Essays on Human Capital Development in Latin America and Spain

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Contents

Symbols and Abbreviations

ABCC	Transformed Whipple Index that yields an estimate of the share of individuals who report a non-rounded age
CELADE	Latin American and Caribbean Demographic Center (Spanish: Centro Latinoamerikano de Demografía)
CEPAL	Economic Comission for Latin America and the Caribbean; ECLAC (Spanish: Comisión Económica para América Latina y el Caribe)
D	Dummy Variable
DFG	German Science Foundation (German: Deutsche Forschungsgemeinschaft)
ED	Euclidean Distance
ESF	European Science Foundation
FE	Fixed Effects
GE	Gender equality
IEGE	Instituto Brasileiro de Geografia e Estadística
IPUMS	Integrated Public Use Microdata Series
IV	Instrumental Variable
LA	Latin America
LA6	Argentina, Brazil, Chile, Colombia, Mexico, and Venezuela
LDC	Least Developed Countries

LOWESS	Locally Weighted Scatterplot Smoothing
LSDV	Least Squares Dummy Variable
OLS	Ordinary Least Squares
RE	Random Effects
UN	United Nations
UNESCO	United Nations Educational, Scientific, and Cultural Organization
US	United States
Wh	Whipple index
Whf	Whipple index of the female population
Whm	Whipple index of the male population

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1 Introduction

1.1 Human Capital and Economic Growth

One of the controversial questions in economics and economic history is the influence of human capital on economic growth. While some studies find a positive impact of education on economic growth, like the studies by Barro (1997), Barro and Lee (1993), or Krueger and Lindahl (2001) others find no effect. Pritchett (1999) asks 'Where has all the education gone' when faced with the results of his empirical investigation. Increases in education are found to have had no effect on economic growth in developing countries since the 1960s. In a cross-section study, Benhabib and Spiegel (1994) similarly find that no influence of changes in average schooling on changes in output per worker.

Was increasing education only an effect rather than a source of economic growth? Galor and Weil (2000) and Galor (2005) attempt to explain the growth regimes previously defined in economic history within one single theory, the 'Unified Growth Theory'. It thus explains the development from Malthusian stagnation to sustained economic growth and assigns human capital development an important role within this process. During the Malthusian epoch, the rate of technological progress and population grwoth were insignificant. Increases in income were counterbalanced by population growth, which led to low but stable income per capita rates. Differences between countries hardly existed and the output per capita moved between 0 and 0.14 percent. In the post-Malthusian regime, this theory assigns human capital still a limited role. The pace of technological progress increased (though it remained on low levels in comparison with today's growth rates) and the industrialization process started. For developed regions like Europe or the Western Offshots this transition took place at the beginning of the 19^{th} century, whereas for Asia and Latin America, it only took place towards the end of the 19^{th} century.

It was during this stage of development when differences in living standards between countries began to emerge. The increasing income and higher demand for educated workers led to slightly increasing human capital.

In the next phase, however, the contribution of human capital to the growth process increased. During the sustained growth regime, the technological progress started to require more human capital and the demographic transition, in Galor's opinion also a consequence of human capital growth, led to larger investments in human capital. The modified age structure increases the size of labor force relative to the whole population. Moreover, the lower population growth enables income per capita and the stock of physical capital per capita to grow substantially.

Thus, according to the Unified Growth Theory, human capital has an important role in enhancing economic development. But, in general, its contribution to economic growth is controversially discussed among economists. Using case study evidence for single countries, various scholars approach this question, but had not come to a conclusion yet. Human capital estimates for a longer time span could help to ahed more light on this question. Regardless of whether human capital has an effect on economic growth, education is also important for socioeconomic outcomes. Education reduces fertility (Glewwe 1991, Thomas 1999) which might be especially important in developing countries. Besides, a better education for mothers is found to improve the health status of their children significantly (Alderman et al. 2001, Glewwe and Desai 1999). Progress in education and equality in education is also able to relieve social tensions.

Common human capital estimates are mainly the average years of schooling, enrollment rates (Barro 1991, Mankiw, Romer, and Weil 1990), literacy (Romer 1989), and educational attainment (barro and Lee 2001). These variables are available for the second half of the 20th century for the industrial countries. However, for developing countries or earlier time periods education data is scarce. Nevertheless, especially the contribution of education to economic growth in earlier time periods might be very interesting. Common education approximations in economic history besides the already mentioned, are signature ability, book production (Buringh and van Zanden 2006, Baten and van Zanden 2007) and, very recently, numeracy. Signature ability and numeracy are, unlike the average years of schooling, also able to capture qualitative aspects of education.

Signature ability is calculated from signatures under marriage registers, judicial records, wills, or army rolls and attempts to approximate literacy. Most literacy studies for the period between 1600 and 1850 use this indicator (Kaestle 1985). However, the relationship between literacy and signature ability is not clear-cut. According to Schofield (1968), signature ability rates overestimate writing ability, while they underestimate the percentage of people being able to read at a very basic level. Generally, signature ability may be a better proxy for literacy in regions where reading and writing was taught at the same time. But in regions where providers of education, for instance the church, taught only reading skills, the relationship between signature ability and literacy will be weaker. It thus is a rough indicator for the minimum number of literates (Kaestle 1985). The term literates is defined broadly here; while some who signed the marriage registers probably hardly knew how to read and write, others were more sophisticated.

A maybe even more important skill is the capability of counting and calculating, which is important for every form of market transactions (De Moor and van Zanden 2008) and diffused historically earlier than literacy (A'Hearn, Baten, and Crayen 2009). Numerical abilities can be approximated by age awareness calculated from age statements.People with lower numeracy are more prone to state a rounded age than people with higher educational levels. While numeracy might not be learned exclusively via school education, it is closely correlated with other indicators of education, for instance literacy or schooling (A'Hearn, Baten, and Crayen 2009).

1.2 Aim of the Thesis

This dissertation scrutinizes the development of human capital in the Iberian world. Although both, Latin America and Spain, have been the focus of new recent studies, empirical evidence is still scarce, especially for the Latin American and Caribbean region. Empirical studies rely exclusively on single country studies for only limited time periods. Broad trends of long-term human capital development in the New World and in Spain therefore have remained unclear until now. The thesis therefore aims at filling in the void. It presents human capital estimates in the long run for the Iberian world. Human capital development can be traced back to the 17^{th} century for a number of Latin American countries. For this purpose it uses two indicators of human capital, education and health. Education is approximated by basic numerical abilities of the population. Health is approximated by adult height, which gives information on the nutritional status and the disease environment during childhood. Health and education are closely related. An improvement in the health status of the population influences, via a higher life expectancy, the economic growth of a country positively. Investments in education increase because individuals will live and work longer. Better education thus leads to higher productivity and higher economic growth (Weil 2007).

The thesis adds to the existing literature on human capital development in various ways: It presents human capital estimates approximated by numerical abilities of the population and the biological standard of living for the Iberian world since the 17^{th} century. For such an early period, no systematic attempt has been made yet to trace human capital development in Latin America. The human capital development in this thesis is essential for understanding socioeconomic development in the past and can give valuable insights in improving the conditions for future growth processes.

Even if the question whether human capital is essential for economic growth is controversial, progress in human capital development per se might be an important aim to achieve. A first step to eliminate social and regional human capital inequalities is to outline its development and to determine the factors that contribute to these inequalities. They constitute a potential source of conflicts within the scope of a vanishing distinction between countries. Studies on this topic may therefore help to promote the understanding of different interests. Moreover, understanding the evolution of human capital in the past can help to determine future policy directions in the field of education policy and may therefore lead to more stable social development in these countries.

For construction of the data base, a number of different primary sources have been used. These were mainly population counts or censuses, but also prison records were drawn on. Part of these sources was collected in Latin America and Spain. It is the first study that makes use of such an extensive data base to compare human capital development within one cultural region. Comparing countries within one cultural region has the advantage that effects of cultural differences can be ruled out, although still some peculiarities of the countries can be taken in account.

1.3 Outline of the Thesis

The thesis comprises six chapters of which four papers are intended for publication. Therefore, within the chapters, I refer to the respective chapter as paper. One of the papers has already been published; the remaining three are under revision in refereed journals. To put the methodology applied in the papers in a broader context, chapter 2 gives a detailed overview of the age heaping methodology applied to approximate numerical abilities in chapters 3 to 5. The last chapter makes uses the biological standard of living to trace regional and social inequality in 19th century Peru. Chapter 2 reviews the existing literature on the age heaping technique. It presents the underlying concepts and ideas more thoroughly than it is possible in the methodology section of the papers. Besides methodological aspects, it also gives an overview of the already existing literature on age heaping in economic history. As this new research line is developing, the literature is not comprehensive yet.

Chapters 3 and 4 examine general tendencies in the development of human capital in the Iberian world. Chapter 5 and 6 focus on more specific questions concerning its development in particular countries, namely Spain and Peru. These studies allow an in depth-study of the economic and social circumstances influencing human capital.

Chapter 3 traces the long-term development of human capital in Latin America since the 17th century to answer the question whether Latin America was really behind in terms of human capital as it is often stated. To answer this question it draws on an extensive database compiled from census material. It is the first study that traces Latin American human capital development over such a long period. Data for Argentina, Brazil, Uruguay, Mexico, Colombia, and Peru shows that the view of the Latin American region as a backward region in terms of economic indicators is far too limited and that the region had good possibilities to catch up in terms of basic education with today's developed countries.

After having outlined roughly the long-term development in numerical abilities in six important Latin American countries, chapter 4 focuses on one important feature in Latin American educational development. While income and education inequality measures in Latin America for the second half of the 20th century reveal one of the highest inequalities worldwide, gender inequality in education is at a very low level in international comparison. For the first half of the 20th century and earlier, however, quantitative information did not exist until now. Klasen (1999) argues that gender inequality has a negative impact on economic development through two channels. The direct effect acts via the quality of human capital, and an indirect effect takes place through the channels of investment and fertility which are associated with more human capital formation. He also states that the effect of female education on economic grwoth may be underestimated due to the fact that women's activities are often not recorded in the national accounts. Applying the age heaping methodology separately for both sexes allows studying the development of gender inequality in 28 Latin American and Caribbean countries for the birth decades 1880 to 1940. The great number of countries studied in this paper clearly cannot scrutinize education histories in all of these countries, but is intended to give a broad overview of general patterns in gender inequality in education.

Progress in education of a country can be hampered by internal problems like civil wars, a drop in education expenditure, or economic crises.Chapter 5 studies the impact of subsistence crises on human capital. It examines whether numeracy development was affected negatively by two subsistence crises in the 1840s and the 1850s. For this purpose, the paper studies the development of numeracy in 19th century Spain and uses grain prices as a proxy variable for the severity of the subsistence crises in the Spanish provinces. The results indicate that regions suffering nutritional shortfalls tend to stagnate in terms of progress in numeracy levels. Even a short crises period of two years may lead to stagnation in the progress of education.

The next chapter applies another indicator of human capital to evaluate regional and social disparities in 19th century Peru. It analyzes in detail one source of age statements already used in Chapter 3 of the thesis, a data set of prisoners in Peru. Besides information on the age of these prisoners, information on human capital in the form of the biological standard of living is available. Their stature sheds light on their living conditions because adult heights result mainly from nutritional status and disease environment during childhood. The chapter studies the development of the biological standard of living of the middle and lower strata of the Peruvian society during the guano boom and traces regional and social disparities during this time.

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2 On the Concept of Age Heaping and Numeracy

2.1 Introduction

A well-known story among demographers is a story of a grey-haired Peruvian women who is completely sure to be either 25 or 69 years old (Ewbank 1981, p. 1). Her age consciousness is obviously questionable. However, most people that are uncertain about their age often choose rounded numbers like 60, 65, or 70. These or other age misstatements cause severe problems to demographers when they try to estimate life expectancy tables, mortality figures, or fertility rates. However, this lack of the concept of numbers, ages, or dates is used in this thesis to approximate numerical abilities. This chapter shows how the concept of age misreporting developed from a problem to demographers to a proxy of education. It also deals with further factors that have to be taken into account when using age misreporting as a proxy variable for education. Moreover, it shows that age misreporting does not necessarily mean that a person is not able to state the own age exactly and how to evaluate these results. A person may be perfectly sure about his or her age, but chooses to report another age due to cultural, economic, or social reasons. Therefore, the limitations of the methodology have to be evaluated carefully. For this purpose, this chapter reviews the already existing literature by demographers and economic historians on the phenomenon of age heaping in detail. Firstly, section 2 explains the concept of age heaping and the methodology to quantify the extent of heaping. The following section reviews the reasons for age misstatements. A description of patterns of heaping and the measurement of age heaping follows in section 4. Section 5 presents different methods to quantify age heaping. Section 6 is dedicated to the limitations of the age heaping technique. The following section reviews evidence of the applications of age heaping in economic history, and section 8 concludes.

2.2 Concepts and Methodology

The phenomenon of age misreporting and the resulting age heaping on certain digits in the age distribution has been of special concern to demographers. The estimation of mortality or fertility rates on basis of age distributions subject to age misreporting leads to biased results. Therefore, demographers have extensively studied heaping patterns and sources of age misreporting, mainly referring to census data from developing countries (Scott and Sabagh 1970; Nagi, Stockwell, and Snavley 1973). While they see the existence of heaping patterns due to age misreporting in age data as a serious problem, economic historians have discovered the value of these sources in order to measure basic numerical abilities of societies by means of the extent of heaping patterns.

Works by Myers (1940, 1954) and Bachi (1951) were the first to find a substantial correlation between the degree of education on the individual level and the degree of age heaping. These correlations found further support in studies by Long (2005), Dillon (2007), Crayen and Baten (2009a), and A'Hearn, Baten, and Crayen (2009). The main result of these studies is that illiterates are more likely to state a rounded age than literates. Moreover, people that are uncertain of their age or lack age consciousness tend to report a rounded age. If a higher share of a population is uncertain about the own age and reports a rounded one, the resulting age distributions display a higher number of people aged 30, 35, and 40 than people aged 31, 36, or 39. These heaping patterns provide information about the degree of age consciousness in a society which we use as a proxy variable for basic numerical abilities. As a strong correlation between literacy and the degree of age heaping was found in a number of studies, age heaping is used to measure basic education of a society. Age heaping as a proxy variable for education is especially valuable for time periods for which we lack other education data. However, we have to keep in mind that age heaping measures basic numerical abilities, namely the ability of individuals to calculate the own age, and is therefore a very basic measure for education.

As Fischer (cited in Dillon 2007, p. 102) puts it: '*To a demographer, age heaping is an inconvenience, but to a historian it is an opportunity, for it allows him to measure the intensity of age bias as it has changed through time.*' We could add to this statement: And for an economic historian, age heaping provides the opportunity to infer about basic skills in bygone times.

