal Society? An Analysis of Educational Inequalities in Mexico Between 1870 and 1940

Abstract:

In this study, I assess educational gender inequality in one of the largest economies in Latin America: Mexico. Therefore, I consider Goldin's (1995) theory of a "U-shape" in the labor force participation of women: in times of increasing income, men are the first to benefit from rising shares of labor market participation. Women's labor market participation increases only after a certain delay. By analyzing an aggregate dataset of more than half a million observations from all over Mexico, I can confirm the "U-shape" in gender inequality related to basic education: during the important phase of increasing industrialization and the rise in schooling, men are the first to benefit. In this phase, the gender gap opens. It is only after a certain delay that women manage to lower the gap. However, I find the "U" only in states with low shares of Indigenous population. In a second analysis on individual-level data, I shed more light on the situation of Indigenous women by assessing a case study: is the small town of Juchitán ruled by a matriarchy? Based on the underlying data, I cannot confirm the hypothesis of a matriarchy, but I can neither reject it.

6.1 Introduction

The importance of studying gender inequality is beyond question: not only is gender inequality an inconvenient condition for every individual suffering from it, but it is also a great disadvantage for societies and an obstacle to economic growth. Several authors have found a negative impact on the economic growth and development of countries in the presence of gender disparities, which can affect both present and future generations (see, for example, Dollar and Gatti 1999, pp. 21–22; Klasen 2002, pp. 367–368). Furthermore, the influence of gender inequality on society has effects not only in monetary terms via lower growth rates but also in terms of health, infant mortality, and fertility. The World Bank (2001, p. 11) argues that low investment in female education leads to poorer health and nutritional practices among women due to a lack of knowledge, which likely affects a large number of children. Murthi, Guio, and Drèze (1995, pp. 747–749) even find a strong and negative relationship between female literacy and child mortality. Higher educated women, on the other hand, marry later, spend more time educating herselves, and have a smaller number of children, which reduces overall fertility. Schultz (1993, p. 338) finds that female education is the most important factor explaining the decline of child mortality rates, which is usually followed by decreasing fertility.[188] In Latin America, women who attended school for seven or more years had 2.9 fewer children compared to those without schooling in the 1980s (Schultz 1997, p. 382).

Declining mortality and, consequently, decreasing fertility is often accompanied by what scholars call the "quantity-quality trade-off" in children (Becker 1960). The underlying assumption is that financial means and parental time are scarce commodities such that parents face a utility function: a higher number of children mean a scarcer amount of resources allocated to each child. Consequently, the decline in fertility among educated women most likely results in a rise in the overall educational level of a society. Finally, discrimination against women and social norms that strengthen "traditional" gender roles restrict women's activities in the society, preventing them from participating in labor markets and political activities (World Bank 2001, pp. 69, 228). Thus, a large set of skills in society remains unused.

[188] While infant mortality rates are high, fertility remains high because deceased children often are "replaced". Once infant death rates decline, the incentives for having a high number of children, including "replacement" of children, vanish (on the fertility transition in 19th-century Europe, see Lee 2003).

Gender inequality is often accompanied by wage differentials between women and men. Even in countries with relatively high levels of education and income, such as the United States and the European Union, women with the same degree of education and experience often do not receive the same wages as men in the same position (Eurostat 2014). However, Goldin (2014, p. 1102) finds that the gender pay gap in the United States (US) narrowed substantially throughout the past few decades, particularly in specific areas such as the technology and science sectors. In contrast, the wage disparities in the developing world are not only higher than in industrial countries but are also accompanied by more serious issues: women in developing countries are more likely to suffer from poverty, higher mortality rates, and lower educational levels than males (Klasen 2002, pp. 345–347). However, gender differences are not homogenous across the developing world. While educational inequality is high in South Asia, the Middle East, and parts of Africa, women in Latin America are comparatively little disadvantaged (Klasen 2002, p. 345; Bustillo 1993, p. 175). Latin American girls are generally about as likely to go to school as boys, and they even have a higher probability of going to secondary school than boys (Bustillo 1993, p. 175). However, Manzel and Baten (2009) show that large differences exist even within the Latin American continent.

In GDP and total population, Mexico ranks among the top twelve countries worldwide, and it occupies the second position within the Latin American continent (CIA 2014). However, with approximately 51% of the population living below the national poverty line in 2010, the country still deals with large inequalities between rich and poor, women and men, and Indigenous and non-Indigenous parts of society (World Bank 2014; Frias 2008). The Gender Inequality Index developed by the United Nations (2013, p. 5) presents a heterogeneous picture of gender equality in Mexico. While female empowerment, measured by the share of women holding parliamentary seats, is relatively high at 36%, the share of women's labour market participation is only approximately 44%, whereas that of men is 80%.[189] With a share of approximately 51% of secondary schooling, women perform slightly worse than men, of whom approximately 57% finish secondary school. These indicators suggest that existing gender inequalities are primarily related to the educational disadvantages of women. In contrast to Latin American women in general, Mexican women still lag behind in

[189] The share of female empowerment in Brazil and Columbia is 9.6% and 13.6%, respectively. The overall share in Latin America and the Caribbean is 24.4%.

secondary education and, thus, have fewer chances to study later on, which limits their participation in the labor market. While we have several ways and methods of assessing the educational situation of Mexican women nowadays, we still lack knowledge about the origins and the development of the gender gap over time. Hence, to understand Mexican gender inequality today, we have to ask ourselves where it came from. When did the educational gender gap in Mexico open, and how did it evolve over time?

In this paper, I will try to answer this question by providing insights into the development of educational gender inequality during the period 1870 to 1940. This period is highly relevant for assessing the gender gap, because Mexico underwent major changes related to political, economic, and demographic aspects, to facing an autocratic regime for several decades and, afterwards, to living through a revolution and its aftermaths. Furthermore, it was the time during which the foundation of public primary schooling was laid and education was made accessible for an increasing share of the population (INEGI 1932, p. 189).

In the considered period, formal education was very heterogeneously scattered across Mexico and inaccessible to a large majority of its people (Vaughan 1990, p. 43, INEGI 1932, p. 189). Therefore, it is necessary and useful to implement an indicator that measures very basic levels of human capital. Basic numeracy, which captures the ability to deal with numbers, provides the necessary properties and allows the creation of a very large and representative database covering all of the Mexican states. The underlying concept is the so-called age-heaping behavior of individuals. In the case that people had to state their ages and did not know it exactly, they tended to round their ages off on multiples of five. This rounding pattern can be translated into an index such as the “ABCC” that represents the share of people able to state their precise age. Age-heaping-based indicators have been successfully used in a variety of studies so far (for example, Myers 1954; Duncan-Jones 1990; A’Hearn, Baten, and Crayen 2009; De Moor and Van Zanden 2010; Juif and Baten 2013). Using this indicator has the great advantage that the considered time period can be covered without gaps. Although school enrollment and literacy rates increased during this time, literacy data at the state level and by gender are only available with gaps, and not before the year 1895, in which the *Instituto Nacional de Estadística y Geografía* (INEGI, Engl. National Institute of Statistics and Geography) conducted the first comprehensive census (INEGI 2014a).[190]

[190] Literacy data are available for 1895, 1921, 1930, and 1940 (INEGI 2014b, 2014d, 2014e, 2014f).

The same is true for schooling data, which are not available before 1907 (Vaughan 1982, p. 41).

The underlying data analysis reveals an educational gender gap in the considered time span. Interestingly, for several Mexican states, gender inequality was low as long as the average level of education was low; it then increased with rising levels of education; and, finally, it decreased in times in which education reached a high level throughout society (see also Friesen et al. 2013). This pattern seems to follow a "U-shape" as described by Goldin (1995) with respect to female labor force participation. Whether this theory is applicable to the underlying data of basic education in Mexico will be subject of this study.

6.2 Theoretical Background, Literature Review, and the Situation in Mexico

6.2.1 Theoretical Background

By analyzing cross section data of more than 100 countries, Goldin (1995, pp. 62–67) shows that the work force participation of women is described by a U-shaped pattern over time.[191] The initial stage of the "U" is characterized by a relatively high share of female labor force participation concerning a society with low income levels and a large share of small-scale agricultural production (e.g., dairy, poultry or cotton). During this first period, women typically work – mostly unpaid – at home on family farms or are engaged in the home production of goods, which is still the case in several of Africa's regions. When income levels and economic development increase over time, female labor force participation decreases, which describes the downward sloping part of the U-shape. However, the "official" decline in women's labor force participation does not necessarily imply a decrease in women's working hours at home (Goldin 1995, p. 62). What occurs is simply a shift in women's tasks from participation in a (home) production process to tasks that are exclusively related to taking care of children and the family home. The decrease in home production is due to the expansion of factories that produce goods in larger numbers and far more efficiently than can be done in home production. Thus, it becomes more attractive to apply for paid work in industry or

[191] On this section, see also chapter two, section five of this thesis.

construction (Goldin 1995, p. 67; Manzel and Baten 2009, p. 38). But why do women not work in those blue-collar jobs?

According to Goldin (1995, p. 67), this second stage of the U-shape is accompanied by social stigma towards women in blue-collar jobs, preventing them from working in factories. Society expects (married) women to fulfill tasks at home, whereas manual labor in industry is not regarded as appropriate. A further reason might be that men receive higher wages in contrast to women, which reduces the necessity for women to apply for paid work (Friesen et al. 2013, p. 5). Consequently, women tend to stay at home to fulfill household duties and take care of the children (Goldin 1995, p. 62). Mammen and Paxson (2000, p. 144) argue that women might actively choose not to work in factories, for example, because the tasks, particularly at early stages of industrial development, are physically demanding and the work hours long, which makes it difficult to compete with men.

As economic development advances over time, the educational and labor market situation changes: in this third and last phase of development or the “U”, respectively, men are the first to benefit from an increasing supply of education. After a certain delay, women also manage to raise their education level. At the same time, the share of white-collar jobs increases, which – in contrast to blue-collar jobs – are not subject to social stigmata. Consequently, women gain the opportunity to work in the white-collar sector, which causes a rise in their labor force participation (Goldin 1995, pp. 67–68).

By analyzing cross-country data of 90 countries between 1970 and 1985, Mammen and Paxson (2000, pp. 146–149) verify Goldin’s finding of a U-shaped pattern related to labor force participation of women. Their results suggest that the poorest and wealthiest countries taken together represent a relatively high share of females in the labor force (above 50%), while the countries with a medium income (per capita earnings of approximately $2,500) have the lowest share of female participation, with approximately 35% (Mammen and Paxson 2000, pp. 148–149). Moreover, they explore the relationship between economic development, approximated by GDP, and the educational gender gap, measured by the differential between female and male years of schooling. At low income levels (up to approximately $800 per capita), women’s average schooling is low and almost static, while the gender gap opens continuosly. While women in the very low income countries (approximately $400 per capita) have one year of schooling less compared to men, the differential increases with rising income to approximately two years for countries with approximately $1000 per capita.

With increasing income, the gender gap narrows again (Mammen and Paxson 2000, pp. 146–147; see also Manzel and Baten 2009, pp. 39–40). The trend of the educational differential – with a decline at low income levels and a subsequent increase at higher levels – might indicate that the U-shape, originally derived from labor force participation by Goldin, is also applicable to an educational gender gap (see also Manzel and Baten 2009).

In this study, I will assess whether there is a U-shape related to basic education in Mexico. The assumption that a U-shape might not only exist in the context of labor force participation but also in educational inequality is based on (1) the above-described finding of a "U" in schooling differentials described by Mammen and Paxson (2000, p. 146) and (2) the increase of education when income rises at higher levels (Goldin 1995, p. 68; Mammen and Paxson 2000, p. 146). Because income in terms of GDP per capita is not available at the state-level for the considered time period in Mexico, I will implement basic education, approximated by the ABCC, as a predictor of an educational gender gap (see also Manzel and Baten 2009 and Friesen et al. 2013).

6.2.2 Literature Review and the Origin of Inequality in Mexico

In 1930, 24.5% of the Mexican females and 30.1% of the males older than six years reported having reading and writing skills, which translates into a gender equality index in literacy of -19.2.[192] While gender equality in literacy increased to -13.3 until 1940, primary schooling was far from widespread in this period: only approximately 8% of the population older than six years reported holding a primary school degree, with an equality index by gender of -17.6 (INEGI 2014f).[193] Hence, there existed substantial inequalities in education between the sexes in Mexico. But where did these extreme disadvantages for girls originate?