2.3 Reasons for Age Misreporting

Several reasons for age misreporting exist. Therefore, the individual reasons for the misreporting have to be taken into account, when approximating education by age misstatements. Errors in data processing, for example typos, problems when deciphering the handwriting of the interviewers, or erroneous classification in a different age group are a potential source of error. But these errors introduced by the interviewers or persons that analyze the census material are likely to cancel each other out (Ewbank 1981, p. 13-15). Miscommunication between interviewers and interviewees can also lead to biased age data (Oppenheim Mason and Cope 1987). Such errors, however, are subject to all data which is obtained from interviews. Therefore, we will not put much emphasis on these reasons, but rather review reasons which are especially important when studying age data; specifically the errors that emerge from intentional or unintentional age misreporting.

2.3.1 Ignorance of the Own Age

The ignorance of one's own age is the most likely source of age misreporting. Especially in societies in which birth documents are not common, people may lack the knowledge of their age. In agricultural societies or societies in which the birthday is not celebrated, the knowledge about the own age is of subordinate importance. People in these societies orient themselves mainly to the change of harvest periods, historical events, or natural disasters. Men in Morocco in the 1960s, for instance, were often not able to report their age, but knew the number of Ramadans they had celebrated. This information helped census takers then to calculate the age (Scott and Sabagh 1970). The other way around, birth certificates used to compile census data or used to infer about the age of the interviewees will dilute heaping patterns in age data, although the respondents were unsure about their true age.

2.3.2 Economic and Social Factors

Factors that involve the preference or avoidance of certain ages due to personal, economic, or social reasons are a further important source of age misstatements. Budd and Guinnane (1991) find that the pensions act, that granted a pension for all British subjects aged 70 or older, induced a share of the Irish population to state an age older than 69. Similarly, men may try to avoid the military service by stating a younger age.

2.3.3 Cultural Factors

Cultural factors of age misreporting are essential. Single women, for instance, might tend to understate their age to have better possibilities on the marriage market (Ewbank 1981). Are certain cultures less prone to heap their ages? Cultures in which the year of birth is of exceptional importance may show less pronounced age heaping patterns. In China, for instance, a high share of the population in the $18^{th}$and 19^{th} century was able to state the age correctly (Baten et al. 2008). The lunar calendar allowed interviewers to calculate the respondent's age relatively accurate, while the conversion from the lunar to the Western calendar may have caused distortions in the age data of past censuses. Minorities which do not use the lunar calendar generally show higher age heaping patterns (Coale and Li 1991, Jowett and Li 1992). For China in the late 20 th century, Jowett and Li (1992) find no correlation between age accuracy and literacy due to the non-existing age-heaping in the Chinese data. State demand for age reporting in form of an extremely long history of census taking may also lead to lower age heaping levels (Crayen and Baten 2009a). Thomas (1987) states that numerical abilities may be higher in societies in which trade plays an important role. Everybody involved in trade had to calculate and therefore, arithmetic as '*the very soul of trade*'(Hodden cited in Thomas 1987, p. 107) may lead to an improvement in numerical abilities.

2.3.4 Proxy Respondents

In certain cases, not the person itself answers the questions of the census takers, but proxy respondents, like neighbors. These are less likely to know the exact age of others and may therefore report an estimated age (West, Robinson, and Bentley 2004). The problem of proxy respondents is addressed more thoroughly in Chapter 4. In general, the interviewers in the Latin American population counts had the instruction to ask each person individually and therefore biases from this source are likely to be small.

2.3.5 Old Ages

Besides the effect that older people received less education and are therefore more prone to report rounded ages, very old people have a higher propensity to give a wrong age because they tend to exaggerate their age. Del Popolo (2000) studies age misreporting among older age groups in Latin American population counts and finds a strong positive correlation between the degree of age heaping and the share of ancient people. A higher age means a higher social reputation. Thus, lower age awareness in a society leads to stronger age exaggeration among the oldest age groups. Kestenbaum (1992) concludes that the problems are especially serious for people aged 95 or older, while del Popolo (2000) finds important effects for the population older than 60 in the less developed Latin American countries and 80 in the more developed countries. A good example for age exaggeration is ancient Rome. Although life expectancy at birth was only around 20 to 25 years, the tombstones show people that died at age 120 (Clark 2007, p. 178). Age statements of older people have therefore to be treated with care. For this reason, we excluded the oldest age groups from our analysis in the following chapters.

2.3.6 Coverage Errors

Under- or over-enumeration of individuals may cause errors in certain age ranges. Migration or the formation of households is the most important factor leading to underenumeration. Engaged women who are still living in their parent's home are often not counted as belonging to their parent's household, but are neither counted in their future spouse's. Similarly, marginal members of households like servants or nonrelatives may not be counted (Ewbank 1981, p. 60).

2.4 Patterns of Heaping

Turner (1958) states that individuals will overstate ages that are ending in those digits which are divisors of the prevalent number system. The most common number system, the prevalent system, has its base on ten. The three divisors are 10, 5, and 2. Thus, heaping on digits ending in 0, 5, or 2 occurs. Since 4 and 6 flank the more preferred digit 5, heaping on those will be lower than on digits 2 and 8. Accordingly, the over-reporting of these ages leads to an avoidance of the digits 1, 3, 7, and 9. The digits 1 and 9 flank the more preferred digit 0 and are therefore avoided to a greater degree than digits 3 and 7. Figure 2.1 shows the ranking of the digits according to the degree of preference which should result from the Turner-Hypothesis.

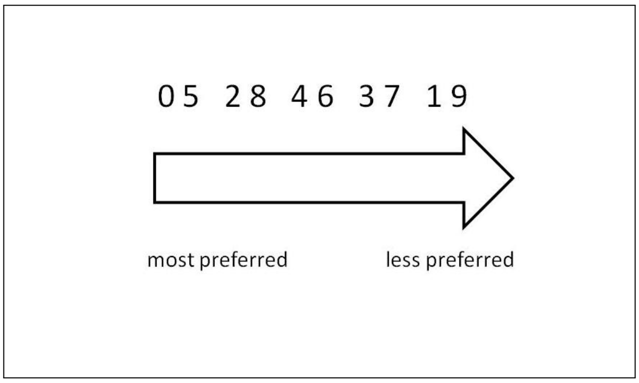

Figure 2.1: Ranking of digits according to the degree of preference

Actually, heaping on multiples of five is the most frequent detected heaping pattern in age data, while heaping on even numbers occurs to a lesser extent. Younger ages are generally reported more accurately and heaping on even numbers plays a more important role in these cases. This could be due to the fact that estimating ages for children is somewhat easier than for adults as long as the child grows. Heaping on multiples of five is less likely, because the height and maturity of a child indicate to a great degree whether a child is 7 or 10 years old. Moreover, in young ages, the exact age is of considerable importance, for example, for the communion, marriage, or military service leading to higher age awareness among the adolescent.

In medieval Europe, multiples of twelve were of exceptional importance. Twelve was a holy number and also the monetary system was based on multiples of twelve. For instance, the shilling comprised of twelve pence, and twelve inches made a foot. Thomas (1987) studies age lists in early modern England and finds heaping patterns on digits zero and six instead of heaping on five which he explains with the '*deeply rooted habit of thinking in sixes, twelves, and twenty-fours*'. De Moor and van Zanden (2008) study, amongst other things, the census of Reims of 1422 and find considerable heaping patterns on multiples of twelve. In contrast, he famous study of Duncan-Jones (1990) which studies age statements from tombstones in the Roman Empire, shows heaping patterns on multiples of five. Similarly, A'Hearn, Baten, and Crayen (2009) analyze 40 samples from 15$^{\text{th}}$ century Italy and find the strongest digit preferences for multiples of five.

Other detected heaping patters like on multiples of seven in Iraq (Duncan-Jones 1990, p. 81) result mainly from the preference of reporting a rounded birth year rather than it reflects different heaping patterns. The Iraqi Census of 1957 shows this strong preference on the final digit 7 as well as heaping on digits 5 and 0, although to a lesser degree. In this case, interviewers asked for the year of birth. A higher share of people stated a birth year ending in a zero, which led to a higher share of ages ending in digit seven in the age distribution. Nagi, Stockwell, and Snavley (1973) assume that the digit preference on digits five and zero is due to the fact that, if respondents did not know their birth year, they were asked for their age. This presumption can explain heaping patterns in the Iraqi census well. Similarly, an exceptional high heaping on age 59 is found in the U.S.-American census of 1959, which also asked for the year of birth (Zelnik 1964). Thus, age heaping and birth year heaping may account for different heaping patterns in the resulting age distribution.

To conclude, heaping patterns may occur on all terminal digits, but are mainly observed on the final digits 5 and 0. Heaping on digits 6 or multiples of twelve may also appear, although the studied age distributions have shown these patterns less frequently. In any case, it has to be carefully evaluated whether the heaping patterns manifest themselves due to the question for the birth year which may result in different age distributions or other cultural preferences. The Latin American and Spanish samples studied in this thesis did not reveal digit preferences different from multiples of five and the interviewers asked in all cases for the age and not for the year of birth.

2.5 Measuring Age Heaping

The program SINGAGE, developed by the US Census Bureau, calculates three indices that measure digit preference in census data. These are the Myers, the Bachi, and the Whipple index. All of them underlay the assumption that the population is uniformly distributed across all digits of the age distribution. With the only exception of age specific mortality or undercount, there is no reason why an age distribution should comprise of more people aged 30 than aged 29.

Myer's blended method uses age groups of ten successive years and calculates an index of preference for each terminal digit in the age distribution. The population which stated an age at each digit is then expressed as a percentage of the total population. Due to mortality, more people will be alive at age x than at age x+1. Therefore, the index takes each of the ten digits in turn as the starting point. Finally, the ten different results are summed and a percentage distribution for each digit calculated. Without age heaping, each digit should attract around 10 percent of the population. A general index for digit preference in an age distribution can be calculated by summing up the absolute deviations from 10 percent at each digit (Myers 1940, 1954). The strength of this indicator is that it considers heaping on all terminal digits.

However, if age heaping is mainly present on multiples of five, the Whipple index is an easier option to calculate the degree of digit preference. This index is given by the sum of people in a special age range (usually ten successive years that contain the same number of ages with every final digit) that stated an age ending in a multiple of five, divided by one fifth of the total population in this age range, times hundred.

$$Wh = \left(\frac{\sum(Age_{25} + Age_{30})}{\frac{1}{5} \cdot \sum(Age_{23} + Age_{24} + ... + Age_{32})} \right) \cdot 100 \tag{2.1}$$

The index varies between 0 and 500. For 500, all age statements in an age distribution end in a multiple of five, in the case of 0, ages ending in multiples of five are avoided. An index of 100 means that exactly one fifth of the population stated an age ending in a multiple of five. In this case, no heaping patterns on multiples of five are present. The Whipple index is also used by the United Nations in order to classify the accuracy of age data in censuses (UN 1955, p. 19).

The Bachi index consists of calculating the Whipple index for each terminal digit. As well as the Myer's index, it varies between 10 and 90 percent. This index gives the minimum proportion of people that stated a rounded age as certain errors might cancel themselves out. A study by A'Hearn, Baten, and Crayen (2009) has analyzed in detail the features of each of these indices. The Whipple index resulted to meet best the desired features of scale independence, a linear response to the degree of heaping, as well as the ability to rank reliably samples with different degrees of heaping. The linear response to the degree of heaping facilitates the interpretation of the index. An increase of 50 percent in the share of persons that stated an age ending in digits 0 or 5 translates into an increase of 50 percent in the Whipple index.

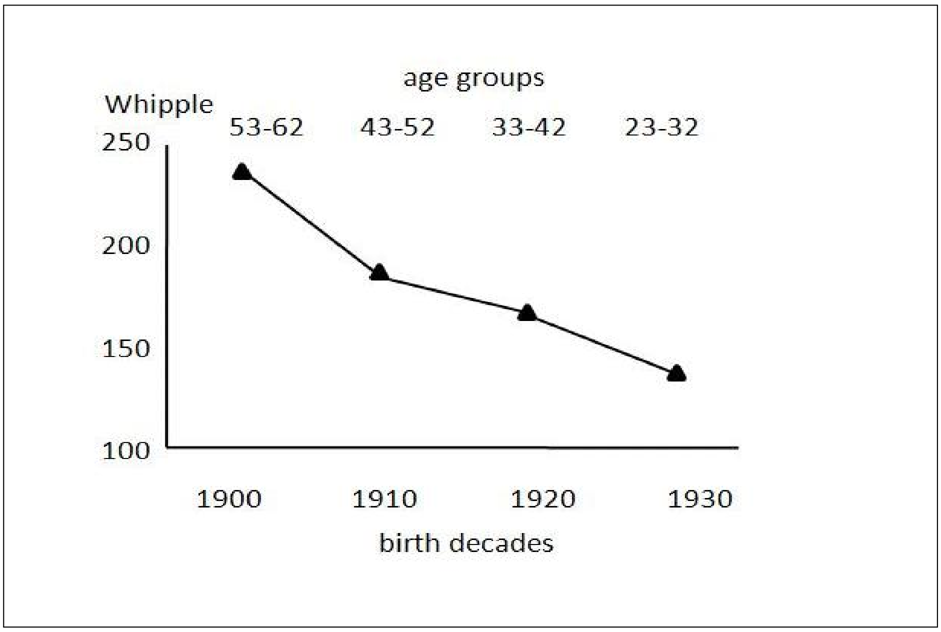

Figure 2.2: Whipple Index of birth decades for census in 1958

In order to study the development of age heaping over a longer time span, the Whipple index is calculated for different age groups. To spread the preferred digits relatively even within these groups, the age groups 23-32, 33-42, 43-52, 53-62, and 63-72 are created. For each of the age groups, an index of digit preference is calculated. In a next step, the Whipple index is assigned to the birth decade in which most of the individuals of each age group have been born. A census taken in 1958, for instance, gives information on the degree of age awareness for people mainly born in the birth decades 1930 (age group 23-32), 1920 (age group 33-42), etc. (see Figure 2.2).

A linear transformation of the Whipple index, the ABCC index, allows expressing the share of people that state the age correctly. It gives thus the level of numeracy in a society (A'Hearn, Baten, and Crayen 2009). Higher age heaping means a lower level of numeracy. Throughout the thesis, the ABCC index instead of the Whipple index is used to describe the evolution of numerical abilities in Latin America and Spain to facilitate the comparison with other human capital indicators.

$$ABCC = \left(1 - \frac{(Wh - 100)}{400}\right) \cdot 100 \quad (2.2)$$

if $Wh \geq 100$; else $Wh = 100$

2.6 Limitations

As the other human capital proxies, age heaping has also its limitations. First of all, age heaping measures basic numerical abilities and cannot distinguish between basic age awareness and more sophisticated forms. This limits age heaping as a proxy variable for education to earlier time periods. Census data for Europe in the second half of the 20th century hardly reveals any heaping patterns (Crayen and Baten 2009a). The same is true for several Latin American countries (see Chapter 4) and age heaping is therefore not a useful indicator to measure education in developed countries after the 1950s. Furthermore, the data from census figures, military recruitment lists, passenger lists or other sources has to be available in single year form. If age data is given in an aggregated form, i.e., only in age groups, the age heaping methodology cannot be applied. Similarly, data verified with birth certificates cannot be used to calculate numerical abilities. Hence, the data used to calculate the degree of age heaping in a society or subgroups of a society has to be carefully evaluated and tested whether it is adequate to calculate numerical ability from this source.

Another important point considering the sources of age data is that it is not always known who gave the age information to the census takers etc. In these cases we remain unsure whose age heaping we really measure. In some cases we have direct information on the census taking procedure and can be sure that we really measure the age heaping of the respondents (see Chapter 3 and 4).

Panel regressions by A'Hearn, Baten, and Crayen (2009) have shown that schooling is an important determinant of age awareness. However, other factors are important, too. An extremely long history of census taking influences the accuracy of age statements. Other institutional factors like state bureaucracy are also potential factors influencing age awareness. Cultural, economic, or social factors leading to age heaping are likely to have no consistent pattern in all censuses studied, but would change from one country to the next or one census to the next. Further, this thesis explicitly studies only Latin America and Spain to make sure that cultural factors are of minor importance. The indigenous cultures in some Latin American countries are a potential source of bias, but no different heaping behavior could be observed so far. However, countries with a higher share of indigenous population also show higher Whipple indexes (see Chapter 4).

Besides the fact that the age heaping technique allows to study periods and countries for which data is scarce, an important advantage is that subgroups of a population can be examined. For instance, special ethnic groups, different regions (Chapter 5), or gender differences (Chapter 4) can be considered, while other data on education is mostly not available for these separate categories.

2.7 Applications of the Age Heaping Technique in Economic History

Mokyr (1982) and Mokyr and Ó'Gráda (1982) were the first to measure '*quantitative sophistication*' by the degree of age heaping to approximate education due to the lack of information on literacy. The authors draw on emigrant passenger list to test the assumption that prefamine Ireland suffered from brain drain. The emigrant population constituted an important share of laborers and servants, but the levels of age heaping were consistently higher than the levels of age heaping in the Irish census of 1841. The empirical evidence thus suggests that the less educated classes decided to leave the country and that a brain drain has therefore not taken place. Moreover, lower occupational classes had higher age heaping levels than higher occupational classes.

Using data from the Saudi Arabian social insurance system, Myers (1976) finds pronounced birth year heaping and a negative correlation between individual earnings and age heaping. He assumes that this is due to the fact that less educated workers earn less. Herlihy and Klapisch-Zuber (1985) study among other things age statements in the Florentine Catastro of 1427. Their main results are that age awareness improved over time, probably in response to government demands for taxes. Additionally, age heaping was higher in rural areas than in Florence itself.

Data from the 1851 and 1881 British censuses suggests a better performance in the labor market of people who reported their age with consistency between the two censuses (Long 2005). Dillon (2007) reports that being black, being resident in Southern US, living in urban areas, as well as living in the household of a laborer or servant meant a higher likelihood of stating a rounded age in 1870/1871. Clark (2007) finds empirical support for a strong correlation between age awareness correlates and social class. In his study on the biological standard of living in Britain from 1740 to 1865, Cinnirella (2008) uses age heaping as an indicator of individual skills in numeracy. De Moor and van Zanden (2008) estimate gender differentials in age heaping for the Netherlands. Due to relatively equal position between sexes these differences were found to be small.

Crayen and Baten (2009b) use age heaping in France and the United States during the 17th to 19th century to study the impact of human capital inequality on subsequent welfare growth. Occupational groups and anthropometric indicators allow them to distinguish between the lower and the middle/higher economic strata of the society. They find a clear negative impact of inequality in numeracy between the social groups on subsequent economic growth for the U.S., but less clear effects for France.

The most ample study that investigates the development of age heaping is a study by Crayen and Baten (2009a). They trace long-term trends in numeracy 1820 to 1949 in 165 countries. In a regression on the determinants of age heaping, school enrollment resulted to be the strongest determinant. Comparing the different world regions, the industrialized countries, Eastern Europe, and East Asia exhibited low age heaping levels throughout the period considered. Eastern Europe could improve its performance during the 19th century exceptionally to catch up with the industrial countries. In contrast, South Asia and the Middle East had very high age heaping levels (in 1840, South Asia had a Whipple index of 450 and the Middle East of 400 which implies that only 12.5 and 25 percent of the population respectively could state the own age correctly).

Estimates for the Latin American region start only in 1880 and show that the region took a middle position and converged towards the age heaping levels of the industrialized countries. The following chapters will give a more nuanced overview of this development, also focusing on earlier time periods.

While the above mentioned studies focus on the long-term development of age consciousness,Baten, Crayen, and Voth (2007) focus on short-term variations in numeracy levels in Britain during industrialization. They find slightly increasing age heaping in decades with higher grain prices. Counties which granted higher poor relief payments to their population suffered less severe deterioration in age heaping from increasing grain prices.

2.8 Conclusion

The review on the reasons for age misreporting has clearly shown that the different reasons for age misreporting have to be taken into account if we use the misreporting patterns to approximate numerical abilities of the population. A different cultural background may lead to different, more, or less pronounced heaping patterns which have to be controlled for. Generally, the question concerning the age in a census reveals less accurate results than questions for the year of birth, as Gray and Gee (1972, p. 110) find in a study on age misreporting in England and Wales. Which question is asked to obtain the age data is of crucial importance. Therefore, the circumstances of the census (Have all individuals been asked individually? Did interviewers ask for age or birth year? Did the interviewers estimate the age of the respondents if they did not know their age? Was age information counter-checked with birth certificates?) have to be taken into account when applying age heaping as a proxy variable for human capital. The age heaping technique itself also has limitations which have to be taken carefully into account. Most importantly, it gives only a rough proxy for the educational level of a society or subgroups of a society. Still, this technique is highly valuable to close gaps in existing data sources on human capital. Applications of age heaping in Economic History already exist, but focus mostly on single countries or limited time periods, with the only exception of the study by Crayen and Baten (2009a). Therefore, this thesis aims at providing a broader overview of the development of age heaping in the Iberian world.

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3 Convergence and Divergence in Numeracy: Age Heaping in Latin America Since the 17th Century

Abstract

This study makes a first systematic attempt at tracing the development of Latin American numeracy over the long run. In order to approximate basic numeracy we use age heaping techniques. We find that Latin America was on a convergence path relative to Western Europe during the early 18th century. During the early 19th century, numeracy development stagnated in some countries. Moreover, differences among Latin American countries increased. While Argentina, Uruguay, and Lima experienced a solid late 19th century development, Mexico and Colombia diverged from them, and from Europe. Brazil had stagnating numeracy until the 1860s, but it progressed afterwards.

Convergence and Divergence in Numeracy: Age Heaping in Latin America since the 17th century[1]

3.1 Introduction

When Pedro de Valdivia, a Spanish conqueror and founder of Santiago de Chile, came to the New World in 1536, 89 of the 150 Spaniards who accompanied him could not sign their names and only one of them had enjoyed formal education (cited in Austin 2003, p.1). The indigenous population of Latin America exhibited a similarly low level of education, or even lower. The Aztecs and Mayas had some schools, but only the sons of the leaders, the caciques, received education in these institutions. This study will follow long-term trends of human capital from the early modern period to the 20th century and address the question of when numeracy improved in the New World. Was there already an international convergence in numeracy in the 18th century? Was European mass immigration of the late 19th century a driving force in improving human capital?

Studies on the development of human capital limit their view mostly to one country or contemplate a shorter time span, since information on human capital measures is, firstly, scarce for most Latin American countries during the first half of the 20th century and earlier and, secondly, the measures lack comparability across time and space. Our empirical investigation aims at estimating human capital development from a comparative perspective covering the early 20th century back to the 18th century, and in some cases back to the 17th century. One important component of human capital is numeracy, i.e., the "ability to count, keep records of these counts, and make rational calculations" (Emigh 2002, p.653). We will employ the age heaping technique which calculates the share of people who were able to report their exact age rather than a rounded age, in population enumerations. This is an indicator of basic numeracy, which is a precondition for developing more advanced skills. Mokyr (1983) introduced the concept of age heaping into modern economic historiography, and recently a new field of research has developed on this topic (A'Hearn, Baten, and Crayen 2009, Baten, Crayen, and Manzel 2008, de

[1] This chapter is based on an article submitted to *The Journal of Economic History*. The concept for the paper was developed jointly, the analyzes and writing was equally shared.

Moor and van Zanden 2008, Clark 2007, Crayen and Baten 2009, Manzel and Baten 2009; see also the applications in Cinnirella 2008, Mironov 2006, O'Grada 2006).

Latin America offers interesting sources to trace numeracy over the long run. The colonial powers carried out population counts and collected data on the population regularly. A great number of these sources has survived and can be used to estimate numeracy trends, although clearly a number of biases need to be addressed. Our central question is how numeracy developed from the 17$^{\text{th}}$ century onwards. Moreover, we will discuss whether slow development of numeracy hindered income growth from initially relatively high levels of GDP per capita. Coatsworth (1998), one of the leading experts in Latin American economic history, argues that income levels in the Southern Cone countries around 1700 were higher than those of the United States. For example, Haiti was one of the richest countries of the World during the late 18$^{\text{th}}$ century on the eve of its revolution (Eltis 1997). As late as in 1800, Argentinean GDP per capita has been estimated as being slightly higher than that of the U.S. (Coatsworth 1998). During the late 19$^{\text{th}}$ and 20$^{\text{th}}$ centuries, Latin America fell behind Western Europe and North America. Human capital is an obvious candidate to explain this divergence. Although it is not our aim to perform growth regressions, new estimates of numeracy trends might allow this in the future. Was Latin American development fast or slow, compared with the U.S. or Europe? Which countries were leading in educational progress? At which point in time may we speak of a convergence process relative to Western European countries?

Our findings reveal that many Latin American countries converged strongly with Western European countries during the 18$^{\text{th}}$ century. In the early 19$^{\text{th}}$ century, however, numeracy progress slowed. Considerable differences within Latin America emerged in the early 20$^{\text{th}}$ century. In general, the Southern Cone countries had more rapid development, while, for instance, Colombia and Mexico showed less progress.

The remainder of the paper is structured as follows. Section 2 presents the methodology and basic concepts of the age heaping technique. We explain the advantages and limitations of our methodology and compare our estimates with literacy data for Argentinean regions. Section 3 reviews the literature on education in Latin America. Section 4 presents the data sources we used to construct a new database of numeracy development in Latin America and discusses the representativeness of our samples. Section 5 shows the estimates for Argentina, Peru, Mexico, Uruguay, Colombia, and Brazil. The following section compares the estimated numeracy trends of these Latin American countries to the U.S. and Europe. Finally, section 7 draws conclusions.

3.2 Methodology and Basic Concepts of Age Heaping

In the following, we will study numerical abilities, which are an important component of overall human capital. In order to provide estimates of very basic components of numeracy, we will apply the age heaping methodology.[2]The idea is that in less developed countries of the past, only a certain share of the population was able to report the own age exactly when census-takers, army recruitment officers, or prison officials asked for it. The remaining population reported a rounded age, for example, 40, when they were in fact 39 or 41. In today's world of obligatory schooling, passports, universities, birth documents, and bureaucracy, it is hard to imagine that people did not know their exact age. But in early and less organized societies this was clearly different. The typical result is an age distribution with spikes at ages ending in a five or a zero and an underrepresentation of other ages, which does not reflect the true age distribution. There was also some heaping on multiples of two, which was quite widespread among children and teenagers and to a lesser extent among young adults in their twenties. This shows that most individuals actually knew their age as teenagers, but only in well-educated societies were they able to remember or calculate their exact age again later in life.[3]

To give an example of rounding on multiples of five, the census of Mexico City 1790 reports 410 people aged 40, but only 42 aged 41. This was clearly caused by age heaping. Apolant (1975, p. 333) gives individual examples of age misreporting: Joseph Milan, who appeared in February 1747 as a witness in an Uruguayan court, should have been 48 years

[2]For more detailed surveys on the age heaping methodology see A'Hearn, Baten and Crayen (2009).

[3]At higher ages, this heaping pattern is mostly negligible, but interestingly somewhat stronger among populations who are numerate enough not to round on multiples of five.

old, according to one judicial record. However, in the same year, but in another judicial record, he declares his age to be ’45 years’. Demographers see this age misreporting as a problem when calculating life expectancies and other population statistics. But exactly this misreporting enables us to approximate numerical abilities of historical populations. The ratio between the preferred ages and the others can be calculated by using several indices, one of them being the Whipple index.[4]To calculate the Whipple index of age heaping, the number of persons reporting a rounded age ending with 0 or 5 is divided by the total number of people, and this is subsequently multiplied by 500. Thus, the index measures the proportion of people who state an age ending in a five or zero, assuming that each terminal digit should appear with the same frequency in the ’true’ age distribution.[5]

$$Wh = \left(\frac{\sum(Age_{25} + Age_{30} + ... + Age_{60})}{\frac{1}{5} \cdot \sum(Age_{23} + Age_{24} + ... + Age_{62})} \right) \cdot 100 \tag{3.1}$$

For an easier interpretation, A’Hearn, Baten, and Crayen (2009) suggested another index, which we call the ABCC index.[6]It is a simple linear transformation of the Whipple index and yields an estimate of the share of individuals who correctly report their age:

$$ABCC = \left(1 - \frac{(Wh - 100)}{400} \right) \cdot 100 \tag{3.2}$$

if $Wh \geq 100$; else $Wh = 100$

The share of persons able to report an exact age turns out to be highly correlated with other measures of human capital, like literacy and schooling, both across countries, individuals, and over time (Bachi 1951, Myers 1954, Mokyr 1983, A’Hearn, Baten, and Crayen 2009). A’Hearn, Baten, and Crayen (2009) found that the relationship between

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

[5]A value of 500 means an age distribution with ages ending only on multiples of five, whereas 100 indicates no heaping patterns on multiples of five, that is exactly 20 percent of the population reported an age ending in a multiple of five.

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

illiteracy and age heaping for less developed countries (LDCs) after 1950 is very close. They calculated age heaping and illiteracy for not less than 270,000 individuals who were organized by 416 regions, ranging from Latin America to Oceania.[7]The correlation coefficient with illiteracy was as high as 0.7. The correlation with the PISA results for numerical skills was even as high as 0.85, hence the Whipple index is more strongly correlated with numerical skills. They also used a large U.S. census sample to perform a very detailed analysis of this relationship. They subdivided by race, gender, high and low educational status, and other criteria. In each case, they obtained a statistically significant relationship. Remarkable is also the fact that the coefficients are relatively stable between samples, i.e., a unit change in age heaping is associated with similar changes in literacy across the various tests. The results are not only valid for the U.S.: In any country with substantial age heaping that has been studied so far, the correlation was both statistically and economically significant.