In her study on female schooling in India, Kingdon (1998, p. 1) suggests two causes for the lower education of girls. One is "labor market discrimination", which implies that the expected returns to female education (i.e., wages) are much lower compared to those for men. While this is partially caused by a generally lower level of education for women, the lower wages appear even in the presence of equal educational levels of both sexes. Consequently, women's motivation to be educated is lower

[192] The formula of the gender equality index in literacy is: gender equality index = (literacy females in % - literacy males in %) / (literacy males in %)*100 (Friesen et al. 2013, p. 3).
[193] Calculations are based on data of the 1940 census (INEGI 2014f).

(Kingdon 1998, pp. 37, 39–41). Additionally, if society prioritizes boys' education, only families with a certain educational background will invest in the education of their daughters. Thus, women's rate of return depends to a much higher extent on the educational level of their parents (Kingdon 1998, pp. 3, 25). The other reason identified by Kingdon is "parental discrimination" towards girls (Kingdon 1998, p. 2). Parental discrimination might have its roots in the beliefs and traditions of societies. Stromquist (1992, p. 56) emphasizes that the often-imposed traditional role of women causes particularly poorer social groups to perceive education for girls as not important for the "survival of the family". Clearly, formal education might not be important when the necessary knowledge for tasks such as child-rearing, household duties, and small-scale agricultural production can be transmitted through "oral-tradition" methods (Stromquist, 1992, p. 58).

A further potential constraint to girls' education is the distance to the school (Manzel and Baten 2009, p. 42). Schultz (1995, p. 32) outlines that the income elasticity of households is much greater for the enrollment of daughters than it is for sons. Thus, if the distance to school is large and parents have doubts about sending (all of) their children to school, or they simply have a limited budget, they can assume to receive larger returns from boys' later income compared to that of girls. Moreover, it is possible that girls are expected to help their parents in the household, such that the constraint of a long distance to school combined with a low family budget substantially decreases the probability of girls being educated.

Goldin (1995, p. 83) states that the US schooling system represents an exceptional case in the world concerning equality by gender in primary and secondary education throughout its history. She outlines that in the US, not only was equality achieved, but girls even went to secondary school for a longer period than boys and they received a larger number of high school diplomas. Given that the US is a neighboring country of Mexico, we might ask ourselves: how is it possible that the development of Mexico's educational system was so much worse, causing considerable gender inequality?

The diverging paths of Mexico and the US are even more astonishing when considering that Mexico's income per capita was very similar to that of the US around 1700. Thereafter, Mexico's GDP per capita decreased sharply and represented only 35% of the US income around 1900 (Sokoloff and Engerman 2000, pp. 218–219). These income disparities presumably led to differences in education, caused by missing investments. Mariscal and Sokoloff (2000, pp. 160–162) argue that, among other factors, unequal wealth distributions within Latin America may have led to delayed investments in public schooling compared to North America.

Within the Mexican society, there are both gender-related inequalities and a number of educational disparities (e.g., among states, social groups, and urban and rural areas) that are presumably related to gender inequality (Manzel and Baten 2009, p. 42). Greer (1969, pp. 467–469) detects significantly higher literacy rates among the northern states, which at the same time have a lower gender gap than the central (without the Federal District, *Distrito Federal*) and southern states between 1930 and 1960.[194] In the southern states, where a large share of Indigenous people lived, women had particularly low literacy rates. Additionally, while approximately 75% of the urban population was literate, not even half of the rural population reported having reading or writing skills (Greer 1969, p. 467). Urban centers were rather populated by non-Indigenous people, whereas the Indigenous groups lived predominantly in rural zones, where the institution of *peonaje* had often caused exploitation and social inequalities (Alba-Hernández 1976, p. 2).[195] This system had its origins in colonial times, when large landowners required a great portion of the workforce to work on their *haciendas* (country estates). The public authorities supported this system by forcing many Indigenous people to work on the *haciendas*, justifying their interference as being in the public interest (Zavala 1944, pp. 717–718). Because large landowners were interested in loyal workers who would not question the system or even start rebellions, it is probable that they were not interested in providing education for their servants, at least not voluntarily (Baten and Juif 2014).[196]

[194] Not all of the federal entities were states – some were territories or districts. However, all of the entities will be referred to as states for convenience.

[195] *Peonaje* stems from the Spanish word *peón* which means laborer (who works typically in the countryside). *Peonaje* can be translated by serfdom.

[196] Between 1867 and 1869, the Federal Government created laws that required owners of *haciendas* to build schools on their land in the Federal District and the territories (Baja California and Tepic, which today is Nayarit) (Vaughan 1982, p. 19).

6.2.3 Mexican Schools and Historical Background Between 1870 and 1940

To learn more about the mechanisms leading to educational inequality in Mexico, we have to consider historical and political circumstances influencing the schooling system and investment in education. Before 1930, the Mexican schooling system can be roughly divided into four phases (INEGI 1932, pp. 189–190). The first phase is characterized by Spanish domination during colonial times, during which education was a privilege for the higher classes of society, particularly European immigrants and their descendants. Indigenous people, on the other hand, had almost no access to formal education. In the second period, reaching from Mexico's independence from Spain in 1821 until the *Reforma*[197] in 1867, schooling became slightly more accessible, and a very small share of Indigenous people and *Mestizos*[198] received at least a certain degree of education. However, the third phase, running from 1867 to the year of constitution in 1917, was still marked by the idea of superiority of certain ethnicities over others. Although education was promoted by the government, it did not reach the middle class and the Indigenous population. In the fourth and last period, starting a few years after the revolution (1910) around 1917, the situation improved slightly, as the democratic movements made attempts to spread education among the remote areas (INEGI 1932, p. 189).

The political and economic situation in the period under study was greatly influenced by the presidency of Porfirio Díaz (1876–1911), who established a regime of "order and progress" that was supposed to create the basis for economic development (Buffington and French 2010, pp. 376, 386). In 1888, the Federal Government implemented a federal law of primary education, which was only applied to the Federal District as well as the territories but became the basis for the later following state legislation. The law determined the division into primary and secondary schooling and made enrollment obligatory for every child between 6 and 12 years of age who lived within a suitable distance to the next school. The schedule consisted of reading and writing, morality and civics, arithmetic and geometry, and a number of other subjects (Vaughan 1982, p. 21). The girls had to attend sewing classes and learned less mathematics compared to boys. From 1908 on, they also had to cultivate small gardens (Vaughan 1982, p. 31, Vaughan 1990, p. 37).

[197] An important reformatory movement that opposed the contemporary government (INEGI 1932, p. 189).
[198] Descendants of an Indigenous and a European parent.

The leading elite during the *Porfiriato*[199] generally supported public schooling, but there was some doubt about the use of certain skills for the working class of mainly Indigenous people and their offspring. Some politicians even doubted the ability of Indigenous people to be educated (Vaughan 1982, p. 23). Another problem was that the teaching language was Spanish, which many Indigenous people did not speak. Furthermore, because most of the Indigenous people lived in rural areas, they had to cover a long distance to school, which increased opportunity costs. This unfavorable development did not change before the year 1911, when the government adopted a law to build schools for the Indigenous population all over the country, particularly in rural areas (Vaughan 1982, p. 51).

After the Mexican Revolution in 1910, which ended President Díaz' presidency, the increasing modernization process in the country boosted the demand for broad-based education. In the following decades, the federal government promoted education particularly in rural areas and in the southern and central regions, which led to increasing rates of enrolled children (INEGI 1932; Vaughan 1982, p. 164).[200]

The economy benefitted from the Porfiriato, particularly during its initial phase. Díaz pushed forward the construction of rail networks, particularly from the north to the center of the country, fostering investment from the US (Vaughan 1982, p. 12). Buffington and French (2010, pp. 376–377, 393–396) outline that the region that profited the most from this development was the north, where a large part of the Mexican mines were located. Moreover, export-oriented industries producing coffee, sugar, or steel managed to attract capital, which favored modernization processes in technology and work relations. Generally, the northern economy was more diversified compared to the rest of the country. In the south, single-crop plantations were concentrated. The sectors located in the central region, such as the traditional grain and wheat production on *haciendas*, opposed innovation and kept producing their goods for the demand of the local population.

Consequently, the educational system evolved in a much better way in the prosperous north in contrast to the rest of Mexico (Vaughan 1990, p. 43). Because the average level of education was higher in the north, the gap between men and women is assumed to be smaller in general. The opposite is the case for rural areas, particularly in

[199] The period in which Porfirio Díaz was president is also called *Porfiriato*.
[200] Enrollment rates went up from approximately 27% in the year 1907 to approximately 46% in 1928 (Vaughan 1982, p. 164).

the central and southern regions of Mexico, where schools were scarcely scattered and the income elasticity for sending children to school was high, especially for daughters. However, we have to bear in mind that the gender gap also tends to be small at initial stages of education (Goldin 1995; Manzel and Baten 2009). Moreover, Bustillo (1993, p. 176) outlines that many Indigenous societies could have more "egalitarian attitudes" towards women. This may have been the case particularly in agrarian-oriented cultures, in which the traditional role of women – such as fulfilling exclusively household tasks – was not as strongly manifested. Women in those societies were engaged in agriculture and other productive fields to a similar or equal degree as men. Gill (1990, p. 38) concludes that the demand for education of societies that are mainly engaged in agricultural activities is relatively low, and consequently, educational levels remain equally low for both sexes.

6.3 Data Characteristics, Selectivity Issues, and Methodology

The comprehensive dataset compiled for this study includes more than 596,000 individuals between 23 and 62 years of age and thus provides a solid basis for the analysis. The database is composed of three different Mexican censuses, conducted in 1930, 1960, and 1970.[201] In all three censuses, people reported their name, age, sex, place of residence, whether they speak Spanish and/or an Indigenous language, their religion, and further personal information. The 1930 census was the fifth and by then largest census in Mexico, with the aim to survey and count all inhabitants (INEGI 1934, p. XV). The 1960 and 1970 censuses contain samples of 1.5% and 1% of the population, respectively (Rabell 2000, p. 142).[202] While the dataset includes information on all 32 federal entities in Mexico for the 1960 and 1970 censuses, the census of 1930 lacks data on the Federal District because the questionnaires were not filed (Familysearch 2014).[203]

For the implementation of the age-heaping technique, I consider only individuals within the age range between 23 and 62. On the one hand, we cannot be completely certain whether people under age 23 stated their ages by themselves or if someone else reported it for them. On the other hand, older people tend to exaggerate their age. For the analysis, age groups are arranged in ten-year steps from 23 to 32 years, 33 to 42 years, and so on. Because numerical skills are primarily gained during the first decade of a person's life, the age groups are arranged according to their birth decades, what allows analysis of the period between 1870 and 1940 (see also A'Hearn et al. 2009, p. 797; Manzel and Baten 2009, p. 46).

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[201] The data of the 1930 census stem from Familysearch (2014). At this point, I thank Loni Hensler (numeracy data) and Christoph Schulze (literacy data) who contributed some of the 1930 data. The data of the 1960 and 1970 censuses are available from the Integrated Public Use Micro Samples (IPUMS) (Minnesota Population Center 2014).

[202] While the 1960 census contains a sample of individuals, the 1970 census was based on households (Rabell 2000, p. 142).

[203] 28 of the federal entities were states and four were territories in 1930: the northern and southern districts of Baja California, the Federal District, and the territory of Quintana Roo (INEGI 1934, p. VII). The territories had their own governments and laws (INEGI 1928, p. 55).

As mentioned above, the indicators employed in this paper are based on the rounding behavior on multiples of five in the case that people did not know their exact age. One of these indicators is the Whipple index:[204]

$$(1)\ Wh = \frac{\sum(n_{25}+n_{30}+\cdots+n_{60})}{\frac{1}{5}\sum_{i=23}^{62} n_i} \times 100$$

The calculation of the Whipple index is based on the assumption that circa 20% (or one-fifth), of all ages end in a five or zero in the underlying age distribution. In the case that 20% of the individuals state a multiple of five, the Whipple takes on the value 100.
A'Hearn, Baten, and Crayen (2009, p. 788) suggested a transformation of the original Whipple index, the so-called "ABCC" index, for a more convenient interpretation:

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

The ABCC ranges between 0 and 100 and can be interpreted as the proportion of people able to state their ages exactly. The ABCC correlates with other measures of basic human capital, such as literacy and schooling, and thus provides a very good proxy for basic human capital (A'Hearn et al. 2009).

The index for the analysis of gender equality in numeracy (GEnum) is based on the Whipple index and has been successfully implemented by Manzel and Baten (2009) and Friesen, Baten, and Prayon (2013):

$$(3)\ GEnum = -\left(\frac{(Whf-Whm)}{Whm}\right) \times 100$$

The index (GEnum)[205] is calculated as the share of the difference between the Whipple of females (Whf) and the Whipple of males (Whm) in relation to the Whipple of males. This is subsequently multiplied by minus 100 such that the index takes on negative values in the case of a numeracy advantage of males. Accordingly, in the case that women have a higher numeracy compared to men, the index takes on positive values, which can be defined as relative "gender equality" in basic numeracy (Manzel and Baten 2009, p. 54; Friesen et al. 2013, p. 11).