In order to assess the robustness of those U.S. census results and the similar conclusions drawn from late 20th century LDCs, A'Hearn, Baten, and Crayen (2009) also assessed age heaping and literacy in 16 different European countries between the Middle Ages and the early 19th century. Again, they found a positive correlation between age heaping and literacy, although the relationship was somewhat weaker than for the 19th or 20th century data. It is likely that the unavoidable measurement error when using early modern data caused the lower statistical significance.

Can we also compare age heaping and literacy in Latin America? To show explicitly that age heaping is a good indicator of the educational status, we will compare age heaping and literacy data from samples of the Argentinean Censuses of 1869 and 1895. These samples were drawn in a representative way and contain information on 38,776 and 43,897 inhabitants respectively, in the age range 23 to 62. In 1869, around 78% of the population were not able to read and write, and 21% declared themselves as literates (1% gave no answer). In 1895, the share of literates had risen to 49%.[8]This implies a rapid

[7]See A'Hearn, Baten and Crayen (2009), Appendix available from the authors.
[8]Only native born Argentines are considered.

improvement of education. Figure 1 shows that age heaping patterns are stronger among illiterates; the spikes of rounded ages are much stronger than among literates. Thus, literates are more willing or able to report their exact age than illiterates. Literates born in the birth decade of 1840 had a Whipple index of 174, while illiterates had an index of 258. This corresponds with ABCC rates of exact age reporting of 81.5 and only 60.5 percent, respectively.[9]The correlation on a provincial level between the share of illiterates and the Whipple index yields a coefficient of 0.87 and is highly significant.

Age heaping has also been compared to other human capital indicators, for example, primary schooling rates. The widest geographical sample studied so far was created by Crayen and Baten (2009), who were able to include 70 countries for which both age heaping and schooling data (as well as other explanatory variables) were available. They found in a series of cross-sections between the 1880s and 1940s that primary schooling and age heaping were closely correlated, with R-squares between 0.55 and 0.76 (including other control variables; see below). Again, the coefficients were relatively stable over time. This large sample also allowed the examination of various other potential determinants of age heaping. To assess whether the degree of bureaucracy, birth registration, and government interaction with citizens are likely to influence the knowledge of one's exact age, independently of personal education, the authors used the number of censuses performed for each individual country for the period under study as an explanatory variable for their age heaping measure. Except for countries with a very long history of census-taking, all variations of this variable turned out insignificant, which would suggest that an independent bureaucracy effect was rather weak. In other words, it is sometimes the case that societies with a high number of censuses had high age awareness. But, at the same time, these societies were also early in introducing schooling and this variable clearly had more explanatory power in a joint regression than the independent bureaucracy effect. Crayen and Baten also tested whether the general standard of living had an influence on age heaping tendencies (using height as well as GDP per capita to serve as a proxy for wel-

[9]These figures compare well to Newland's (1994) who gives a share of literates of 52% in 1900 for the population older than 10.

fare) and found a varying influence: in some decades, there was a statistically significant correlation, but in others there was none. Cultural determinants of age heaping were also observable, but their strongest influence was visible in East Asia, not in the Latin American countries under study in this article.

Below, we will employ the ABCC measure of age heaping, computing indexes for different countries and birth decades. In order to do so, we use the age groups 23-32, 33-42, etc.[10] We omitted the age range from 63 to 72, as this age group offers too few observations, especially for the 17th and 18th centuries, when mortality was relatively high.[11]

An advantage of the age heaping methodology is that age statements are more widely available than other human capital proxies like signature ability or school attendance. As Reis (2008) argues, the age heaping measure is a very basic measure of human capital. Therefore, it is especially valid to study human capital development in Latin America in the 17th and 18th centuries when more advanced human capital indicators were quite scarce and reflected only the skills of the elite.

3.3 Literature Review: Latin American Human Capital Development in the Very Long Run

What does the previous literature reveal about Latin American numeracy and education? There is some information about number systems in the ancient Indian cultures. The Mayas used a vigesimal number system represented by bars and dots. They measured time intervals by tuns (periods of 360 days), winals (periods of 20 days) and k'ins (days) (Closs 2002, p.143). The Aztecs combined simple numbers to display larger ones. In the Aztec number system, 399 is, for instance, represented by (15+4) x 20+15+4 (Conant

[10] An advantage of this method is to spread the preferred ages, such as 25 or 30, more evenly within the age groups and it adjusts also for the fact that more people will be alive at age 50 than at age 54 or at age 55 than at age 59 (Crayen and Baten 2009).

[11] Given that young adults aged 23 to 32 round partly on multiples of two rather than five, we use the adjustment method suggested by Crayen and Baten (2009) to increase the Whipple value (minus 100) by 24 percent, before calculating the ABCC measure.

1923, p. 83). The Incas used a technique called quipo to record numerical information without writing. Knots in strings represented numbers and allowed a sophisticated administration of the Inca Empire, including population counts (Julien 1988). Thus, although other indigenous tribes lacked numerical concepts, numbers and dates in general were not uncommon in Latin America before the discovery.

During the colonial period, schooling was seen as a method to "civilize" the native elites, reduce indigenous customs, and spread the Catholic religion. Education was in the hands of different religious orders, mostly the Jesuits, but also some Franciscans and Dominicans (Leininger Pycior 1984). Schools were rare in colonial Latin America, especially before the 19th century. Moreover, education was mainly provided to the European elite or the sons of the caciques (Bakewell 2004, p. 90) and took place almost exclusively in Spanish.

After independence, enforcement and financing of schools was often placed in the hands of the municipalities, which resulted in strong regional disparities. Prosperous regions and cities usually had a higher coverage of schools than the rural areas (Vaughan 1990). Compulsory primary education was theoretically introduced over the late 19th and early 20th centuries, although not reinforced consistently. Schools were poorly endowed and the teachers not well educated (Meyer Loy 1971). One reason for the decelerated development of schooling institutions is often seen to be in the resistance of the ruling elite to finance public schools. Leaving most parts of the population uneducated reinforced their leading position in politics (Mariscal and Sokoloff 2000). Lindert (2004, p.87) has called primary public education *'Ěthe kind of education that involves the greatest shift of resources from upper income groups to the poor.'* He discusses a number of positive and negative influences on the decision to introduce large-scale tax-financed universal primary schooling. The rural elite were especially afraid of mass migration of rural workers to the cities (Morse 1974). From the point of view of a member of the landed elite, why should one sacrifice via taxation a large proportion of one's income for the schooling of poor day-laborers who mainly performed manual tasks on one's estate? And even if there had been a willingness to sacrifice that income, would not more educated laborers have been a threat to the landed elite?

Statistics on the development of education in the New World are rare. The Oxford Latin American economic history database lists only literacy data for the second half of the 20th century. Earlier literacy estimates exist for selected countries (Newland 1994, Engerman, Haber, and Sokoloff 2000, Astorga, Bérges, and FitzGerald 2005), even though Javier Núñez (2005) criticises the estimates for the period around 1900. He argues that there was a lack of comparability between different definitions of literacy due to the fact that censuses have been taken in different years and referred to different population segments. Moreover, definitions of literacy varied among countries. While some defined literacy merely as "being able to read", others only considered people that were "able to read and write". To overcome this problem, Núñez suggests combining literacy data from population censuses with a measure of signature ability using marriage registrations, or with literacy statements in crime statistics. This methodology allows him to reestimate literacy rates for the turn of the 20th century for a number of Latin American countries. He finds poor literacy development for Brazil in the first half of the 20th century, which he explains with the fact that Brazil abolished compulsory primary education in 1891 and reintroduced it only in 1934 under the rule of Getúlio Vargas.

For the late 19th and early 20th centuries, Benavot and Riddle (1988) assessed school enrolment rates for an impressive number of countries. Their data show a moderate increase in primary school enrolment for Latin American countries, and was more pronounced in the urbanized countries with a high share of European immigrants like Argentina, Uruguay and Chile, as well as in the British colonies of the Caribbean.

During the 20th century, strong differences remained among countries. Astorga, Bérges, and FitzGerald (2005) estimate the share of literates older than 15 years in the LA6 countries, i.e., Argentina, Brazil, Chile, Colombia, Mexico, and Venezuela, at 33% in 1900, 60% in 1950, and 89% in 2000.[12] For the remaining Latin American countries, literacy rates are at 32% in 1920, 46% in 1950, and 82% in 2000. Moreover, the main improvement in literacy took place during the period from 1900 to 1939 for the LA6, but only from 1940 to 1980 for the remaining countries.

[12] Cuba is excluded.

European immigration was a decisive factor for the development of education in Latin America. Clara Eugenia Núñez (1993) distinguishes two types of Latin American countries - those with a high share of indigenous population, and those with a high share of European immigrants, such as Argentina, Chile, Uruguay, and Cuba. Immigrants to these countries had a positive impact on the promotion of education.[13] They also provided teachers (Thorp 1998, p. 37). In general, Núñez (1993) argues, educational development in Latin America was only delayed three or four decades, compared with Italy or Spain. But it was not only retarded by the lack of financial resources and the hesitating attitude of the elite, but probably also by the Independence Wars. During the early 19th century, the newly independent countries suffered from political instability along with the negative consequences for trade and capital flight (Haber and Klein 1997); therefore, it is not surprising that the independence conflicts had negative side effects for most Latin American countries. We will assess this question below.

Manzel and Baten (2009) estimate the differential between male and female age heaping for Latin American and Caribbean countries after the 1880s as well as the average levels, but they do not cover the early history. In sum, several (mostly qualitative) studies on Latin American educational development exist, but comparable estimates of human capital measures are missing and these would be necessary to trace the development over a long-term period.

3.4 Data Sources

Starting with the complex *Visita General* of the Viceroy Francisco de Toledo in 1572, population counts in the New World were carried out regularly. The first counts were intended to obtain a detailed overview of the territory and its inhabitants and did not contain systematic age statements. Most visitas focused on small regional units and repeated within five to ten years. In the 17th century, there followed the *empadronamientos de tributarios*, population counts to determine the taxes of individuals. *Padrones de*

[13] Although they had lower educational levels than immigrants in the United States.

población (population counts with a limited geographical or social scope) and partial censuses were carried out during the 18th and 19th centuries, covering larger regions and a larger share of the population (Mellafe 2004, pp.148-170). In the late 18th century, the Council of the Indies started a series of systematic census records (Platt 1998, p.8). By means of this information, the Spanish Crown estimated the amount of taxes and learned about the number of men able to fight in the army. For the post-colonial period, censuses of the republics are available, although most of them stem only from the late 19th and 20th centuries. Therefore, information on the first decades after independence is scarce.

Latin America is actually the only continent in the developing world for which population enumerations are widely available for such an early period (Platt 1998, p.7). An advantage of the surviving original records is the detailed amount of information they provide. Some of the population enumerations not only list names but also ages and information on the ethnicity, profession, place of birth, number and age of children, and the number of slaves in a household.[14]This information allows an in-depth study of age heaping already during colonial rule, and up until the 20th century. Our data covers Argentina, Brazil, Colombia, Mexico, Peru, and Uruguay[15]and represents therefore, a large part of the Latin American subcontinent. All in all, these countries today represent around 80% of the Latin American population.[16]An important question is whether our various sources are representative of the whole society during the period under study. The population enumerations were supposed to have universal coverage in the whole area considered, as well as in all social strata. Nevertheless, officials of the Spanish Crown were seen as invaders by the native population and the reasons for the enumeration (taxes, military recruitment) led to fear and distrust. Therefore, demographers are convinced that most of the census data is subject to underenumeration. Gootenberg (1991) even assumes that all population estimates of Peru are wrong due to a severe underenumeration. In particular, men aged 16 to 36 attempted to avoid the military draft (Orozco y

[14]In some cases, the census schedules also contain information on the wealth of a family.

[15]While borders changed during the colonial and post-colonial period, we always refer to today's borders here.

[16]Central America had not a similarly dense population and no mineral resources, so that the Spanish Crown was less interested in this area (Mabry 2002, p. 58) and there exist only few population enumerations for these countries.

Berra 1980). The famous *Censo de Revillagigedo* (1790-1794) in Mexico City, for example, shows an overrepresentation of widows. Women tended to declare themselves as widows or *solteronas* (spinsters) in order to protect their husbands and sons (Arrom 1985).The avoidance behavior of younger males underestimates the overall number of inhabitants. But it does not actually bias our numeracy estimates as long as it is uncorrelated with their educational status. The available evidence suggests that military draft avoidance was spread across a large part of the population, except perhaps the very rich (Orozco y Berra 1980, p. 72). Consequently, even data which suffers from underenumeration can provide relatively unbiased information on the development of education in terms of numerical abilities in the colonial society of Iberian America. Some biases are unavoidable; therefore, the strategy we will follow is to compare different samples wherever possible.

An important question is whether the household heads reported the age for all household members or whether all people in the age range studied here (age 23-62) were asked individually. One might expect that the household head was certain about his or her own age, but did not know the exact age of other household members. Hence, there might be an exaggerated age heaping among those who were not household heads. We compared male household heads and other male members of the household in the census of 1744 of Buenos Aires and found that there was actually no substantial difference, even though one might expect that the other members had a lower educational status. We conclude that potential reporting by a household head on other male members of the household was not a large problem in case that this census was representative. In addition, a few padrones contain personal notes of census takers that a certain person states his or her age as 30, 'but looked considerably older' (see for instance Cook 1968, p.34). This implies that census takers asked each person individually for census-specific information. Thus they did not rely only on the information provided by the household head and did not adjust for obviously erroneous age statements.

Table 1 and Appendix A contain detailed additional information on the sources that were used to construct a numeracy series for colonial and post-colonial Latin America. Some of our sources were restricted to the capital, others to some regions of a country.

The most special data sets come from prison records. Sometimes prison samples have a strong concentration of ages 23 and 24, which results in a skewed age distribution. Therefore the ABCC index is sometimes upward biased for the youngest prisoners.

In order to assess the representativeness of our samples in detail, we compare the ethnic composition of our census samples with the ethnic composition of the whole population for all cases for which information was available from the literature. Table 2 lists the results. It is noteworthy that the skin-color classification was abolished in most countries after Independence and we are therefore not able to compare the later samples by these characteristics. The Argentinean samples of 1744 and 1771 reflect the population of Buenos Aires generally quite well, with the exception of blacks and mulattos, who are slightly underrepresented in 1744.[17] In sum, while not all census samples reflect the exact share of each ethnic group in the colonial society, our data reveal no severe biases. But there is one major exception: The Peruvian data is clearly not representative as we only possess data for Lima until the 1880s and the population of the capital is probably biased towards the higher social classes. For this reason, we will estimate a numeracy trend for Lima only (not for Peru) and bear in mind that the level of numeracy will be upward biased.