[204] On the description and the use of the following indices see also Tollnek and Baten (2016) or chapter two, section two, and chapter three, section four, of this thesis as well as A'Hearn et al (2009, p. 788–789), Manzel and Baten (2009, p. 45–46), and Juif and Baten (2013, p. 231–233), for example.
[205] When referring to the Gender Equality Index in numeracy in the following, I will only use "GE" for convenience.

Figure 6.1: ABCC Trend in Mexico, 1870–1940

Note: Birth decades 1870-1900 are based on the 1930 census, birth decades 1900-1930 on the 1960 census, and birth decades 1910-1940 on the 1970 census. For variable descriptions and sources see section 6.9 (Data Sources) and Appendix B.6.

To rule out potential biases because of low numbers of observations, I include only those estimates in the analyses that contain a minimum of 50 observations for the common categories birth decade, gender, and federal entity.[206] Other biases might originate from a potential improvement of the populations' numeracy skills due to regular successive censuses. However, Figure 6.1 indicates that this was not the case in Mexico in the considered period: numeracy increases continuously over time, and there are no considerable leaps from one birth decade to another.[207] Another issue could be whether the settings of the different censuses varied strongly and thus, if the comparability of the information is given. In this case, there should also be large leaps from certain birth decades to others, which is not the case. Consequently, I include the data of all three censuses in the analyses, because a higher number of observations lead to more robust results. For the birth decades in which data of more than one census overlap, I calculated the arithmetic average of the respective index to further reduce potential biases.[208]

[206] Hence, each value of the gender equality index related to birth decades and federal entities is based on at least 50 females and 50 males and, hence, on 100 observations in total.
[207] The birth decades including more than one census are 1900 and 1910–1930. However, there are no leaps from these birth decades to the successive ones.
[208] I also calculated the weighted averages, which delivers very similar results.

Table 6.1: Summary Statistics of Aggregated Data,
All States and States With Low Indigenous Shares (<30%)

Variable	Obs.	Mean	Std. Dev.	Min	Max
Sample including all observations					
Gender Equality Index numeracy	245	-8.34	10.10	-37.38	27.59
ABCC	250	73.66	14.04	42.76	98.68
ABCC squared	250	5,622	2,055	1,828	9,738
North	250	0.38	0.49	0	1
Central	250	0.37	0.48	0	1
South	250	0.24	0.43	0	1
Indigenous population (share>30%)	250	0.18	0.38	0	1
Sample including states with low Indigenous population shares (<30%)					
Gender equality index numeracy	204	-8.20	9.69	-37.38	27.59
ABCC	205	75.25	13.80	43.96	98.68
ABCC squared	205	5,852	2,054	1,933	9,738
North	205	0.47	0.50	0	1
Central	205	0.41	0.49	0	1
South	205	0.12	0.32	0	1
Urban dummy (share>30%)	205	0.41	0.49	0	1
Population share state	153	3.23	2.53	0.06	8.94
Population density	153	36.39	133.00	0.10	1185.12
Share Catholics	121	97.90	2.31	88.32	99.94
Share no religion	121	0.75	1.32	0.00	8.08
Share Protestants	121	0.60	0.58	0.02	3.26

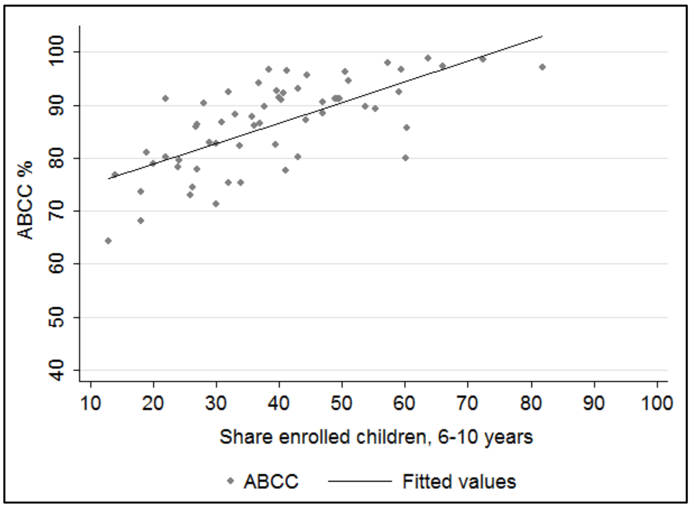
Note: The ABCC and GEnum data are aggregated by state and birth decades from 1870 to 1940. Sources: Mexican censuses 1895-1970 (see section 6.9 and Appendix B.6). Variable descriptions: Appendix B.6.

Table 6.1 contains summary statistics on the aggregated data and the independent variables included in the regressions. The ABCC, the squared ABCC, and the regional dummy variables are available for nearly every birth decade and entity.[209] The data related to the other independent variables stem from Mexican censuses between 1895 and 1940.[210] However, for different reasons, not all of the data were available for every birth decade and entity. For example, the former Territory of Quintana Roo was separated from the State of Yucatán, to which it belonged before, only in 1904 (INEGI 1918, p. 7). Consequently, most of the explanatory variables for the regression models concerning Quintana Roo are not available before 1910.[211] Because urbanization rates

[209] There are only a handful of missing values because of low numbers of observations (N<50) and because the Federal District was not available in the census of 1930 (see Appendix B.6).
[210] Because the INEGI conducted the first census in 1895, earlier data are not available. The values of 1895 and 1921 are assigned to the birth decades of 1890 and 1920, respectively. All of the censuses between 1895 and 1940 were conducted by the INEGI (2014a).
[211] The case of Baja California, which consists of the northern and southern districts (today: Baja California and Baja California Sur) is similar; some of the variables were only available for the whole of Baja California up to 1920. In the case that data on Quintana Roo and Baja California Sur were not separately available, the values of Yucatán and Baja California (norte) were also set to missing.

were not available for all of the time periods, I created a dummy variable that takes on the value of one for the states with an urban share above the Mexican average.[212] The implementation of a dummy variable has the advantage that it is applicable for the whole period between 1870 and 1940.[213]

Figure 6.2: Scatterplot of ABCC Values and Enrollment Rates



Note: The enrollment rates are from 1907 and 1930 and are lagged by approximately one decade (the share of 1907 is assigned to birth decade 1920, and the share of 1930 to birth decade 1940). Sources: See Table 6.1.

Data on enrollment rates of children were only available for two points in time, 1907 and 1930. Because this would dramatically reduce the observation numbers, they are not included in the regressions. Nevertheless, Figure 6.2 provides interesting insights into the relationship between enrollment and basic numeracy: enrollment rates and ABCC are highly correlated.[214] Consequently, we can assume that the ABCC is a good proxy for basic education in the considered period in Mexico.

6.4 The Development of Numeracy and Gender Inequality in Mexico

6.4.1 The Development of Mexican Numeracy

In the following, we will differentiate between three major regions in Mexico: north, center, and south (Pick and Butler 1994, p. 27).[215] The major regions consider

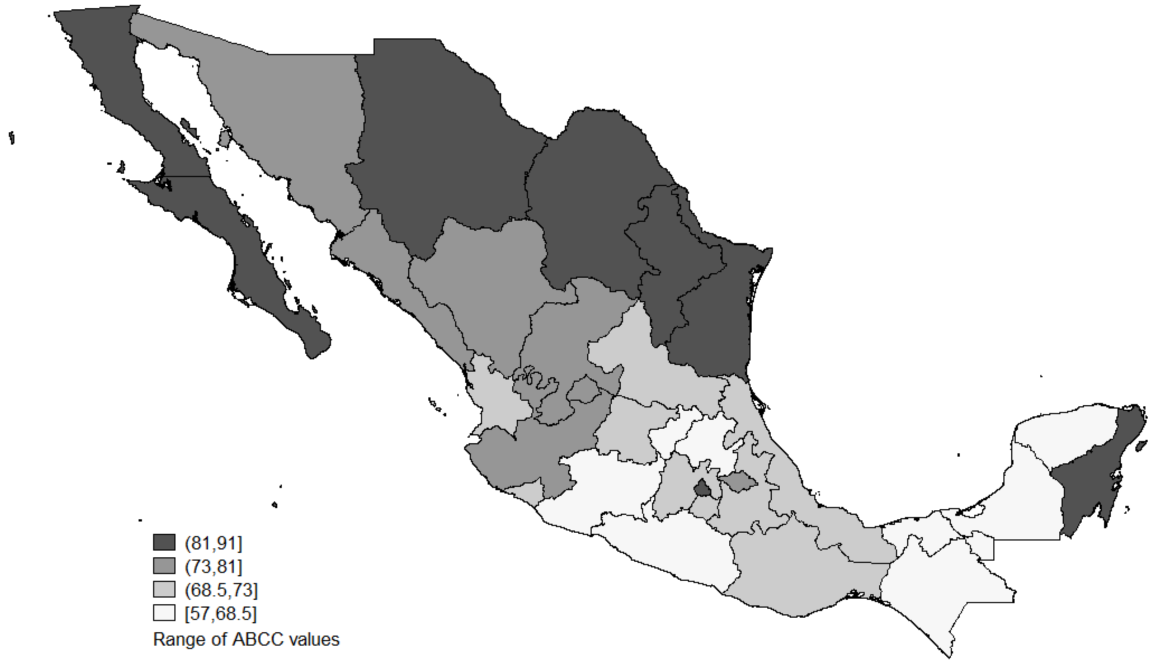
[212] Data on the urban share were available for 1910, 1921, 1930, and 1940 (INEGI 1932, 1954, 2014e). The average urban share in this period was 30% in Mexico (calculations are based on data of the four observed years). For more information on the urban dummy variable, see Appendix B.6.
[213] Additionally, it does not require a linear relationship with gender equality (that likely does not exist), as would the use of a variable with an urban share.
[214] Hence, including both measures in the regression model could lead to multicollinearity.
[215] On the division of the states into major and subregions, see also Appendix A.6.

similarities in the geographical and social aspects of neighboring states. Figure 6.3 illustrates the division of the 32 states into the major regions.

Figure 6.3: Division of Mexican Entities
Into 3 Major Regions: North, Center, and South

Source: Own illustration on basis of a map from Diva-Gis (2014). Data sources: See Table 6.1.

Figure 6.4: ABCC Values of Mexican States (Average Over Birth Decades 1870–1940)



Sources: See Figure 6.3.

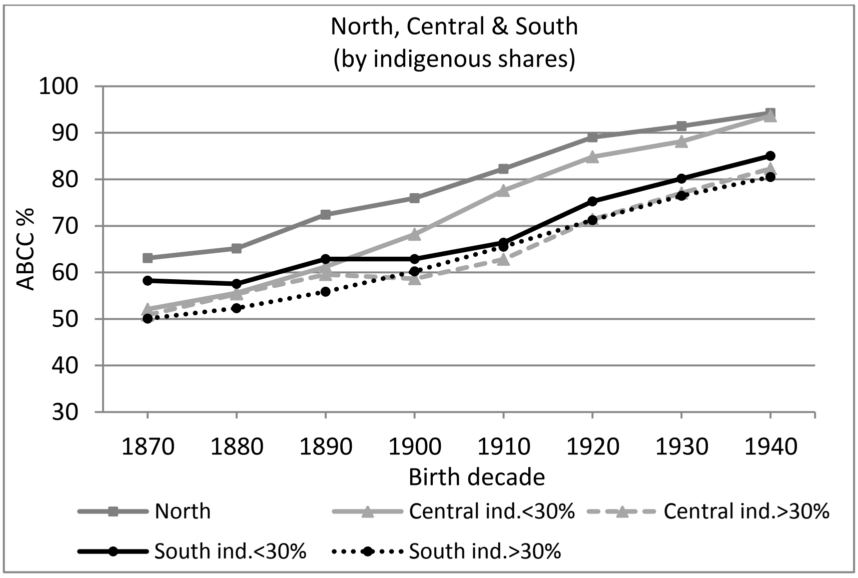
Figure 6.4 shows the average ABCC values by federal entity for Mexico over the birth decades. The results reflect the assumptions drawn from the historical and political background: the majority of the northern states, which benefitted from a good infrastructure, close relations to the US, and a better educational system compared to the rest of Mexico, represent the highest average ABCC values, ranging mainly between 81% and 91% of numeracy (on literacy, see Greer 1969, pp. 467–469). A few of the northern states represent values between approximately 73% and 81%, and only two states have values between approximately 68.5% and 73% of ABCC. The central Mexican states represent the middle and lower bounds of the distribution, with values ranging mainly between 57% and 73% of numeracy, which is in line with the economic and political circumstances in this region in the given time period. Of course, the Federal District of Mexico is the great exception: schooling was introduced there considerably earlier than in other districts or states, and the access to schools was much easier for children in the city. This might be a reason for the ABCC value of approximately 91%, representing the largest value in Mexico. The ABCC values of the southern states range between the middle and lower bounds of the distribution, with values mainly between 57% and 73%.[216] The southern states represented a fairly high share of Indigenous people who often lived in remote rural areas with a very low number of schools. Additionally, they faced exploitative systems (*peonaje*). Their low human capital values might be a result of this situation.

Because of the different and adverse circumstances Indigenous people were confronted with, I will subsequently differentiate between regions with high shares of Indigenous population (>30%) and regions with relatively low shares of Indigenous people (<30%).[217]

[216] There is one exception, Quintana Roo, in the very southeast, which had a value of approximately 82%. The value might be slightly upward biased because some of the early decades are missing.

[217] The Indigenous population is measured by the share of people speaking an Indigenous language. The percentage of Indigenous population in each entity is the arithmetic average calculated on the basis of five censuses for which the necessary data were available: 1895, 1900, 1910, 1930, and 1940 (INEGI 2014b, 2014c, 2014e, 2014f). The Mexican mean was 13.6% Indigenous population in the respective time period (see Appendix A.6). However, most of the states represented either fairly high or low shares of Indigenous population. Consequently, it is useful to choose an "extreme" benchmark value. The states above this benchmark value were clearly above the Mexican mean. In 2010, those states still contained a considerable share of Indigenous population (INEGI 2014g). The only exception was Puebla, with an average of 28%. Puebla had large declines in some of the time periods; therefore, this state was not included in the states with high Indigenous shares. However, robustness tests are conducted for which an Indigenous share below 25% serves as a benchmark to check potential changes when excluding Puebla from the low Indigenous sample. The robustness test yields very similar results (compare the results from Table 6.3 and Appendix A.6). For more information on Indigenous shares, see also Appendix B.6.

Figure 6.5: ABCC Trends in Northern, Central, and Southern Mexico, 1870–1940



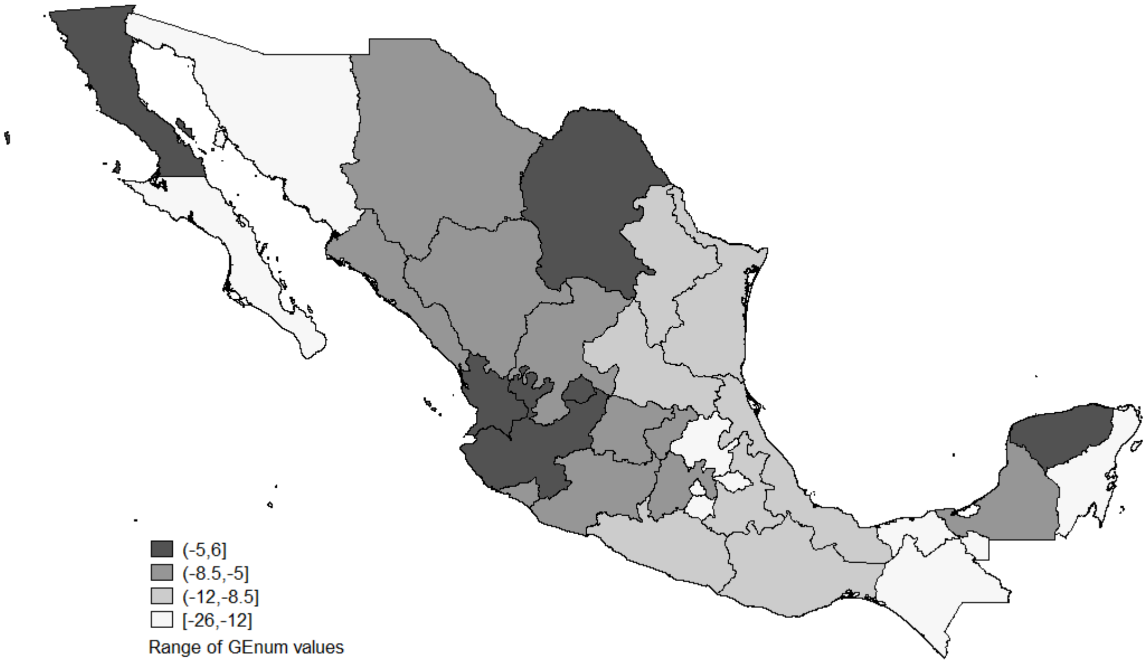
Note: Each ABCC observation (aggregated by state and birth decade) is based on a minimum of 50 observations. Trends are based on arithmetic averages. Sources: See Table 6.1.

Figure 6.5 illustrates the ABCC trends of the three major Mexican regions over the birth decades from 1870 to 1940.[218] The people living in the northern states, which did not include entities with high Indigenous shares, represented the highest ABCC level over the whole period, and they managed to increase their values substantially to approximately 94% of numeracy in 1940. In contrast, the southern states with a high share of Indigenous population had among the lowest values. They started with an ABCC value of approximately 50% and increased their level continuously to approximately 80% in 1940. To gain an idea about the relative value of this number, we draw a comparison to another Latin American country: the share of Uruguay's numerate population was approximately 79% in 1820 (Baten and Juif 2014). Hence, although the numeracy trend of the southern high Indigenous states includes a steep increase over time, there was still much room for improvement in this disadvantaged part of the country. The southern states with lower Indigenous shares took a similar path of development as the central high Indigenous state (Hidalgo), but on a slightly higher level, and they increased their value to approximately 85% in the last period. While the central states with lower Indigenous shares started at fairly low ABCC levels (approximately 51%), they managed to improve their numeracy level significantly to nearly 94% in 1940. On the contrary, numeracy in the central high Indigenous state (Hidalgo), did not exceed 81% in the last observed period.

[218] For ABCC trends by states, see Appendix A.6.

6.4.2 The Development of Mexican Gender Equality in Numeracy

Figure 6.6: Gender Equality Indexes in Numeracy of Mexican States (Average Over Birth Decades 1870–1940)



Sources: See Figure 6.3

Figure 6.6 shows the average gender equality values in numeracy for the Mexican states aggregated by the birth decades from 1870 to 1940. The values range between -26 and a positive value of approximately 6. In the vast majority of states, the gender equality indexes are negative, implying that women had an educational disadvantage compared to men. However, there are observable differences among the three major regions. Most of the northern states have medium to higher GE values ranging between -8.5 and 6.[219] Among the states with the highest GE values are Baja California (northern district) and Coahuila, which also have fairly high ABCC values. This implies that if the general level of basic education is higher in this region, the gender gap declines.

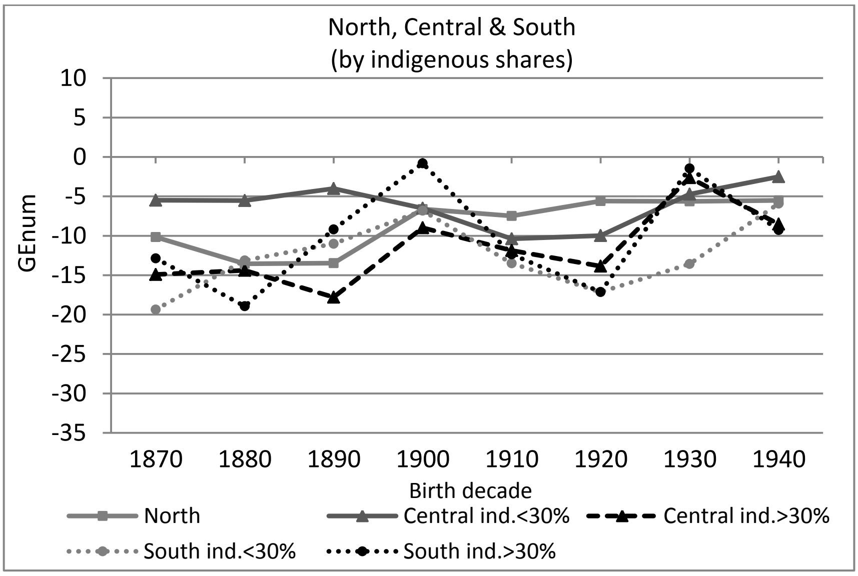
In central Mexico, the majority of the states have medium to higher gender equality values in numeracy, among them Jalisco (in the west), which also has a medium to higher level of numeracy. However, in contrast to the northern region, there are several states with a relatively high gender equality index on the one hand and rather low ABCC values on the other. An exceptional case in the central region is the Federal District, which has a fairly high ABCC value (approximately 91%) but a low GE index

[219] Baja California Sur and Sonora are exceptions, with fairly low GE values. A few of the northern states also have medium values between approximately -12 and -8.5.

(-12.6). This seems unexpected, because public schooling was promoted earlier in the capital compared to other entities of the country. However, it is most likely that boys were the first to benefit from schooling in early phases of increasing education, whereas girls followed after a certain delay (Goldin 1995, p. 67).

The gender equality values of the southern states are generally lower compared to the central and northern states. While some of the entities represent rather low ABCC values and medium to low gender inequality, others have low to medium average levels of numeracy and low to medium gender equality.

Figure 6.7: Trends of GEnum in Northern, Central, and Southern Mexico, 1870–1940



Note: Each GE observation (aggregated by state and birth decade) is based on a minimum of 50 males and 50 females (=100 total minimum observations). Sources: See Table 6.1.

Figure 6.7 illustrates the development of gender equality over time, divided by region and Indigenous shares. In 1870, the northern states started at a medium level of gender equality, which slightly decreased during the following decades. It reached its lowest value in 1890 but increased strongly thereafter. Between 1900 and 1940, the north maintained a relatively low gender inequality value, at approximately -6 GE points or more. In contrast, the low Indigenous central states began with relatively high values of gender equality, which decreased during the decades 1910 and 1920 but recovered again towards the end of the period (with a GE value of approximately -2.5). The southern entities with lower Indigenous shares had a fairly low initial gender equality value (of nearly -20), which they managed to improve until 1900. After a decline in 1920, gender equality increased again towards the 1940s. In some of the decades, equality levels remained lower in the south compared to the central and northern regions. The high Indigenous southern and central states took a different and less predictable path than the others: they improved significantly towards the middle of the period, followed by a sharp decline in equality values around the 1920s (with GE values of approximately -15). Towards the end of the period, gender equality in numeracy increased again.

It is possible that the general increase in gender equality (and numeracy) until 1900 originated from a longer period of peace and political stability under Díaz' presidency. After 1900, revolutionary tendencies started to destabilize the political environment, which might also have had a negative impact on gender equality. At the same time, the public schooling system expanded. Because male children were likely the first to benefit from an increasing number of schools, the gender gap widened for several decades (Goldin 1995). After 1920, when the revolution was completed and the political environment was stable again, the gender gap declined.[220]

To summarize, we can say that the gender equality values of the regions with either higher or lower ABCC values (with the exception of high Indigenous states) tend to be higher in general. In contrast, states with medium but increasing levels of basic numeracy also tend to have medium levels of gender equality.[221] Might this be a hint of a U-shape in basic education?

6.5 Regression Analysis: Testing the "U-shape" Hypothesis

To test whether educational gender equality follows a U-shaped pattern in Mexico, I conduct several panel regressions. The gender equality index is implemented as the dependent variable, including aggregated data on the level of the 32 federal entities and the birth decades from 1870 to 1940. The most important predictors for a potential U-shape are the ABCC and squared ABCC values: the linear values of the ABCC stand for initial levels of basic education, whereas the squared term represents levels of higher education in the long run. Initial levels of education are expected to influence gender equality in a negative way, while higher levels of education should have a positive effect. In doing so, I follow the model developed by Manzel and Baten (2009, pp. 56–62), who tested the U-shape for various countries in Latin America.

[220] However, we also have to consider potential effects of the data, such as lower numbers of observations for certain periods.
[221] For the high Indigenous states, the relationship is not as clear; they follow a slightly distinct pattern.