Finally, an important point for Latin America in particular is whether migrants should be included in the individual samples. Here, we are mainly interested in the long-term human capital formation of countries, and permanent migrants were an important part of the population. Therefore, we decided to include migrants as well. This also makes individual and aggregated samples comparable, because in the aggregated data migrants were included anyways. However, we have to expect some shifts in the numeracy graphs during periods of mass immigrations, assuming that the immigrants to Latin America were more numerate than the native population.

[17] During the 19^{th} century, the share of blacks and mulattos declined. Their share in the censuses of Buenos Aires was around 25% in 1810, 1822 and 1838. In 1887 it had declined to only 1.8% (Andrews 1989).

3.5 Age Heaping Trends from Colonial Times to the 20th Century

What sort of long-term development of numeracy can we observe in the New World? Our strategy to assess the trends is to review firstly Argentina, for which we possess the most comprehensive data, and then add other Latin American countries - Brazil, Colombia, Mexico, Peru, and Uruguay - for which the data set is still substantial, but has some gaps and selectivities.

3.5.1 Argentina

For Argentina, we can provide a first long-term estimate of numeracy beginning from the 17th century. The values for Buenos Aires in the late 17th and early 18th centuries indicate very low numeracy (Figure 2). Initially, less than 40 percent of the population of Buenos Aires reported an exact age. The censuses of the capital of 1744 and 1771 reconfirm each other: The youngest cohort of the older census of 1744 has a similar value as the older cohort of the following census. Overall, there is a remarkable increase of around 30 percent in age numeracy until the mid-18th century. A sample from the military census of Buenos Aires in 1818 covers the birth decades of the late 18th century. It also included females and those who were not household heads. The flat shape of the line suggests stagnation during the late 18th century, but at a high level of around 75-80 percent.

For the birth cohort of the 1810s the numeracy levels are about 70% for Buenos Aires. This value is lower than the one for the late 18th century and only slightly higher than it was in the 1750s. Hence numeracy seems to have stagnated in the late 18th and early 19th centuries. We also observe a temporary stagnation around 1800 and the period of the independence conflicts (ca. 1810-1824) in Uruguay, Mexico, and Colombia. Apart from the political struggle, which probably had a negative impact on education, the expulsion in 1767 of the Jesuits, who ran most schools in Latin America, may also have had an adverse effect on educational development.

For the 1810s, we also have the first estimate for the whole country. Numeracy in all of Argentina is lower than in the capital (around a 9 percent difference in 1810), suggesting a positive effect of access to education in the capital and of the economic structure, which was based on more skilled occupations. In general, the period between 1810 and 1840 saw a recovery in numeracy from the low level of the 1810s. After the 1840s, a continuous increase in numeracy took place, both in the capital and the whole country. This trend ended in 1880, when the phenomenon of age heaping had disappeared, according to 1947 census data. Please note that the numeracy level in 1880 is higher, if the census of 1947 is considered. But the same birth decade still has some age heaping, if the youngest age group of the 1914 census is looked at. This gap is typical for periods of mass immigration of relatively skilled migrants. Although immigration rates were lower after 1914, there was still a large absolute number of migrants to Argentina. Hence the population which reported their age in 1914 and 1947 was different due to this selective migration effect.

In order to estimate a representative numeracy trend for the whole country, we carried out an OLS regression, controlling for the share of males in each census (the share of males varies between 0.47 and 0.77) and controlling for a census of the capital with a dummy variable (Table 2). Both variables reflect an easier access to education. The capital effect is statistically significant for Argentina. The resulting time dummies are shown in Figure 3, assuming a male population share of 50 percent, and a persistent advantage in the capital. The period from 1680 to 1760 saw a strong upward trend in numeracy. However, the regression results also indicate that there may have been a temporary stagnation or even deterioration of numeracy between the late 18th and the mid-19th centuries, even after controlling for gender and better access to schools in the capital. During the second half of the 19th century, numeracy development in Argentina was clearly positive. Argentina was one of the first Latin American countries that introduced free compulsory primary education (in 1884, see Cortés Conde 1985), which supported this positive numeracy trend. Moreover, substantial European immigration reinforced this process. Although immigrants who started to enter the country in large numbers during the second half of the 19th century had lower educational levels compared to immigrants to the United States, they had better levels than native Argentineans and fuelled the rapid growth in human capital (C. E. Núñez 1993, p. 371).

3.5.2 Mexico

Our Mexican numeracy estimates begin in 1680 for places in the provinces of Hidalgo, Guanajuato and Oaxaca (central and southern Mexico; Figure 4).[18] The ABCC index suggests that only 40 percent of persons born in the 1680s were able to state their own age exactly. A number of different sources confirm that basic Mexican numeracy improved to values of around 60 to 65 percent around mid-18^{th} century, although there was some variation. Our sources for Coahuila in the north during the late 18^{th} century suggest that this trend continued. However, the census of Guadalajara (1821/22) in central Mexico reports considerably lower numeracy for the late 18^{th} century. Generally, the provinces in the northern parts of Mexico have been the richer ones and spent more on education than the centre and the south, with the exception of the federal district of Mexico City (Vaughan 1990). Thus, lower numeracy in Guadalajara might reflect these within-country disparities. Data for the birth decades 1800 to 1860 are missing. Therefore, we cannot confirm exactly whether numeracy levels stagnated around independence. But the relatively poor numeracy levels in the birth decade 1870 confirm this view. For the birth decades 1880 and later (census samples of 1930 and 1950), numeracy indexes were still relatively low, although numerical abilities improved in this period. We estimate a trend for Mexico in a regression analysis similar to that for Argentina, controlling for the share of males in each census as well a dummy variable for a census of the capital (Table 3). Moreover, we controlled for the share of the indigenous population in Mexico, although it actually turned out insignificant. In a similar vein, the capital, Mexico City, did not display significant differences to the country as a whole, whereas the male share was significant for Mexico. This leads to the conclusion that gender differences in numeracy were larger in Mexico than in Argentina, which confirms later results for the early 20^{th} century (Manzel and Baten 2009). Many time dummy coefficients were insignificant. The resulting coefficients of the time dummy variables are shown in Figure 3. Until 1750, Mexican numeracy levels were higher than the Argentinean ones, but Mexican numeracy seems to have stagnated

[18] In the case of Mexico we had to pool different places in order to get a higher number of observations per birth decade. These decisions are reported in the appendix.

while Argentina managed to improve its performance strongly.

3.5.3 Peru

Peru was the starting point of the Spanish conquest of South America. For at least 200 years after contact, Lima remained the most important city of the continent due to its proximity to the sea, the silver mines, and other factors. It was a mostly European city, with only a modest share of indigenous population living within the city walls (Mabry 2002, p. 59). For Lima, we have some very early observations starting with the birth cohorts of the 1640s and 1650s, which are characterized by very low numeracy levels (Figure 5). Until the 1660s and 1670s, there was some improvement. These numeracy indexes are based on age statements of male household heads in Lima only and will therefore actually overestimate the general numeracy of the population. We do not have Peruvian age data for the birth decades of the 18^{th} century. There is a gap of 160 years, terminating in the 1820s with a sample of prison inmates who were mostly born in Lima. This sample is, as discussed in section 3, a slightly biased sample of the capital population. The numeracy estimates, especially those based on the youngest prisoners born in the 1850s and 1860s, were apparently upward biased, if we compare them to the first birth cohort of the representative census of Lima 1940. This census of 1940 also allows us to estimate the numeracy gap between Lima and Peru in general, which was around 17 percent for the birth decade of the 1880s, the largest gap between the capital and the whole country observed so far. The gap narrowed somewhat afterwards. Due to the limited availability of census data before the 1880s from other parts of Peru, we cannot estimate Peruvian numeracy in a regression analysis, but rather show the available data graphically. For the same reason, we restrict the interpretation to the city of Lima.

3.5.4 Uruguay

Our data on Uruguay refer mostly to Montevideo (Figure 6). For the early 18th century, numeracy is around 60 percent, i.e., at a similar level as in Buenos Aires. This is not surprising as Montevideo was founded in 1726 mainly by *Porteños* (inhabitants of Buenos Aires), who settled there. Afterwards there is some variability. Rural Soriano and Maldonado have a lower numeracy than, for example, prison inmates in Montevideo. For the early 19th century, we have two samples from prisons in Montevideo which display some random fluctuation. We explained above in section 4 that this sometimes occurs when prison sources are studied. A high share of Europeans (around 60 percent) in the prison could have added to a relatively high level of numeracy in those samples.

However, the evidence suggests that there was not much numeracy improvement throughout the late 18th century. During mid-19th century, numeracy would be around 80-85 percent, if we assume that the prison samples broadly reflect the overall level (in spite of their variability). For the birth decades after 1900, the census of 1963 is available, in which the phenomenon of age heaping had disappeared. This indicates that between the mid-18th century and 1900, Uruguay must have experienced substantial numeracy growth. In sum, numeracy in Montevideo is characterized by high initial levels during the early 18th century, then a stagnation during the late 18th century, and again a rapid development during the late 19th century during the period of mass immigration. The latter refers not only to Montevideo, but to the whole country. The mid-19th century numeracy levels were probably lower in rural Uruguay than in the capital. Therefore, the increase up until 1900 would be even stronger if the whole country was considered.

For Uruguay, it is not possible to adjust for the capital effect and other variables in a regression analysis, as we have little data for rural Uruguay, and the other explanatory variables are not reported in a systematic way. Therefore, we decided not to estimate a numeracy trend with regression methods, but to study the available data on Montevideo and Soriano/Maldonado up until the mid-19th century, and display the trend for the whole country around 1900 graphically.

3.5.5 Brazil

Evidence on Brazilian numeracy starts relatively late in the data set available to us (Figure 7). The sample for the period of the 1810s to 1840s is positively biased; the population of São Cristovão consisted of middle- and upper class Brazilians - for example, the Portuguese king chose to reside there after having fled Portugal in 1808 - and had a higher numeracy than the average Brazilian population, but a higher share of slaves in the sample reduces this effect (Figure 7). However, stagnation of the growth rate is a first hint that Brazilian numeracy did not develop rapidly during this period. The census sample of 1890 can be regarded as representative for the Brazilian population. It suggests a modest growth of numeracy for the birth decades of the 1830s to 1860s. The 1920 census sample is slightly positively biased as detailed age information is only reported for the regional capitals of the Brazilian districts. The census data of 1950 is again nationally representative. The trend of the 1830s to 1860s continues almost linearly into the trend of the 1890s to 1920s. The slightly upward biased urban sample in between confirms this development. Although there was a solid improvement, Brazil had not yet overcome age heaping by the 1920s, in contrast to Argentina and Uruguay.

A large problem in Brazil were regional disparities in education. In 1834, the responsibility for education was assigned to the provinces and for several years the central government subsidized the poorer provinces. But in 1845 these subsidies were stopped and the provinces were left unable to provide an adequate schooling system. As a consequence, the number of children enrolled in public schools declined (Barman 1994, p. 242). These financial difficulties fostered regional disparities within Brazil even more. Most of the improvement in education during the later 19th century took place in Rio de Janeiro and São Paulo while the northeast, especially, fell behind (Lewis 2006, p.125).

3.5.6 Colombia

Evidence regarding Colombian numeracy is still scarce. Calculations from our primary sources suggest that numeracy levels were relatively high during the early 18^{th} century (Figure 8). In the merchant city of Cartagena de las Indias numeracy was even better than in other regions of the country. For the first half of the 19^{th} century, we find ABCC indexes of the same magnitude in a broad sample of provinces, which suggests that numeracy stagnated or improved only slightly. The census of 1928 reveals low numeracy for the birth decades of the 1880s and 1890s. The data for 1900 reveal, in comparison to the representative census data of 1964, that these provinces were probably negatively selected, as numeracy was around 10 percent lower. But even if some upward adjustment of this magnitude is imagined, Colombian numeracy development seems quite slow until the 1880s.

To which degree is the regional selection of the three early Colombian samples representative of the country? In Table 4, we report the number of observations for the samples in 1777, 1870, and 1928, by region. These are sorted by their ABCC numeracy value in the birth decade of the 1930s, for which we possess data on all regions. Bogota has the highest numeracy levels, with 98% of the population reporting an exact age. The centre and the Amazonas regions have the least numerate population. None of the earlier census samples include Bogota or the second numerate region, Eje cafetero. But the two least numerate regions are represented, which suggests some downward bias among the earlier samples until 1928. The census of 1870 represents a broad mix of regions, including some with above-average and below-average numeracy. In 1777 and 1928, a higher share of regions fell into the the lower half of the 1930s numeracy spectrum. Of course, the relative ranking probably changed between 1777 and 1930, but this result might be a first hint that the difference in level between the three early samples might be partly caused by regional composition. However, the stagnation between the 18^{th} and late 19^{th} centuries is probably a reality as the regional composition of the first and third samples was broadly similar.

Can this poor performance during the second half of the 19th century be explained by negative events that hampered Colombian education? In fact, the many changes of government and the civil war of 1876/77 had a negative influence on educational levels. Ramirez and Salazar (2007) find that the financing of education changed considerably with different governments. Moreover, during the civil war of 1876/77, educational reforms were abandoned. Schools were transformed into hospitals, teachers became soldiers, and governmental spending on education was suspended.

Looking at the whole period, Colombia started with relatively good numeracy levels in the beginning of the 18th century, but development during the 19th century is stagnant. Only after 1900, Colombia converged again to the more advanced Latin American countries.

3.5.7 Comparison of Latin American Countries

We will now estimate the levels of numeracy in the six countries under study with a LOWESS regression.[19]This method carries out a weighted linear least squares fit of the data points. Data points near the point whose response is being calculated are weighted stronger than data points further away (Cleveland 1981). The result is a general overview of the level in the six different countries (Figure 9). In comparison, Argentina had relatively low values initially, but numeracy grew faster than in other countries during the early 18th century. It reached the levels of Mexico, Uruguay (which was mainly Montevideo in this period), and Colombia in the 1750s. Mexico and Colombia fell behind in numeracy after 1810, in comparison to the other countries (but recall the regional bias in late 19th century Colombia). The conflicts of independence, the political instability of the early republican governments, capital flight, and the disruption of internal trade seem to have hampered numeracy development in these two countries most. But whereas Mexico remained at lower levels than the other countries after 1900, Colombia started to converge again. The level of numeracy in Lima was relatively high during the 19th century, as we would have expected from a capital, even if the data is only based on

[19]'Locally Weighted Sum of Squares'.

prisoners. However, the representative values of the 1880s to 1900s show Lima behind the national values for Argentina and Uruguay, and the overall Peruvian values would have been even lower.[20]This development coincides with a draining war between Peru and Chile in the region of Tarapacá. The level of numeracy in Brazil was somewhat lower than in Argentina, Uruguay, and Lima during the late 19^{th} century, but still higher than in Mexico or Colombia.[21]

To conclude, numeracy improved in all countries of our sample, but the slowest growth took place in Mexico and Colombia. A temporal deterioration or stagnation of numeracy levels during the late 18^{th} or early 19^{th} century could be found in most countries.