Table 6.2: Gender Equality Regressions in Numeracy, Birth Decades 1870–1940

Model:	**M1**	**M2**	**M3**	**M4**	**M5**	**M6**
Estimation method:	**RE**	**WLS**	**RE**	**WLS**	**RE**	**WLS**
Dep. var.:	**Gender Equality Index in numeracy**					
Included states	**All**		**Indigenous share<30%**		**Indigenous share>30%**	
ABCC	-0.364	-0.491	-1.077*	-1.497***	0.109	1.223
	(0.44)	(0.26)	(0.07)	(0.01)	(0.96)	(0.52)
ABCC squared	0.002	0.003	0.007*	0.009**	0.001	-0.006
	(0.62)	(0.40)	(0.09)	(0.02)	(0.93)	(0.70)
North	6.447*	4.886**				
	(0.09)	(0.01)				
Central	4.808	4.380***				
	(0.11)	(0.00)				
South	ref	ref				
State dummies included?	no	no	no	yes	no	no
Time dummies included?	yes	yes	yes	yes	no	yes
Constant	0.616	5.963	28.687	52.891***	-22.657	-57.462
	(0.97)	(0.68)	(0.16)	(0.01)	(0.72)	(0.28)
Observations	245	245	204	204	41	41
R-squared	0.119	0.125	0.109	0.384	0.0947	0.364
Chi²/F (p-value)	0.000	0.000	0.000	0.000	0.003	0.000
Number of states	32	-	26	-	6	-

Note: Robust p-values in parentheses. ***, **, * indicate significance on the 1%-, 5%- and 10%-level. Time dummy variables are birth decades. WLS = Weighted Least Squares. Weighting factor is the square root of the number of observations underlying each gender equality unit by state and birth decade. RE = random effects. RE standard errors are clustered by state. For RE models, the R-squared within and the p-value of the Chi² are reported; for WLS-models, the p-value of the F-test is reported. Variable descriptions and sources: See Table 6.1 and Appendix B.6.

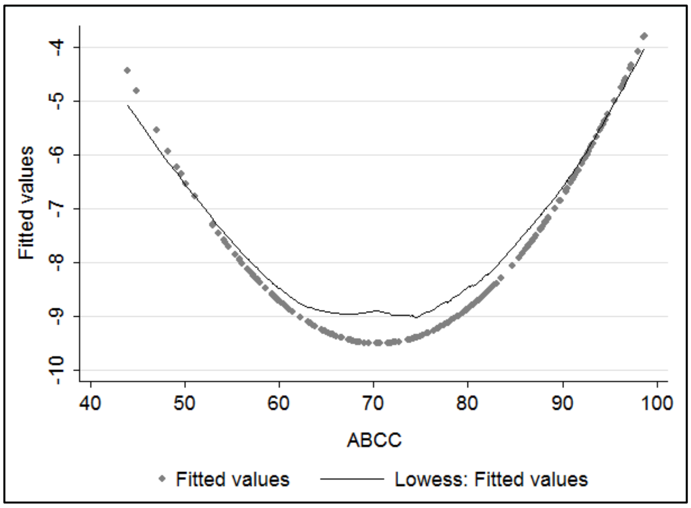
Table 6.2 includes Random Effects models (RE, models M1/M3/M5)[222], as indicated by the Hausman test. Furthermore, I conduct Weighted Least Squares regressions (WLS, models M2/M4/M6) because the data contain a number of outliers (see scatterplot in Appendix A.6).[223] Weighting the aggregated data by the square root of their observation numbers yields more reliable results because outliers receive a lower weight and thus have a smaller impact. Furthermore, because it is most likely that the high Indigenous states follow a different pattern of gender equality than other states, the sample is

[222] For all three samples (including all states, low Indigenous states, and high Indigenous states) the Hausman test delivers fairly high p-values (>0.6). Thus, the state-specific unobserved error term is not assumed to correlate with the exogenous variables, and the random effects estimator can be applied.
[223] The outliers are not due to data entry errors (this was checked), and they do not follow any systematic pattern. Therefore, they were not excluded from the analysis.

divided into states with low and high Indigenous shares. All of the models include the ABCC (as linear values) and the ABCC squared to test a potential U-shape. Additionally, the effects of states, regions, and birth decades are controlled in the different models. The regression models in Table 6.2, including the whole sample (M1/M2), do not yield significant effects in favor of a U-shape hypothesis, although the variables for the ABCC and ABCC squared values show the expected signs. Controlling for the major regions yields a positive and significant effect on gender equality for the north compared to the south, which serves as a reference category. The coefficient of the central region is also positively (and in the WLS-model significantly) correlated with gender equality. These results confirm the findings of the descriptives, which yielded an advantage for the northern and central regions over the south.

Models M3 and M4 in Table 6.2 show the results for the restricted sample, including only the states with lower Indigenous shares. While the coefficient of the ABCC is negative and significant, the squared ABCC has a positive and significant impact. These results might be a hint of a potential U-shape related to gender equality in numeracy for the particular case of the low Indigenous states. The underlying trend is illustrated in a scatterplot (Figure 6.8).

Figure 6.8: Lowess Scatterplot of the Fitted Values
of Gender Equality in Numeracy and ABCC (Only States With Indigenous Share<30%)



Note: The fitted values of the gender equality index are plotted against the ABCC values using the lowess scatterplot, "which does not impose a special functional form […]" (see, for example, Manzel and Baten 2009, p. 59). "Lowess" stands for "locally weighted scatterplot smoothing" (Manzel and Baten 2009, p. 59). The underlying regression is a WLS controlling for ABCC and squared ABCC values. Weighting factor is the square root of the number of observations underlying each gender equality unit by state and birth decade. For the trends of the complete sample and the sample including high Indigenous states, see Appendix A.6. Sources: See Table 6.1.

On the other hand, the results for states with high Indigenous shares are completely different (Table 6.2, models M5/M6). There is no specific significant pattern observable, and the RE- and WLS-models even deliver different signs for the important variables. Consequently, we can assume that a potential U-shape of educational gender equality is exclusively observable for the low Indigenous states.

To test whether a potential U-shape is observable for the low Indigenous states under the control of additional factors, I conduct several WLS regressions.[224] The following additional independent variables are included: the relative population share of each state, the population density, a dummy variable controlling for high urban shares, religious shares, and dummy variables controlling for the three major regions (see Table 6.1 for observation numbers).[225] The relative population share and the population density of a state, as well as the urban dummy variable, are expected to affect gender equality positively, as the number of schools is assumed to be higher in densely populated areas or in regions that contain a large share of the Mexican population. Including the relative population share of each state, in addition to population density, accounts for the possibility that a large state with a low average population density might still contain a high percentage of the whole Mexican population, which might lead to higher investments by the government.

Although the majority of the Mexican population was Catholic, an increasing number of people converted to the Protestant belief or stated themselves as not belonging to a religious group. With the extension of rail networks from the north to the center, Protestant missionaries gained a rising share of members, and they emphasized the formation of schools for girls (Bastian 1987, pp. 163–164). Because of its patriarchal structures, being Catholic might have a negative effect on gender equality, whereas Protestantism or "no religion" might have a positive impact.

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[224] The WLS-models yield more robust results than the RE-models for the data under study.
[225] The urban dummy variable equals one for a share larger than 30%. See Appendix B.6.

Table 6.3: Gender Equality Regressions in Numeracy, States With Low Indigenous Shares (<30%)

Weighted Least Squares	**M1a**	**M2a**	**M3a**	**M4a**	**M5a**	**M6a**	**M7a**	**M8a**
Dependent variable:	**Gender Equality Index in Numeracy (Indigenous Share<30%)**							
ABCC	-1.67**	-1.76**	-1.06	-1.70**	-1.98**	-1.85**	-1.12***	-1.50***
	(0.02)	(0.02)	(0.16)	(0.03)	(0.01)	(0.02)	(0.01)	(0.01)
ABCC squared	0.01**	0.01**	0.01	0.01**	0.01**	0.01**	0.01***	0.01**
	(0.02)	(0.01)	(0.19)	(0.04)	(0.01)	(0.03)	(0.00)	(0.02)
North		6.54**	7.74***		27.38***	27.25***		
		(0.01)	(0.01)		(0.00)	(0.00)		
Central		2.97	3.65*		19.06***	19.13***		
		(0.20)	(0.07)		(0.00)	(0.00)		
Population share by state	0.41	0.49*	0.50*	1.74*				
	(0.12)	(0.10)	(0.08)	(0.06)				
Population density (log)					3.36	3.16		
					(0.29)	(0.39)		
Urban dummy (share>30%)							8.57*	7.03
							(0.09)	(0.26)
Share Catholics (log)	6.67							
	(0.92)							
Share no religion (log)	-1.07							
	(0.12)							
Share Protestants (log)		-2.52***	-2.65***					
		(0.00)	(0.00)					
State dummies included?	no	no	no	yes	yes	yes	yes	yes
Time dummies included?	no	no	yes	yes	no	yes	no	yes
Constant	15.62	47.43*	21.76	59.32*	45.99	41.37	25.94*	45.86***
	(0.96)	(0.09)	(0.43)	(0.08)	(0.15)	(0.24)	(0.09)	(0.01)

Table 6.3: Gender Equality Regressions in Numeracy, States with Low Indigenous Shares (<30%) – Continued

Weighted Least Squares	**M1a**	**M2a**	**M3a**	**M4a**	**M5a**	**M6a**	**M7a**	**M8a**
Dependent variable:	**Gender Equality Index in Numeracy (Indigenous Share<30%)**							
R-squared	0.082	0.172	0.264	0.400	0.359	0.392	0.330	0.384
F-Test (p-value)	0.024	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Observations	117	121	121	152	152	152	204	204

Note: Robust p-values in parentheses. ***, **, * indicate significance on the 1%-, 5%- and 10%-level. Reference category for region is south. ABCC and GEnum values include birth decades 1870-1940. For the included time periods of the control variables see Appendix B.6. Variable descriptions and sources: See Table 6.1 and Appendix B.6.

Table 6.3 reports the results for the models with additional control variables in the low Indigenous states. While the coefficient of the relative population share by state is positive and significant in three out of four models (models M1a–4a), the coefficient for population density is positive but insignificant (models M5a–6a). The urban dummy variable seems also to have a positive and moderately significant effect on gender equality (model M7a).[226] The positive trend of the variables for the relative population share and the urban dummy variable reflect the assumption that people living in areas with a high population share or urban areas represent a smaller educational gender gap. This is most likely due to better access to schools because of a better infrastructure and higher educational investments by the government (Vaughan 1990, p. 43). It is also possible that informal education of numerical skills acquired in families or communities operates more efficiently in densely populated areas through spill-over effects (see, for example, Manzel and Baten 2009, p. 52).

The Catholic and "no religion" coefficients do not seem to influence gender equality in numeracy significantly (Table 6.3, model M1a).[227] However, the coefficient for the Protestant share seems to have a negative significant influence on gender equality, which is in contrast to what we would have expected (models M2a–3a). When interpreting this result, we have to think of the circumstances that persons converting to the Protestant belief in this period might have faced. As the vast majority of Mexicans were Catholic, it is possible that, being the minority, Protestants were at the margin of the Mexican society and did not have good access to schools.[228]

The results for testing the three major regions confirm the findings from the regression model including the whole sample. The coefficients of the northern and central regions have a positive and mainly significant effect on gender equality in relation to the south (models M2a–3a, M5a–6a). Moreover, the ABCC and squared ABCC show the relevant signs for a potential U-shape at the 5% significance level in seven out of eight models (all models in Table 6.3, except M3a). Consequently, when interpreting the underlying results carefully, we can say that there are hints of a U-shape

[226] When controlling for birth decades, the urban coefficient remains positive, but it is no longer significant (model M8a).
[227] When controlling for religious shares, the number of observations is lower than for the other models because data were only available for four time periods and included a number of missing values. Therefore, the controls for the states were not included because they did not yield robust results (the F-test was not calculated).
[228] Moreover, the data quality could play a role in this case because the religious shares partially vary considerably from one decade to another, which is also critically mentioned in the summary of the 1930 census (INEGI 1932, p. 59).

in educational gender equality, exclusively in the states with low shares of Indigenous population.[229]

Generally, one could argue that the direction of causality may not only work from the level of basic education towards gender equality but also the other way around. To test whether educational gender equality affects basic numeracy, an instrumental variable approach would be necessary. However, this is not possible with the data under consideration because there are no data available for a valid instrument that correlates with numeracy but not with gender equality.[230]

6.6 Juchitán: A Case of Matriarchy?

As stated above, the states with high Indigenous shares follow a different pattern of educational gender equality development than the other states.[231] Therefore, I proceed with a case study focusing on a small town in the state of Oaxaca: Juchitán de Zaragoza.[232] Oaxaca's Indigenous population share ranks among the highest in Mexico, with an average of approximately 50% in the considered period. Around 1930, Juchitán was one of the larger locations in Oaxaca (and remains so today), with more than 14,000 inhabitants, including a very high share of Indigenous people (INEGI 2014e, 2014g). The case of Juchitán is particularly interesting because women seem to play an important role in the community life, such that several scholars claim the existence of a matriarchal society, among them Holzer (1996) and Bennholdt-Thomsen (1994).

In the respective period, Juchitán was a market economy operating on a subsistence basis. To this day, the market is an important center in the town. As Bennholdt-Thomsen (1994, pp. 38–47) states, the market is exclusively in the hands of women who sell their homemade products there. Consequently, women need to acquire a set of skills enabling them to produce the goods they will sell on the market and to trade them efficiently. Because they sell the products and deal with the money they

[229] Including all of the Mexican entities yields the necessary signs for a U-shape, but not at a significant level (see scatterplot Appendix A.6). A robustness check was conducted, including the states with a share of Indigenous population lower than 25% (because of the state of Puebla, which had average Indigenous shares of approximately 28%). The robustness test yields very similar results (see Appendix A.6).

[230] Manzel and Baten (2009, pp. 61–62) applied an instrumental variable approach by implementing a dummy variable for former European colonies in Latin America, which might affect numeracy directly, but not gender equality. They were able to show that the direction of causality runs from the level of education towards gender equality.

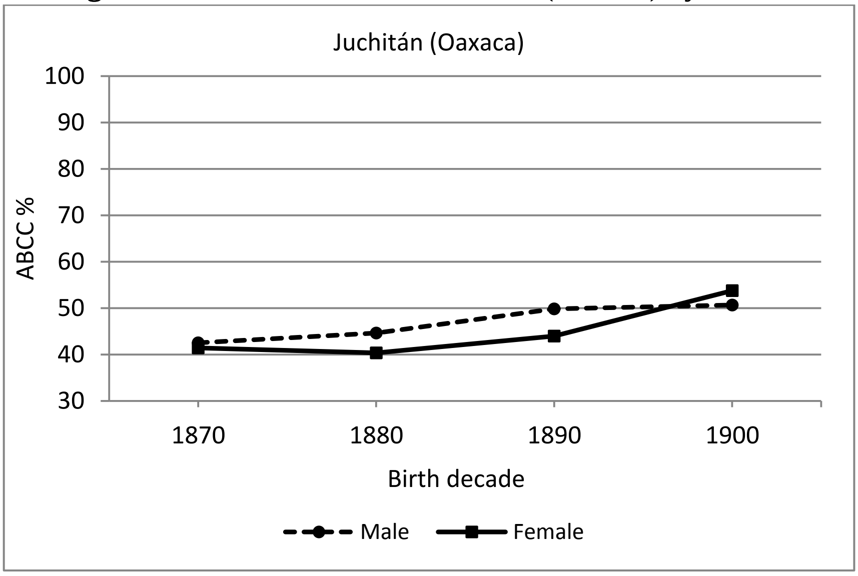
[231] When including control variables other than the proxies for education, the number of observations decreases below the statistical minimum of 30 observations in most of the models.

[232] In the following, it is only referred to as Juchitán.

earned, the women are assumed to control a substantial part of the family's finances (Chiñas 2002, pp. 33–34, 39).

In summary, there are spheres in everyday life in Juchitán in which the women seem to play a decisive role. Boserup (2007) outlines that the important role of women in trading and selling on markets does not seem to be the case in all of the developing regions. In most countries of Hindu and Arab influence, for example, trading on markets is exclusively in male hands. Although a higher share of women are active on markets as traders and customers in Latin America, the numbers are moderate in Mexico, where women in trade and commerce represent approximately 29% of the total labor force in this sector (Boserup 2007, p. 77). Thus, the *exclusive* role of women on the market in Juchitán seems to be exceptional even when compared to the rest of Mexico. This might be perceived as a type of matriarchy, particularly in a society such as Mexico, in which patriarchal structures predominate. This idea is in line with Bustillo (1993, p. 176), who argues that in Indigenous societies the typical gender roles are not as manifested as in other societies.

Figure 6.9: ABCC Trend in Juchitán (Oaxaca) by Gender



Source: See Table 6.1.

To explore the possibility of a matriarchal society in Juchitán, I focus on basic human capital approximated by numeracy and compare it among men and women on an individual level by using the data of the 1930 census. Figure 6.9 illustrates the numeracy trends for men and women in Juchitán from 1870 to 1900. The trend shows that basic numeracy in Juchitán is fairly low towards the end of the 19th century, with ABCC values clearly below 60% for both sexes. While the ABCC of males and females start at the same level of approximately 42%, male numeracy increases more strongly than female numeracy. However, the gap seems moderate, and the women manage to improve their numeracy towards the end of the period, such that they surpass the men in the 1900s.

To test whether the difference in numeracy by gender in Juchitán is significant, I conduct several logit regression models on an individual level, including all observations from the 1930 census. The variable "numerate" is employed as the dependent variable, taking a value of one if people reported an exact age and zero if the age is rounded to a multiple of five. Furthermore, I include dummy variables controlling for female, living in Juchitán, and whether the place of residence belonged to a state with a high Indigenous share (>30%). In the next step, interaction effects are introduced between the dummy variables (1) "female" and "high Indigenous state" and (2) "female" and "Juchitán". In doing so, I am able to test whether (1) females from high Indigenous states generally have a significantly different numeracy compared to men from those states, and whether (2) the women from Juchitán have a significantly different numeracy from the men in this location.[233] If the Juchitec people live in a matriarchal society – or a society in which women play at least an important role – the basic human capital skills of women should be higher, or at least not significantly lower, compared to the level of men.

[233] The interaction dummy variables are always interpreted with respect to the reference category.

Table 6.4: Logit Regressions of Individual Numeracy, Birth Decades 1870–1900

Logit regression Marginal effects	**L1**	**L2**	**L3**	**L4**	**L5**	**L6**
Dependent var.:	**Numerate**					
Included observations:	**All**			**Urban places** (5,000-20,000 inhabitants)		
Female	-4.06***			-4.33***		
	(0.00)			(0.00)		
State high indig. share	-13.35***			-9.94***		
	(0.00)			(0.00)		
Juchitán	-19.91***			-14.71***		
	(0.00)			(0.00)		
Female high indig. state		-5.71***			-6.55***	
		(0.00)			(0.00)	
Female low indig. state		8.56***			31.25***	
		(0.00)			(0.00)	
Male high indig. state		ref			ref	
Male low indig. state		12.31***			34.64***	
		(0.00)			(0.00)	
Female Juchitán			-1.63			-1.63
			(0.52)			(0.52)
Female not Juchitán			17.39***			21.66***
			(0.00)			(0.00)
Male Juchitán			ref			ref
Male not Juchitán			21.31***			25.76***
			(0.00)			(0.00)
State dummies included?	yes	yes	yes	yes	yes	yes
Time dummies included?	yes	yes	yes	yes	yes	yes
Pseudo R-squared	0.020	0.020	0.020	0.022	0.022	0.022
Chi² (p-val.)	0.000	0.000	0.000	0.000	0.000	0.000
Observations	252,873	252,873	252,873	107,930	107,930	107,930

Note: Robust p-values in parentheses. ***, **, * indicate significance on the 1%-, 5%- and 10%-level. “ref” indicates the reference category. Time dummy variables are birth decades. Marginal effects are reported. Coefficients are multiplied by 125 to correct for the missing 20% of the population that reported an age ending on 0 or 5 correctly (see Appendix B.6, chapter three of this thesis). “High” indig. share stands for states with more than 30% Indigenous population; “low” indig. stands for states with less than 30%. Sources: See Table 6.1 and Appendix B.6.

Model L1 in Table 6.4 shows that females have, in general, a significantly lower chance of being numerate than males, although the size of the coefficient (-4) is not as large as we might have expected.[234] Moreover, people from states with high Indigenous shares

[234] Clearly, 20% of the population may have correctly reported ages ending in zero or five. To account for

have a significantly lower chance of being numerate than individuals from states with lower shares; the same holds for people living in Juchitán. Model L2 shows that women from high Indigenous states have a significantly lower chance of being able to count than their male counterparts, whereas females from low Indigenous states perform clearly better than males from high Indigenous states. In contrast, model L3 indicates that Juchitec women did not have a significantly lower chance of being numerate than the males in this town. The coefficient is negative but represents a very high p-value and is of minor size (-1.6). Given the significant disadvantage that women from high Indigenous states generally had, this result is somewhat surprising. Because Juchitán has a large share of Indigenous population, we might have expected to observe a similar tendency as for the other high Indigenous entities. To test the robustness of the previous results, the models are additionally performed including only individuals living in urban centers with between 5,000 and 20,000 inhabitants (models L4–L6).[235] The coefficients change in size, but their sign and significance remain the same.

In summary, the educational difference between women and men in Juchitán does not seem to be substantial and is clearly not significant compared to the disadvantage that women from high Indigenous states have in general compared to men from those states in the sample under study (with a lower chance of being numerate of approximately -6 and -7 percentage points, Table 6.4, models L2/L5). But might this be a hint of a matriarchal society?

First, the findings might point in the direction of Bustillo (1993), who argues that the gender roles that in the Western world are typically perceived as "traditional" – taking care of the family home and raising children – may not be as manifested among Indigenous groups. It is possible, that this is why we do not observe a large gender gap in the data. However, a relatively even distribution of tasks in terms of agricultural or home production of goods might primarily occur in societies (still) characterized by an agricultural subsistence economy. Therefore, it is possible that the demand or the necessity for (formal) education is generally lower than in societies with, for example,

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this bias, I proceed as follows: the regression coefficients reflect the case in which the dependent variable's conditions are met ("numerate"=1), and thus, the person reported an exact age. However, this outcome represents only 80% of the precise age statements, as 20% of those who reported a multiple of five ("numerate"=0) were also doing so correctly. By increasing the outcome coefficients by 20%, I account for the downward bias of correct age statements ending in a zero or five. This is achieved by multiplying the coefficients by 1.25 (and by 100 to obtain percentages) (see also Juif and Baten 2013, p. 233 and Appendix B.3, chapter three of this thesis).

[235] This is done to guarantee the comparability of the data with Juchitán, which at the time had approximately 14,000 inhabitants.

growing industrial and service sectors (Gill 1990, pp. 12–14). Consequently, the low gender inequality might result from a generally very low level of education. Therefore, the hypothesis of a matriarchy cannot be confirmed based on the underlying database, but neither can it be rejected.

6.7 Conclusion

Using a new and comprehensive dataset, this paper provides insights into the development of numerical skills and educational gender equality among the 32 Mexican states from the end of the 19th century to the middle of the 20th century. While women generally had lower numerical skills compared to men in all three major regions – north, central and south – the gender gap was clearly smaller in the northern part of the country (see also Greer 1969). First, this development was most likely caused by political decisions favoring industry and promoting the construction of rail networks from the US border in the north to the center of the country (Vaughan 1982, p. 12). Second, the northern states benefitted substantially from trade with the US. The good infrastructure and investments by the government led to a much faster improvement of the schooling system in these regions (Vaughan 1990, p. 43). The strong increase and permanently higher levels of numeracy in the north compared to the other regions might be the result of this development.

Moreover, the findings suggest that Indigenous people were disadvantaged in terms of education. Rigid structures originating from the European conquest, such as *peonaje* and the fact that Indigenous people often lived in remote areas that were of little interest to the ruling classes, left the Indigenous population behind in an educational system that was mainly created for the Spanish speaking elite (INEGI 1932, p. 189).

Furthermore, the regression results indicate that there might be a U-shaped development of gender equality in relation to general numeracy when limiting the sample to the states with low Indigenous shares. The U-hypothesis of educational gender equality was derived from Goldin's U-shaped hypothesis related to female labor market participation (Goldin 1995). Speaking in terms of educational gender equality, this means that at initial levels of basic education, male children are the first to benefit because the income elasticity of households is much greater for female children (Schultz 1995, p. 32). Only when education arrives at a certain level do women also benefit from increasing education, which reduces the gender gap (Goldin 1995; Manzel and Baten 2009).

Because the development of gender equality seems to follow another pattern in states with high Indigenous shares, the small town of Juchitán, considered by some scholars as a matriarchal society, served as a case study. The analysis revealed that women in states with high Indigenous shares generally had lower numeracy values than men (from high and low Indigenous states). In contrast, the women in Juchitán did not have a disadvantage in numeracy compared to the men there, but neither did they have a clear advantage. Therefore, the hypothesis of a matriarchy can neither be confirmed nor rejected based on the underlying data.