3.6 Comparison of Latin American Countries with European Countries and the U.S.

How do the trends in Argentina and Mexico compare with the information available on Western Europe, Eastern Europe, and the U.S.? For Western Europe, we compare with the ABCC index for the UK reported in A'Hearn, Baten, and Crayen (2009), for East-Central Europe we take the comprehensive Hungarian data from the same source.[22]For the population of the North American colonies that later became the U.S., Fischer (1977) reports the ratio of people reporting ages with multiples of ten to a 10-year moving average of ages for a sample of some 4,000 individuals in Essex County (Massachusetts) in the years 1636-72. These ratios can be transformed into an ABCC index of 69 percent reporting exact ages. The birth cohorts of these individuals are mainly the 1620s and 1630s. Another sample refers to adult males in Westchester County (in Upstate New York, N = 259), who were born mainly in the 1670s and had an age numeracy of around 73 percent (Wells 1975). Starting with the birth decade of the 1800s, we are on firmer ground for the U.S. with the censuses of 1850, 1870, and 1900. The increase in U.S.

[20]In the Figure, only the values for Lima are included.
[21]We did not emphasize the decline in early 19^{th} century Brazilian numeracy because the São Cristovão sample might be positively biased.
[22]Plus some additional data on the early 19^{th} century (Baten and Benyus 2009).

numeracy is slightly underestimated between the 1670s and 1800s, as the latter date also includes the Southern U.S., which had substantially higher age heaping. For Western Europe, we have some early observations from English migration records, which suggest an ABCC index of about 76% for the birth cohorts around 1600.[23]Already around 1700, the UK had age numeracy of around 93 percent, but full numeracy was only reached during the later 19th century.

Interestingly, numeracy in Hungary was on a similar level as that in Mexico during the 18th century, whereas Argentina was doing slightly worse. But the Latin American countries as well as Hungary converged towards the high levels of Western Europe and the U.S. by the late 18th century, reducing the gap from 50% around 1650 to 30% around 1780. But the early 19th century marked a stagnation in Mexico and Argentina, whereas Hungary continued to converge during the 19th century. It even surpassed the U.S. temporarily, which experienced a stagnating development, especially in the Southern United States, until mid-19th century. During the late 19th century, Argentina started converging again and reached the basic numeracy level of Western Europe around 1880, whereas Mexico further deviated. The Mexican development was slow during the 19th century. Hence, the country fell behind in international comparison.

3.7 Conclusion

This paper makes a first systematic attempt to estimate the long-term development of human capital, measured in terms of basic numeracy, for six Latin American countries from the 17th to the 20th century. We assessed a large number of 19th and 20th century censuses as well as padrones for the 17th to early 19th century, but clearly have to admit that the data set has important gaps and shortcomings. The large time span covers part of the colonial rule, the early post-independence period, the era of the first globalization as well as the first half of the 20th century. It thus permits new insights into the socioeconomic development of the New World. We discussed in detail the selectivity issues of these

[23]Although migrants sometimes show slightly upward biased numeracy levels.

sources and adjusted if possible before estimating long-term trends.

Overall, numeracy increased during the period under study in all Latin American countries. We find that Argentina, Mexico, and Lima (Peru) started in the 17^{th} century with relatively low numeracy levels, but began to catch up with Western Europe and the U.S, reducing the gap from around 50 to 30 percent around the 1780s. Hence, Latin American countries performed well until the late 18^{th} century in terms of numeracy. Starting in the late 18^{th} century and especially during the time of the independence conflicts (1810s/1820s), however, numeracy levels stagnated in many countries. Given the rapid development in European human capital, this implied a divergence between Europe and Latin America.

In the late 19^{th} century, differences in numeracy within Latin America increased. While Argentina, Uruguay, and Lima (Peru) experienced favorable development, Mexico and Colombia showed slower progress. Brazil had stagnating numeracy until the 1860s, but were able to improve its performance afterwards. The countries with important immigration from Europe, in particular, had a more rapid numeracy development. Numeracy in Mexico and Colombia in the late 19^{th} century, however, stagnated, and these two countries also received relatively less immigration, a fact which allows a better understanding of their long-term histories. Another main determinant of numeracy growth, investments into public education also grew substantially during the late 19^{th} and early 20^{th} century, sometimes in interaction with immigration.

Can human capital explain income development in comparative perspective? The estimates of Coatsworth (1998) suggest that Latin America was richer than the colonies that would later form the United States. This cannot be explained with early human capital formation. We find that the share of persons in Latin America able to state their age exactly was lower than in North America. Other factors, such as resource abundance, remain the most likely explanation for the high income level in Latin America around 1700. However, one can speculate that if the positive numeracy trend in Latin America in the 18^{th} century had continued with the same speed during the 19^{th} and early 20^{th} centuries, Latin America would have had much better development perspectives.

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3.9 Appendix

3.9.1 Tables

Table 3.1: Data sources

Country/Region	**Year**	**Observations (age 23-62)**	**Individ. data?**	**Bias relative to total population?**
Argentina				
Buenos Aires	1744	3,179	yes	urban, military census, incl. slaves
Buenos Aires	1771	11,140	yes	urban, incl. slaves
Buenos Aires	1778	895	yes	urban
Buenos Aires	1818	890	yes	capital
Argentina	1869	38,776	yes	no
Buenos Aires	1869	5,005	yes	capital
Santa Fé	1887	1,102	yes	regional
Argentina	1895	43,897	yes	no
Buenos Aires	1895	7,818	yes	capital
Argentina	1914	3,286,844	no	no
Argentina	1947	7,729,939	no	no
Brazil				
São Cristovão	1870	691	yes	upper class district, incl. slaves
Brazil	1890	5,536,449	no	no
Brazil	1920	1,010,056	no	all district capitals
Brazil	1950	13,798,696	no	no
Colombia				
Cartagena	1777	1,144	yes	merchant city
Colombia	1777	782	yes	regional
Colombia	1870	2,387	yes	various regions
Colombia	1928	567	yes	various regions
Colombia	1964	6,058,045	no no	
Mexico				
Hidalgo/Guanajuato/ Oaxaca	1740-44	1,228	yes	regional
Mexico - Central	1777	4,379	yes	regional
Mexico - City	1777	608	yes	capital
Mexico - North	1777	705	yes	regional
Mexico - City	1790	4,212	yes	capital, only Spanish and Mestizo household heads

Country/Region	**Year**	**Observations (age 23-62)**	**Individ. data?**	**Bias relative to total population?**
Guadalajara	1821	16,625	no	regional
Coahuila	1823	1,598	yes	regional
Mexico	1930	4,967	yes	regional
Mexico	1950	9,934,234	no	no
Peru				
Lima	1700	2,797	yes	capital, household heads
Lima prison	1866-1909	1,871	yes	capital, prisoners
Lima	1940	352,755	no	capital
Peru	1940	2,370,166	no	no
Uruguay				
Montevideo	1772	1,362	yes	capital
Montevideo	1791	296	yes	capital
Soriano/ Maldonado	1834-36	1,166	yes	regional
Montevideo prison	1846	1,565	yes	capital, prisoners
Montevideo prison	1868	1,268	yes	capital, prisoners
Uruguay	1963	1,290,319	no	no

Notes: Estimated values are not included here. For sources, see appendix.

Table 3.2: Ethnic composition of the census samples

Ethnical Group	**Composition estimates in previous literature**	**Composition in census samples**
Argentina:		
Buenos Aires 1744	Corona Baratech (1951), Bs As 1744	
White/Spanish	80.2	87.9
Indigenous and Mestizos	2.9	3.73
Black and Mulattos	16.9	6.56
Buenos Aires 1771	Corona Baratech (1951), Bs As 1770	
White/Spanish	66.8	66.8
Indigenous and free Black	4.8	5.8
Slaves	28.4	21.9 (Black slaves 13.58)
Mexico:		
Oaxaca 1777	Cook and Borah (1999), table 20b	
White/Spanish	12.33	5.45
Pardos	3.75	5.29
Indigenous	83.92	12.68
N/A	0	64.44
Durango 1777	Cook and Borah (1999), table 20b	
Mestizos	81.61	33.3
Indigenous	18.39	66.3

Notes: Estimated values are not included here. For sources, see appendix.

Table 3.3: Regressions of numeracy on share of males, capital effect, and birth decade dummies for Argentina and Mexico

Country	(1) Argentina	(2) Mexico	(3) Mexico
Constant	84.71***	-9.51	-4.26
	(0.00)	(0.77)	(0.92)
Capital	6.41***	-0.43	-1.37
	(0.00)	(0.92)	(0.81)
Share male	0.31**	1.59**	1.52*
	(0.04)	(0.02)	(0.06)
Share indigenous	-	-	-0.06
			(0.79)
Birth decade 1680	-80.30***	-30.25***	-31.06**
	(0.00)	(0.00)	(0.022)
Birth decade 1690	-82.35***	-19.18*	-19.99
	(0.00)	(0.05)	(0.12)
Birth decade 1700	-74.16***	-14.12	-14.94
	(0.00)	(0.15)	(0.23)
Birth decade 1710	-64.16***	-15.72**	-16.38
	(0.00)	(0.05)	(0.13)
Birth decade 1720	-56.28***	-19.07**	-19.69*
	(0.00)	(0.03)	(0.09)
Birth decade 1730	-52.03***	-14.40*	-14.89
	(0.00)	(0.07)	(0.16)
Birth decade 1740	-41.13***	-14.28*	-14.77
	(0.00)	(0.07)	(0.17)
Birth decade 1750	-43.30***	0.51	0.38
	(0.00)	(0.96)	(0.98)
Birth decade 1760	-29.70***	-8.99	-8.88
	(0.00)	(0.22)	(0.38)
Birth decade 1770	-33.38***	-6.87	-6.65
	(0.00)	(0.38)	(0.53)
Birth decade 1780	-26.68***	-4.21	-3.98
	(0.00)	(0.59)	(0.71)
Birth decade 1790	-27.80***	-10.26	-10.03
	(0.00)	(0.19)	(0.35)
Birth decade 1800	-	-5.23	-
		(0.57)	
Birth decade 1810	-40.45***	-	-
	(0.00)		
Birth decade 1820	-34.65***	-	-
	(0.00)		

Country	(1) Argentina	(2) Mexico	(3) Mexico
Birth decade 1830	-29.51***	-	-
	(0.00)		
Birth decade 1840	-27.12***	-	-
	(0.00)		
Birth decade 1850	-19.67***	-	-
	(0.00)		
Birth decade 1860	-17.81***	-	-
	(0.00)		
Birth decade 1870	-9.34*	-13.25	-
	(0.060)	(0.17)	
Birth decade 1880	-3.42	-7.71	-
	(0.41)	(0.42)	
Birth decade 1890	0.00	-4.60	-4.94
	(1.00)	(0.55)	(0.68)
Birth decade 1900	0.00	6.68	6.41
	(1.00)	(0.48)	(0.60)
Birth decade 1920	-	3.46	13.19
		(0.16)	(0.28)
Observations	44	36	32
Adj. R^2	0.98	0.70	0.69

Notes: P-values in parentheses. */**/*** denote statistical significance at the 10, 5, and 1 percent levels, respectively. The constant represents the numeracy of female, non-capital inhabitants born in the 1910s (in Col. 3 non-indigenous).

Table 3.4: Regional distribution of observations, sorted by regional numeracy in the 1930s

Region	**ABCC 1930s**	**No. obs. 1777**	**No. obs. 1870**	**No. obs. 1928**
Central	88	236		
Amazonia	91		1,016	419
Andina Sur	91		287	
Andina Norte	91	447		
Orinoquia	91		176	
Pacifico Norte	93		184	148
Caribe	93	99	100	
Pacifico sur	93		597	
Eje cafetero	95			
Bogota	98			

Notes: Estimated values are not included here. For sources, see appendix.

3.9.2 Figures

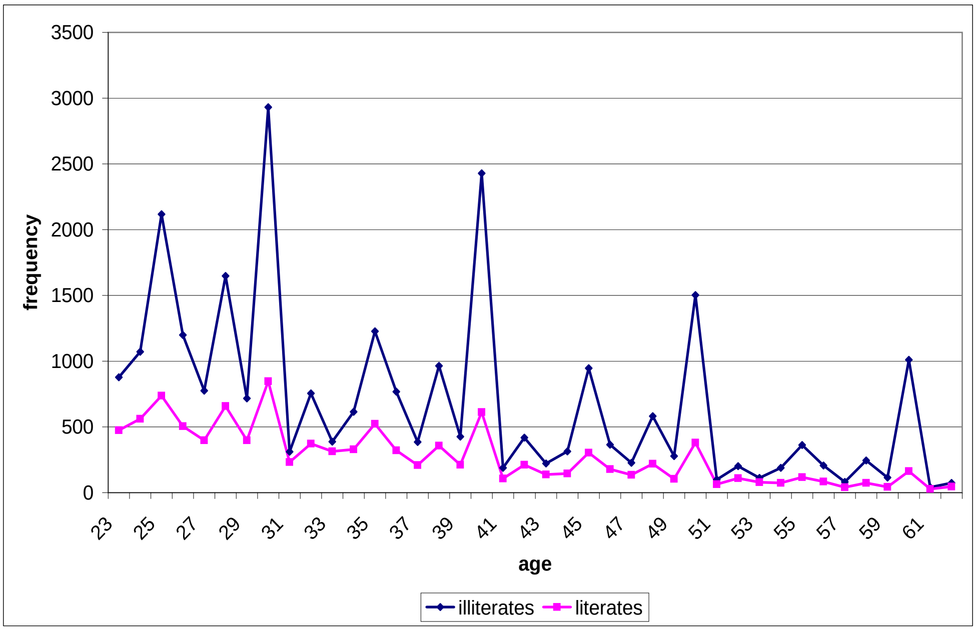

Figure 3.1: Age statements by literacy status (Census of Argentina in 1869)

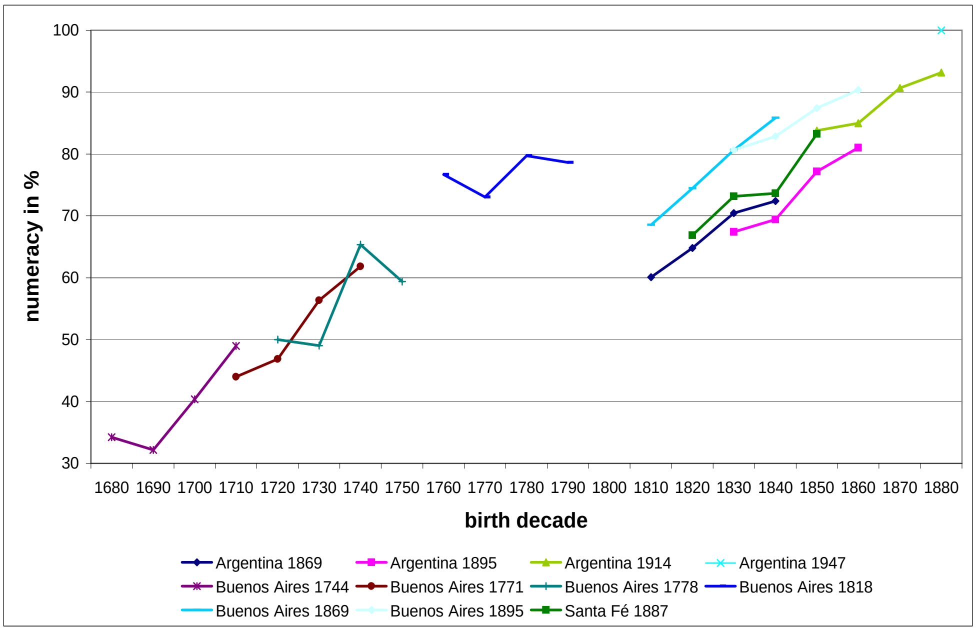

Figure 3.2: Argentina - ABCC index of basic numeracy by birth decades
Note: The decades refer to birth decades (1800-1809, etc.). Sources: see text and Table 3.1

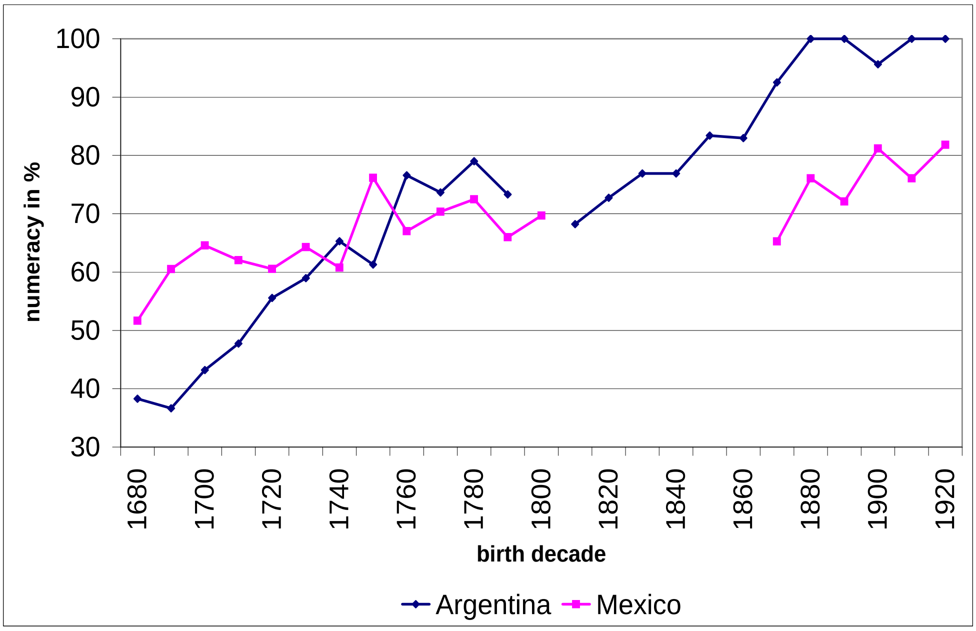

Figure 3.3: Trends of the ABCC index for Argentina and Mexico by birth decades, controlling for capital effect and gender composition
Note: The decades refer to birth decades (1800-1809, etc.). Sources: see text and Table 3.1

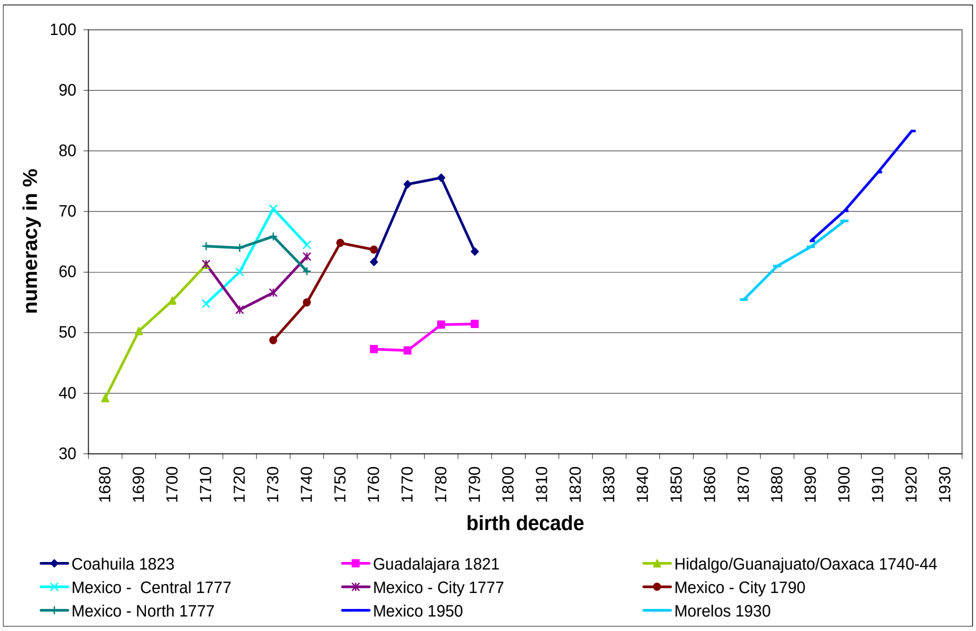

Figure 3.4: Mexico - ABCC index of basic numeracy by birth decades
Note: The decades refer to birth decades (1800-1809, etc.). Sources: see text and Table 3.1.

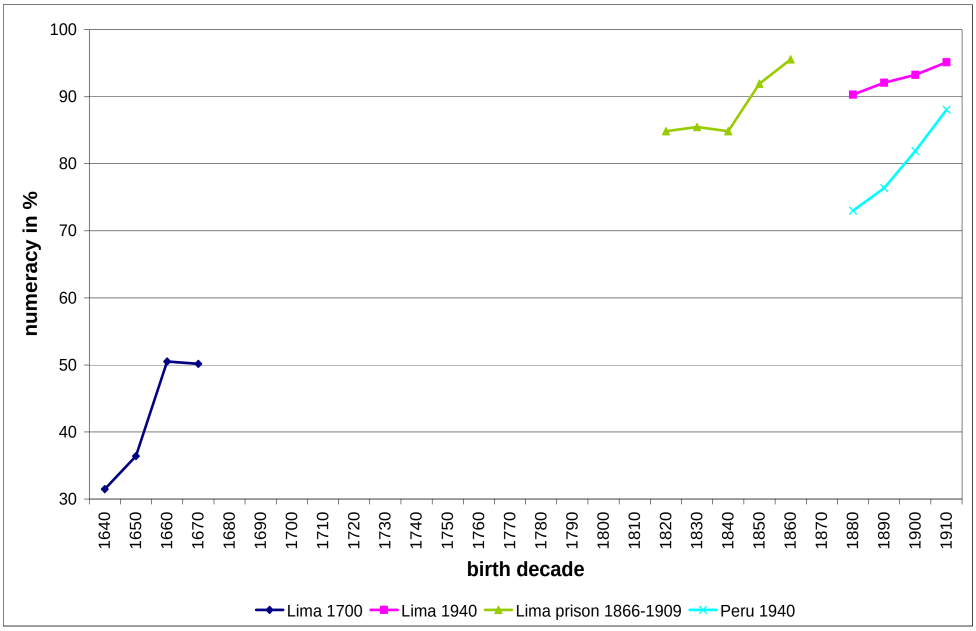

Figure 3.5: Peru - ABCC index of basic numeracy by birth decades
Note: The decades refer to birth decades (1800-1809, etc.). Sources: see text and Table 3.1.

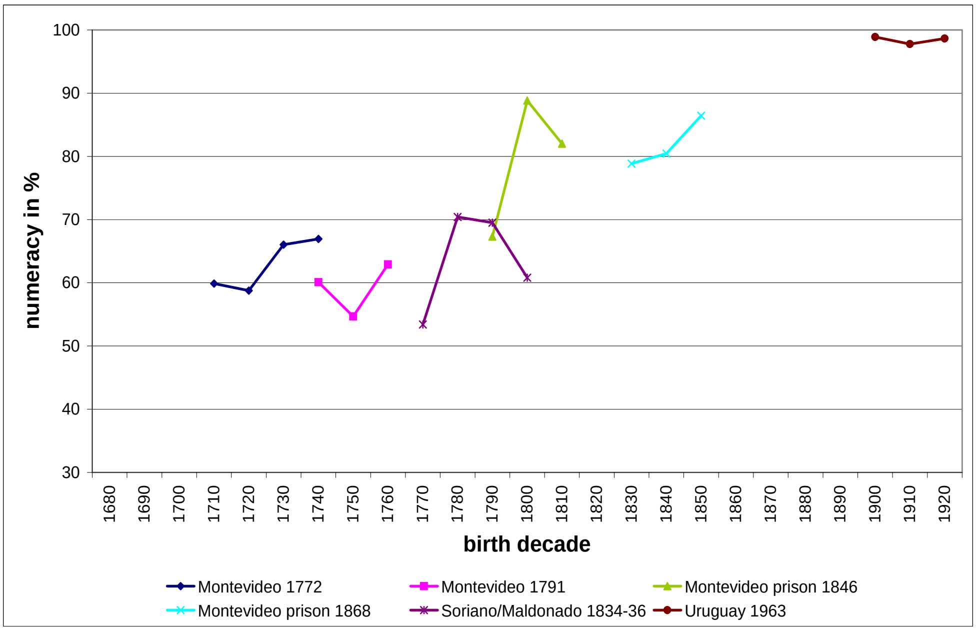

Figure 3.6: Uruguay - ABCC index of basic numeracy by birth decades
Note: The decades refer to birth decades (1800-1809, etc.). Sources: see text and Table 3.1.

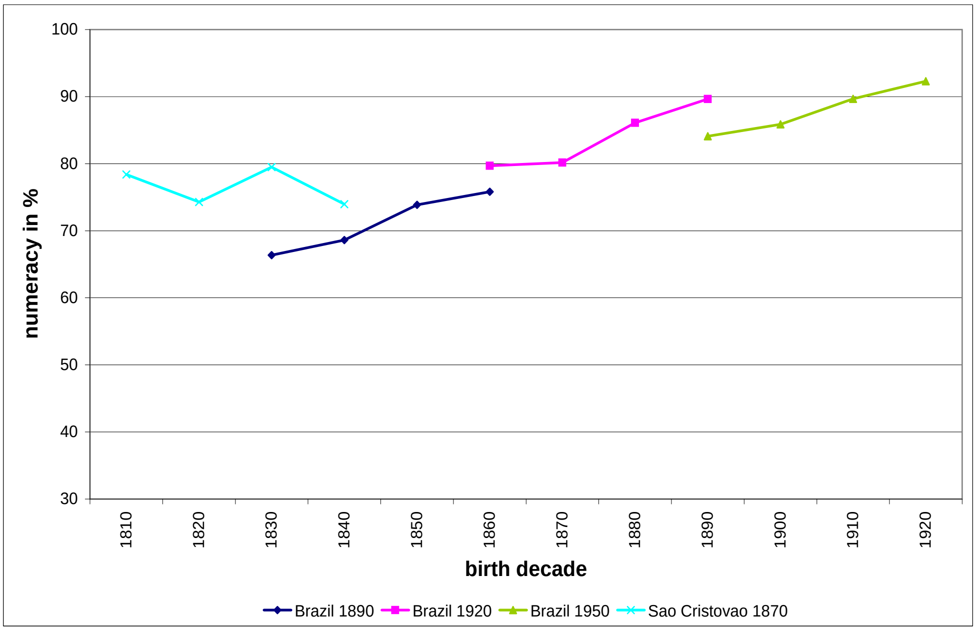

Figure 3.7: Brazil - ABCC index of basic numeracy by birth decades
Note: The decades refer to birth decades (1800-1809, etc.). Sources: see text and Table 3.1.

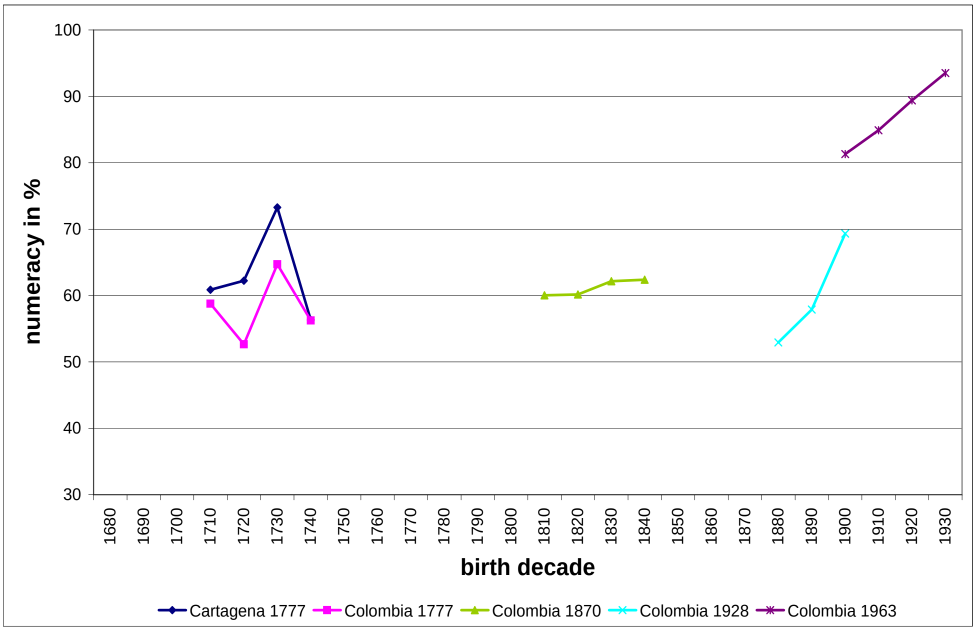

Figure 3.8: Colombia - ABCC index of basic numeracy by birth decades
Note: The decades refer to birth decades (1800-1809, etc.). Sources: see text and Table 3.1.