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Appendix A.6: Additional Tables and Figures

Table A.6.1: Observation Numbers and Average Values of ABCC and GEnum and Percentages of Indigenous Population by Region, Subregion, and State

Region	Subregion	State	Indig. pop. (%)	No. of obs. ABCC	ABCC (mean)	No. of obs. GEnum	GEnum (mean)
North	North	Chihuahua	6.9	17,466	83.0	17,466	-7.5
North	North	Coahuila	0.1	18,356	81.6	18,356	-4.3
North	North	Durango	0.8	12,256	77.8	12,256	-7.7
North	North	San Luis Potosí	10.2	19,328	70.8	19,328	-10.0
North	North	Zacatecas	0.0	14,176	76.3	14,176	-7.4
North	Northeast	Nuevo León	0.0	20,897	82.5	20,897	-11.2
North	Northeast	Tamaulipas	0.0	14,815	82.4	14,815	-10.2
North	Northwest	Baja California	0.4	10,362	89.7	10,362	-14.5
North	Northwest	Baja Calif. Sur	0.1	3,043	85.8	2,822	6.2
North	Northwest	Nayarit	3.7	10,743	72.4	10,743	2.2
North	Northwest	Sinaloa	1.8	12,066	74.3	12,066	-8.1
North	Northwest	Sonora	9.9	16,484	80.3	16,484	-11.6
Central	Central	Distrito Federal	1.8	49,623	90.5	49,623	-12.6
Central	Central	Hidalgo	30.7	19,259	64.7	19,259	-11.6
Central	Central	México	17.9	29,501	73.3	29,501	-7.0
Central	Central	Morelos	13.6	11,152	73.1	11,152	-11.9
Central	Central	Puebla	28.4	36,418	71.4	36,418	-8.6
Central	Central	Querétaro	8.2	8,226	65.7	8,226	-6.2
Central	Central	Tlaxcala	16.9	8,417	73.8	8,417	-12.1
Central	West	Aguascalientes	0.0	4,544	78.1	4,544	-2.6
Central	West	Colima	0.0	6,815	68.8	6,776	-6.3
Central	West	Guanajuato	0.9	34,187	69.2	34,187	-5.5
Central	West	Jalisco	0.3	43,200	75.1	43,200	-3.0
Central	West	Michoacán	5.8	36,393	64.8	36,393	-4.9
South	Gulf	Tabasco	8.7	8,831	66.8	8,831	-25.9
South	Gulf	Veracruz	19.2	43,173	71.2	43,173	-11.3
South	Pacific South	Chiapas	33.2	21,359	57.2	21,359	-13.2
South	Pacific South	Guerrero	21.7	23,256	63.7	23,256	-10.9
South	Pacific South	Oaxaca	53.1	24,490	69.0	24,490	-11.1
South	Southeast	Campeche	40.9	6,158	63.7	6,115	-5.3
South	Southeast	Quintana Roo	32.5	528	81.9	128	-11.7
South	Southeast	Yucatán	68.9	10,627	67.7	10,627	-3.8
Total			13.9	596,149	74.0	595,446	-8.4

Note: Major regions are based on Pick and Butler (1994, p. 27). The dummy variable on Indigenous shares (>30%) is based on averages over all available points in time (see Appendix B.6). Puebla is a "border" case with an average of 28%. It is not included in high Indigenous states because numbers varied considerably from on point in time to the other. A robustness check is conducted, including Puebla in high Indigenous states (hence, excluding it from the main regression in Table 6.3). The robustness test yields very similar results as the main regression (see Table 6.3 and Appendix A.6). The observation numbers of ABCC and GEnum refer to individual observations underlying the aggregated data. ABCC and GEnum values are arithmetic averages over the birth decades 1870-1940. The observation number of Quintana Roo is lower compared to the other regions; however, the relative population share of this state is similar as in the data. Only non-missing values are included in the regression analysis. Sources: See Table 6.1.

Table A.6.2: Robustness Check: Gender Equality Regressions Including Only States With Low Indigenous Shares (<25%)

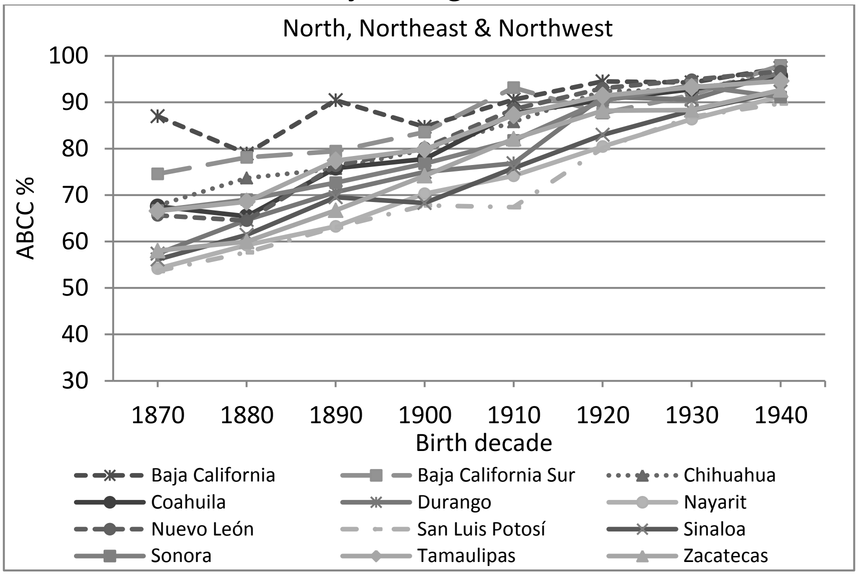
Weighted Least Squares	**M1a**	**M2a**	**M3a**	**M4a**	**M5a**	**M6a**	**M7a**	**M8a**
Dependent variable:	**Gender Equality Index in Numeracy (Indigenous Share<25%)**							
ABCC	-1.66**	-1.73**	-1.12	-1.81**	-1.97**	-1.94**	-1.12***	-1.57***
	(0.03)	(0.02)	(0.15)	(0.02)	(0.01)	(0.01)	(0.01)	(0.01)
ABCC squared	0.01**	0.01**	0.01	0.01**	0.01**	0.01**	0.01***	0.01**
	(0.02)	(0.02)	(0.19)	(0.03)	(0.01)	(0.02)	(0.00)	(0.02)
North		6.74***	7.85***		27.50***	27.16***		
		(0.01)	(0.01)		(0.00)	(0.00)		
Central		3.07	3.76*		19.06***	18.00**		
		(0.19)	(0.07)		(0.00)	(0.01)		
Population share by state	0.47*	0.51*	0.53*	1.98**				
	(0.09)	(0.09)	(0.07)	(0.05)				
Population density (log)					3.59	3.90		
					(0.26)	(0.31)		
Urban dummy (share>30%)							8.62*	9.70**
							(0.09)	(0.03)
Share Catholics (log)	-1.55							
	(0.98)							
Share no religion (log)	-1.37*							
	(0.06)							
Share Protestants (log)		-2.55***	-2.65***					
		(0.00)	(0.00)					
State dummies included?	no	no	no	yes	yes	yes	yes	yes
Time dummies included?	no	no	yes	yes	no	yes	no	yes
Constant	51.83	46.82	31.54	59.61*	45.74	40.73	26.36*	45.57**
	(0.87)	(0.10)	(0.26)	(0.06)	(0.15)	(0.21)	(0.09)	(0.02)

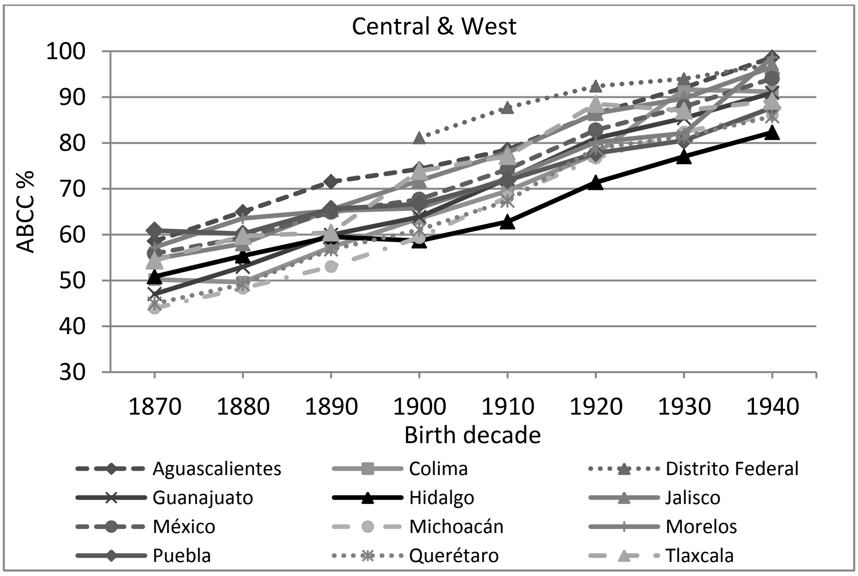
Table A.6.2: Robustness Check: Gender Equality Regressions Including only States with Low Indigenous Shares (<25%) – Continued

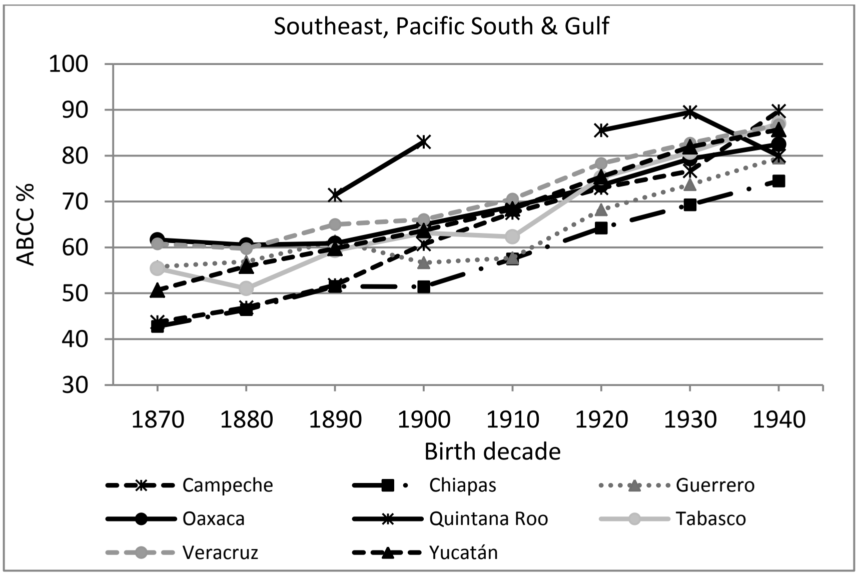
Weighted Least Squares	**M1a**	**M2a**	**M3a**	**M4a**	**M5a**	**M6a**	**M7a**	**M8a**
Dependent variable:	**Gender Equality Index in Numeracy (Indigenous Share<25%)**							
R-squared	0.095	0.178	0.269	0.406	0.362	0.397	0.331	0.385
F-Test (p-value)	0.006	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Observations	112	116	116	146	146	146	196	196

Note: Robust p-values in parentheses. ***, **, * indicate significance on the 1%-, 5%- and 10%-level. Reference category for region is south. Sources: See Table 6.1.

Figures A.6.1.1–A.6.1.3: ABCC Trends of the Mexican States by Subregions and States, 1870–1940

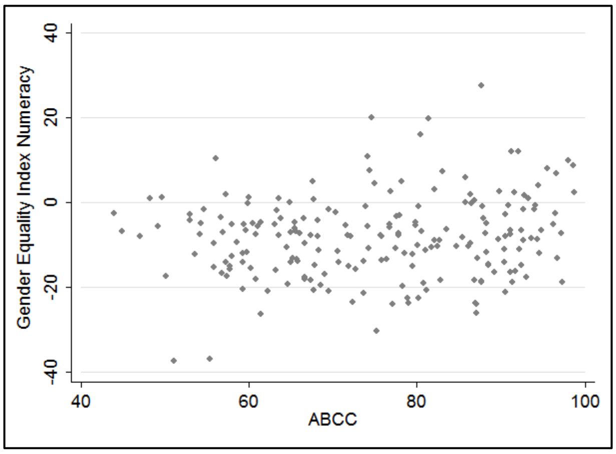






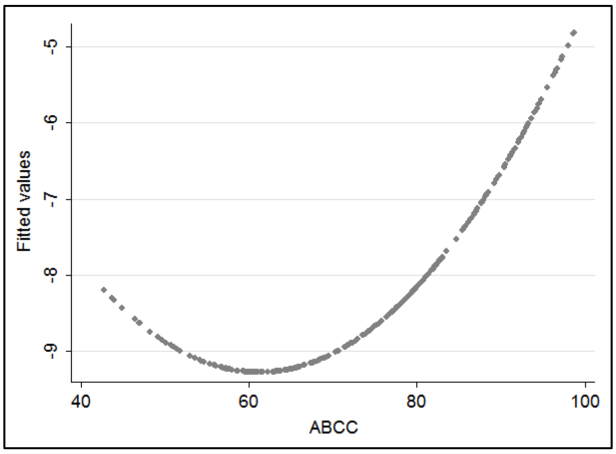
Note: Trends are based on arithmetic averages. Sources: See Table 6.1.

Figure A.6.2: Scatterplot of GEnum and ABCC (States With Indigenous Shares<30%)



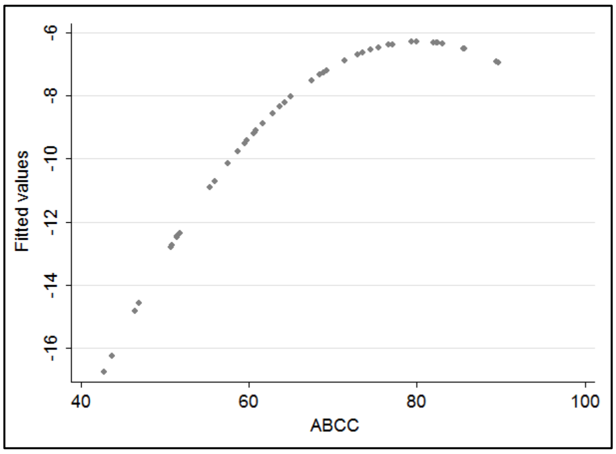
Note: Based on a WLS regression of GEnum on ABCC and ABCC squared. Sources: See Table 6.1.

Figure A.6.3: Scatterplot of Fitted Values and ABCC (All States)



Note: Based on a WLS regression of GEnum on ABCC and ABCC squared including all observations. Sources: See Table 6.1.

Figure A.6.4: Scatterplot of Fitted Values and ABCC (States With Indigenous Share>30%)



Note: Based on a WLS regression of GEnum on ABCC and ABCC squared including only states with Indigenous shares >30%. Sources: See Table 6.1.

References I (Appendix A.6)

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Appendix B.6: Data Sources and Variable Descriptions

Gender Equality Index in Numeracy (GEnum):

Calculated from the Whipple of males and females. It expresses the relative gender equality in numeracy. The minimum number of observations by category (state, birth decade, sex) is 50, so that each data point by state and birth decade consists of at least 50 men and 50 women. The considered birth decades run from 1870 to 1940. Included are the 32 federal entities of Mexico. Data of the Federal District were not available for the 1930 census (birth decades 1870–1890) because the original documents were not filmed (Familysearch 2014). For Baja California Sur, the number of observations was smaller than the required miminum in the birth decade of 1910. For Quintana Roo, the number of observations was sufficiently high in the birth decade of 1940.

Data Sources: Mexico Census 1930, FamilySearch (2014); Mexico Census 1960 and 1970, Minnesota Population Center (IPUMS) (2014).

ABCC/Squared ABCC:

Linear transformation of the Whipple index, ranging between 0 and 100. The ABCC expresses the share of people that are able to report their ages exactly. The minimum number of observations by category (state, birth decade) is 50. On Data of the Federal District, see gender equality index numeracy above. For Quintana Roo, the number of observations was smaller than the required miminum in three of the birth decades (1870, 1880, and 1910).

Data Sources: Mexico Census 1930, FamilySearch (2014); Mexico Census 1960 and 1970, Minnesota Population Center (IPUMS) (2014).

Share Indigenous Population:

The share of Indigenous population by state and census year (1895, 1900, 1910, 1930, and 1940, available from tables that are downloadable from the INEGI-webpage: *Tabulados Básicos*) serves as the basis for the calculation of the Indigenous dummy. The values from 1895 are assigned to the birth decade of 1890. The Indigenous dummy takes the value of one, if the Indigenous share is larger than 30% (on arithmetic average over birth decade by state), and zero otherwise. The dummy is also assigned to the birth decades of 1870 and 1880 because it is assumed that there was not a major change in the share of Indigenous population between the decades from 1870 to 1880 compared to the average of the birth decades between 1890 and 1940. Moreover, the shares between 1890 and 1940 were relatively stable. The dummy takes the value of one for Campeche, Chiapas, Hidalgo, Oaxaca, Quintana Roo, and Yucatán (see also Appendix A.6).

Data Sources: INEGI (2014b, 2014c, 2014e, 2014f). Note: The *Tabulados Básicos* from 1910 (INEGI 2014c) contain the values for 1900-1910.

Population Share State:

Stands for the relative population share living in the respective state. Values were available for 1895, 1900, 1910, 1921, 1930, and 1940 from the *Tabulados Básicos*. The values of 1895 and 1921 are assigned to the birth decades of 1890 and 1920, respectively.

Data Sources: INEGI (2014d, 2014f). Note: The *Tabulados Básicos* from 1921 (INEGI 2014d) contain the values for 1895-1921; the *Tabulados Básicos* from 1940 (INEGI 2014f) contain the values for 1930-1940.

(Log) Population Density:

The population density expresses the number of inhabitants per square kilometer in each state. Values were available for 1895, 1900, 1910, 1921, 1930, and 1940 from the *Tabulados Básicos*. The values from 1895 and 1921 are assigned to the birth decades of 1890 and 1920, respectively. The shares are logarithmized to approximate a normal distribution.

Data Sources: INEGI (2014d, 2014e, 2014f). Note: The *Tabulados Básicos* from 1921 (INEGI 2014d) contain the values for 1895-1921.

Urban Share:

The share of population living in urban places with at least 2,500 inhabitants by state serves as the basis for the calculation of the urban dummy. It takes the value of one, if the urban share is larger than 30% (calculated on basis of arithmetic averages over birth decade by state), and zero otherwise. Values were available for 1910, 1921, 1930, and 1940 from the *Tabulados Básicos*. The values from 1921 are assigned to the birth decade of 1920. The benchmark value for urban places in 1910 is higher than in the other years (4,000) and thus urbanization might be slightly downward biased. Nevertheless, the values from 1910 are still included because the urban dummy is constructed as the arithmetic average of all four given points in time, which reduces a potential bias. The dummy is also assigned to the birth decades from 1870 to 1900.Of course, the urban share changed to a certain degree during this time period. However, while the urbanization rate within a state might have changed over time, it remained relatively similar across states (which is important because the focus is mainly on differences between states). Because a large part of the urbanization process took place at the beginning of the 20th century (Unikel et al. 1976), potential variation across states is captured in the underlying observed periods. Moreover, the states that are counted as above the average of 30% over the time period from 1910 to 1940, already had an urban share of approximately 20% in 1910 (although urbanization was underestimated in this period). Hence, the most important changes between states are included in the observed data. The mean urbanization share in Mexico in this period was 30.5%. Consequently, we can assume that the urban dummy is a good proxy for the whole time period. The dummy takes the value of one for Aguascalientes, Baja California, Baja California Sur, Campeche, Chihuahua, Coahuila, Colima, Distrito Federal, Guanajuato, Jalisco, Nuevo León, Tamaulipas, and Yucatán.

Data Sources: INEGI (1932, 1954, 2014e). Note: The *Anuario de 1930* (INEGI 1932) contains the values for 1910. The *Tabulados Básicos* from 1930 (INEGI 2014e) contain the values for 1921-1930. The *Anuario Estadístico 1953* contains the values for 1940.

(Log) Share Catholics, Protestants, No Religion:

Expresses the proportion of people belonging to one of the two Christian religious groups (Catholic, Protestant) or who stated themselves as not belonging to any religious group by state. Values were available for 1895, 1900, 1910, 1921, and 1940 available from the *Tabulados Básicos*. The values of 1895 and 1921 are assigned to the birth decades of 1890 and 1920, respectively. The shares are logarithmized to achieve an approximate normal distribution.

Data Sources: INEGI (1932, 2014b, 2014c, 2014f). Note: The *Anuario de 1930* (INEGI 1932) contains the values for 1921.

Enrollment rates:

Share of school aged children (6–10 years) who are enrolled in school related to all children within the respective age range. Numbers were available for 1907 and 1930 available from the *Tabulados Básicos* and Vaughan (1982, p. 158). Enrollment rates are postponed by approximately one decade because schooling affects the average educational level after a certain time lag. Thus, the data from 1907 are assigned to the birth decade 1920, and the data from 1930 to the birth decade 1940 (see also Friesen et al. 2013).

Data Sources: INEGI (2014e), Vaughan (1982, p. 158).

References I (Appendix B.6)

Friesen, Julia, Baten, Joerg and Prayon, Valeria (2013). “Women Count: Gender (In-)Equalities in the Human Capital Development in Asia 1900–60.” Working Paper, University of Tuebingen.

Unikel, Luis, Ruiz Chiapetto, Crescencio and Garza Villareal, Gustavo (1976). *El Desarrollo Urbano de México: Diagnóstico e Implicaciones Futuras*. México, D.F.: El Colegio de México.

Vaughan, Mary Kay (1982). *The State, Education, and Social Class in Mexico, 1880–1928*. DeKalb, Illinois: Northern Illinois University Press.

References II (Data sources, Appendix B.6)

INEGI (1932): *Anuario de 1930*. 2a Época, No. 16. México, D.F.: Instituto Nacional de Estadística y Geografía.

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INEGI (2014d). *Censo de Población y Vivienda 1921. Tabulados Básicos*. México, D.F.: Instituto Nacional de Estadística y Geografía, Dirección General de Estadística, at: http://www3.inegi.org.mx/sistemas/tabuladosbasicos/default.aspx?c=16768&s=est (accessed 16 December 2014).

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7 Summary and Outlook

In this doctoral thesis, I assessed determinants of wellbeing and inequality among social groups, regions, and gender for a variety of countries in Europe and Latin America from the early modern period to the mid-19th century. I used indicators of human capital, fertility, and net nutrition as determinants of wellbeing to analyze several large and new datasets.

The comparison of human capital among socioeconomic groups in the early modern period, approximated by occupation, showed that farmers had favorable numeracy values. This result is somewhat unexpected, given that Unified Growth Theory accounts the origin of sustained economic growth primarily to the advancements in urban centers. In a further study, we were able to show that farmers had a large number of children compared to other groups of the early modern period. The social hierarchy of early modern society was rigid and upward mobility a very rare option. Because the farmers had a large number of children who could not all remain in this group, they had to face downward mobility into lower socioeconomic groups. The farmers' children were most likely provided with favorable human capital values because of their access to high-protein nutrition and the transmission of human capital skills from their parents. Consequently, it is likely that the descendants of farmers spread their favorable skills among other groups which promoted human capital increase in early modern Europe. Because the role of farming groups in the process of human capital formation has been an undervalued issue so far, these two papers close the gap that had opened by the focus on highly skilled groups in urban centers.

In chapter five, I assessed a potential "rivalry" for resources among siblings in early 19th-century Bavaria. Therefore, I used the heights of conscripts as a measure of net nutritional status and health. Given the harsh living conditions of the Malthusian period, one might assume that a large number of siblings lead to lower heights in the children of these families. However, this is not the case; on the contrary, the findings suggest that the higher the number of children in a family is, the taller are its children. Surprisingly, this pattern is particularly pronounced among brothers for whom we might have expected that a potential rivalry would be strong. In seeking the cause of these results, we can link the results of this chapter to the previous one in which we found that highly skilled groups (and the farmers) had a large number of children. Consequently, it seems most likely that those groups, which tended to have higher incomes, were able to provide the necessary means and nutrition to their children such that all of their numerous descendants were able to grow relatively tall. I confirmed this assumption in the analysis.

In the sixth chapter of this doctoral thesis, I analyzed educational gender inequality in Mexico which is one of the largest economies in Latin America. Therefore, I compiled and analyzed a large dataset containing more than half a million observations. The results of the numeracy indicator showed that the gender gap of the entities with a low share of Indigenous population indeed followed a "U-shape" which had been adopted from the "U-shape" of labor force participation of women. The "U" in education means that in times of increasing industrialization, which is accompanied by a rising demand (and supply) for formal education, men are the first to benefit. During this phase, the gender gap opens and leaves women behind. It is only after a certain delay that women manage to increase their human capital. By analyzing individual data comparing women and men of Indigenous and non-Indigenous background, I conclude that the large group of Indigenous population is still fairly disadvantaged in most of the Mexican regions.

In this doctoral thesis, I provide valuable insights into the development of long-term human capital formation, fertility patterns, and inequality among socioeconomic groups, regions, and between women and men.

However, there are several questions that need to be answered by future research: what was the role of women in the process of human capital formation in the early modern period? What about female occupations and their impact on human capital and fertility? During the 19th and beginning 20th centuries, women gained slight but increasing opportunities of educating themselves and presumably managed to increase their decision power within families. It is possible that women's role in the process of declining fertility rates and a quantity-quality trade-off was larger than generally perceived. These are important questions that further research might partially address on the basis of the large datasets compiled in this doctorate.