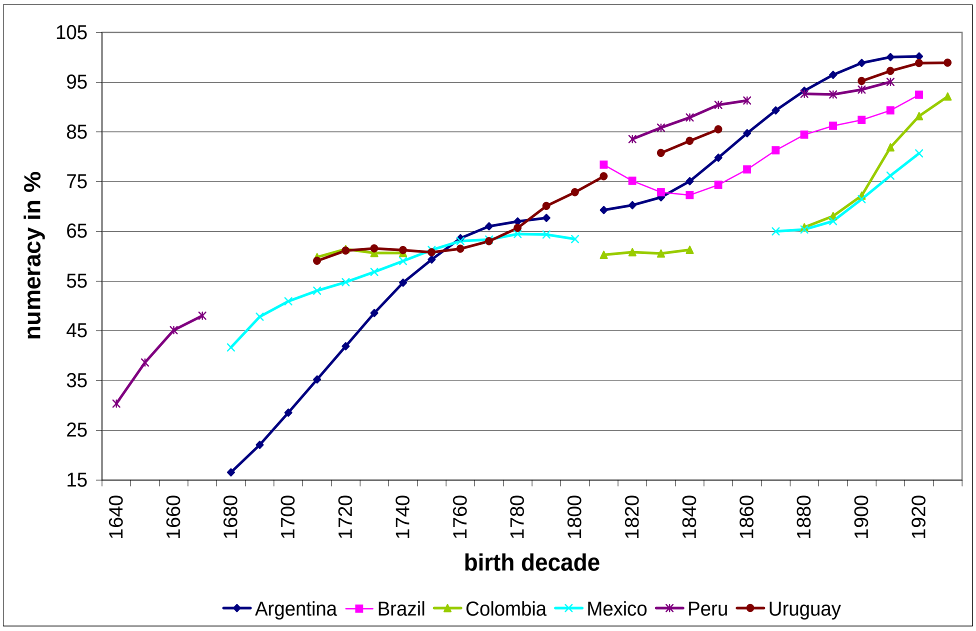

Figure 3.9: ABCC index of basic numeracy by birth decades for six Latin American countries, LOWESS-transformed
Notes: For Argentina and Mexico, the estimates are based on regressions in table 3.3. The LOWESS bandwidth is 0.5. Sources: see text and Table 3.1.

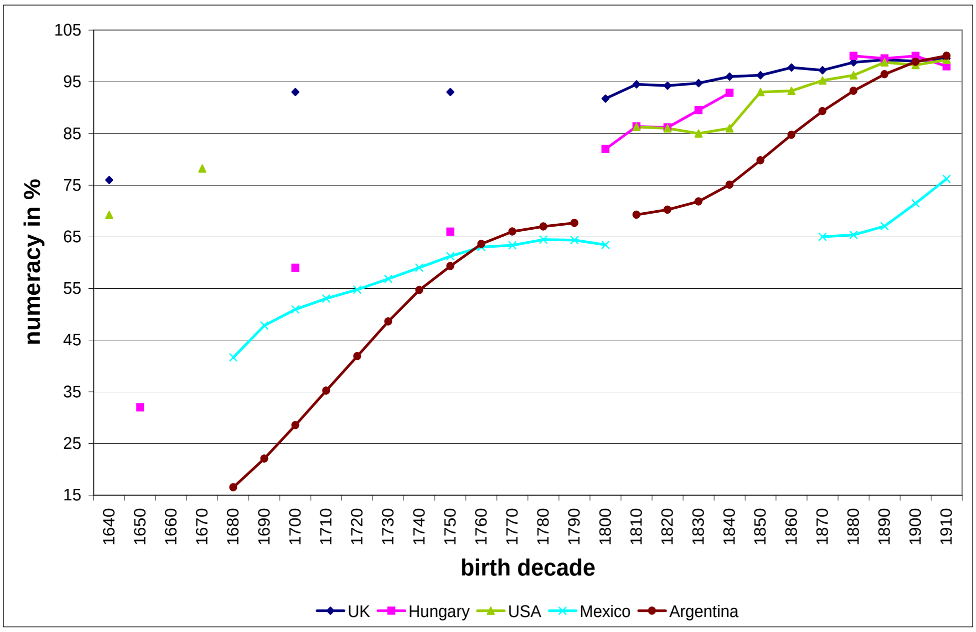

Figure 3.10: ABCC index of basic numeracy by birth decades for Argentina, Mexico, the UK, Hungary, and the U.S.

Notes: The decades refer to birth decades (1800-1809, etc.). Sources: see text and Table 3.1

3.9.3 Data Sources

Sources for Argentina

There is a large number of primary sources to study the development of numeracy in Argentina. The military census of 1744 for Buenos Aires is the first source available and has been reproduced in the *Documentos para la Historia Argentina* (Caillet-Bois 1919). For Buenos Aires we also have census data for 1771. The latter data set contains information on 11,140 individuals, after children and the elderly have been excluded. Data from the military census of 1818 fills the gap between 1771 and 1869. Moreover, we can incorporate into our analysis the samples of the first two national population censuses of the years 1869 and 1895. They contain extensive information on a representative sample of the Argentinean population and were collected by Somoza and Lattes (1967). This data permits new insights into differences among Argentinean regions as well as information on urban and rural areas. The time series can be complemented with aggregated data from the censuses of 1914 and 1947.

Sources for Peru

Our earliest source on Peruvian age data is a population census of Lima in 1700. The main purpose of the census was to determine the number of persons available for military service in case of foreign aggression. The Lima enumeration of 1700 is seen as one of the most important ones in the colonial period (Cook 1985). Names of the inhabitants and information on age, profession, and race of male household heads is given. Hence, we do not possess age information on all 37,000 inhabitants of Lima (Perez Canto 1985, p. 185) but on about 3,000 male household heads only. This certainly leads to an overestimation of numeracy. Our estimates might also be upper-bound estimates of numeracy because the indigenous population was underrepresented in this sample. It is noteworthy that the share of indigenous population in Lima was lower than in other cities (Mabry 2002, p. 58). Moreover, we do not have age information for females. Our analysis of numerical abilities will therefore primarily give insights into the educational development of the elite. We also analyzed the census data of 1940, which shed light on the birth cohorts from the 1880s onwards, in order to assess the difference between Lima and Peru as a whole. A further source on Peru is a prison sample from the years 1866 to 1909 which, to a certain degree, is biased towards the lower social classes of Lima, although the level of age heaping in the 1880s calcuclated from this source was actually quite similar to the level of the overall population in Lima (Baten, Pelger, and Twrdek 2008).

Sources for Mexico

The *Archivo de las Indias* in Seville offers a considerable wealth of primary sources for Mexico. For 1740-1743, population enumerations for Hidalgo, Guadalajara, and Oaxaca are included in our sample. For 1777, age data for Mexico City, Durango, Chihuahua, Baja California, Oaxaca, Puebla, and Veracruz are available. The *Censo de Revillagigedo*, carried out between 1790 and 1794 in Mexico, is our most important source for northern Latin America. It was the first enumeration that used a standard format for listing the population by name, age, sex, and family status (Werner 2001). Not all census forms have survived, but the remaining still provide information on 15 quarters of Mexico City, of which we have included a sample of 4,212 individuals. The Guadalajara Census project was started jointly by researchers from Mexico and the U.S. and aims at the preservation of and public access to census data of Guadalajara, a province in the Western Pacific area of Mexico. Another source refers to Coahuila province in the north (census year 1823), bordering Texas. For the 20th century, we have data on different provinces in 1930 and aggregated data from the census of Mexico in 1950.

Sources for Uruguay

The National Archive in Montevideo offers further interesting sources on Uruguay for studying the development of numeracy: prison records (1847-1868), the census of San Juan (1865), the census of Soriano (1832), and the census of Maldonado (1836). Further information comes from the published census of 1963.

Sources for Colombia

The Colombian census data originates from the National Archive in Bogotá. The earliest sources are population counts from the year 1777 from different provinces in Central and North Colombia. The census records of Cartagena de las Indias have been studied extensively by Calvo and Meisel (2005). Information on four quarters of the important merchant city have survived. The census of 1870 offers information on Cauca, Magdalena, Chocó, Quindio, and other departments and thus provides hints on the development of basic numerical abilities in a great variety of Colombian provinces. The census of 1928 of Putumayo, Vaupés, and Chocó additionally provides individual age data.

Sources for Brazil

Our material on Brazil starts only in the 19th century. It is based on aggregated data of the censuses in 1890 and 1920. For the latter, only the provincial capitals are reported in sufficient age-specific detail. For 1950, we have the Brazilian census for the whole country in an aggregated form. For 1872, we have numeracy estimates for the district São Cristovão, which was an upper-class-biased district. This sample includes not only the upper strata of the society but also a higher share of slaves (38 percent versus 15 percent on average for Brazil in 1872; see Leff 1974).

3.9.4 Primary Sources

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Mexico [Mexico 1740-44] Census of Ixmiquilpan 1740: Archivo General de Indias, Ind, 107; Census of Pozos 1743: Archivo General de Indias, Ind, 107; Census of southern central Mexico 1743: [Place unreadable, Platt (1998): Tlazazalca, Michoacán, Tetela del Rio or Guerrero], Archivo General de las Indias, Ind, 108; Census of Chichihualtepec 1743: Archivo General de las Indias, Ind, 108; **[Center 1777]** Census of Ciudad de los Angeles 1777: Archivo General de las Indias, Mex, 2578; Census of Piaxtla 1777: Archivo General de las Indias, Mex, 2578; Census of Totoltepec 1777: Archivo General de las Indias, Mex, 2579; Census of Nopalucan 1777: Archivo General de las Indias, Mex, 2579; Census of Quanquecholan 1777: Archivo General de las Indias, Mex, 2579; **[North 1777]** Census of San Gregorio 1777: Archivo General de las Indias; Census of Real de Minas de Nuestra Senora del Rosario 1777: Archivo General de Indias, Gua, 103 and Gua, 250;Census of los Remedios 1777: Archivo General de las Indias, Ind, 1526; Census of San José de Animas 1777: Archivo General de las Indias; Census of San José de Pimas 1777: Archivo General de las Indias; Census of Suchil 1777: Archivo General de las Indias; Census of Penol 1777: Archivo General de las Indias; Census of Tonanchi 1778: Archivo General de las Indias; **[Mexico City 1777]** Census of Mexico City 1777: Archivo General de las Indias; Census of Revillagigedo 1790: Instituto Nacional de Estadística, Geografía e Informática (2003); Census of Guadalajara 1821: Guadaljara Census project [http://www.fsu.edu/]; Census of the Municipality of Monclova 1822-23; Censo del Pueblo de San Francisco de Tlaxcala 1823; Censo de la Hacienda de Castaños y Bajan 1822-23; Censo de la Hacienda de Alamo 1823; Censo de la Hacienda de Encinas 1823; Censo de la Hacienda de San Vicente el Alto 1823; Censo de la Hacienda de Santa Ana 1823; Censo de la Hacienda de San Juan Bautista 1823; Censo de la Hacienda de San José 1823; Censo de la Hacienda de San Ignacio del Paso Tapado 1823: Grupo Exploradores Coahuiltecos [http://mx.geocities.com/camino_real_ mva/]; Census of Guanajuato 1930: FSI, Microfilm 4107114; Census of Minas de Luz 1930: FSI, Microfilm 4107114; Census of Mineral de los Llamitos 1930: FSI, Microfilm 4107114; Census of Ahualuco 1930: FSI, Microfilm 4107751; Census of Coyuca de Benitez 1930: FSI, Microfilm 4107141; Census of Tepoztlán 1930: FSI, Microfilm 4107265; Census of Mezquital 1930: FSI, Microfilm 4107065; Census of Tetecala 1930: FSI, Microfilm 4107265; Census of Tlaltizapan 1930: FSI, Microfilm 4107265; Census of Tetecala 1930: FSI, Microfilm 4107265; Census of Tlaltizapan 1930: FSI, Microfilm 4107265; Census of Mexico 1950: UN (1955), Demographic Yearbook, p.304.

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3.9.5 Data Set

Table 3.5: Data set

Country/Region and Census Year	Birth decade	Observations	Whipple	ABCC
Buenos Aires 1744	1680	303	363	47
Buenos Aires 1744	1690	501	371	46
Buenos Aires 1744	1700	941	338	52
Buenos Aires 1744	1710	1,434	328	54
Buenos Aires 1771	1710	949	324	55
Buenos Aires 1771	1720	1,832	313	58
Buenos Aires 1771	1730	3,358	275	65
Buenos Aires 1771	1740	5,001	277	65
Buenos Aires 1778	1720	105	300	60
Buenos Aires 1778	1730	153	304	59
Buenos Aires 1778	1740	243	239	72
Buenos Aires 1778	1750	394	286	63
Buenos Aires 1818	1760	88	193	81
Buenos Aires 1818	1770	190	208	78
Buenos Aires 1818	1780	254	181	84
Buenos Aires 1818	1790	358	210	78
Argentina 1869	1810	3,221	260	68
Argentina 1869	1820	6,598	241	72
Argentina 1869	1830	11,142	218	76
Argentina 1869	1840	17,815	234	73
Buenos Aires 1869	1810	352	226	75
Buenos Aires 1869	1820	826	202	80
Buenos Aires 1869	1830	1,493	177	85
Buenos Aires 1869	1840	2,334	181	84
Santa Fé 1887	1820	114	232	74
Santa Fé 1887	1830	234	207	79
Santa Fé 1887	1840	280	205	79
Santa Fé 1887	1850	474	191	82
Argentina 1895	1830	4,001	230	74
Argentina 1895	1840	7,989	222	76
Argentina 1895	1850	13,875	191	82
Argentina 1895	1860	18,032	200	80
Buenos Aires 1895	1830	682	177	85
Buenos Aires 1895	1840	1,415	169	86
Buenos Aires 1895	1850	2,548	150	90
Buenos Aires 1895	1860	3,173	163	87

Country/Region and Census Year	Birth decade	Observations	Whipple	ABCC
Argentina 1914	1850	340,213	165	87
Argentina 1914	1860	574,992	160	88
Argentina 1914	1870	922,034	137	93
Argentina 1914	1880	1,449,605	151	90
Argentina 1947	1880	1,140,200	96	100
Argentina 1947	1890	1,697,562	100	100
Argentina 1947	1900	2,286,936	99	100
Argentina 1947	1910	2,605,241	122	96
São Cristovão 1870	1810	59	186	83
São Cristovão 1870	1820	143	203	79
São Cristovão 1870	1830	239	182	84
São Cristovão 1870	1840	250	228	74
Brazil 1890	1830	586,793	235	73
Brazil 1890	1840	1,021,027	226	75
Brazil 1890	1850	1,605,498	205	79
Brazil 1890	1860	2,323,131	221	76
Brazil 1920	1860	102,312	181	84
Brazil 1920	1870	180,316	179	84
Brazil 1920	1880	279,862	156	89
Brazil 1920	1890	447,566	165	87
Brazil 1950	1890	2,221,106	164	87
Brazil 1950	1900	3,844,441	157	89
Brazil 1950	1910	5,774,083	141	92
Brazil 1950	1920	8,143,411	155	89
Cartagena 1777	1710	269	257	69
Cartagena 1777	1720	476	251	70
Cartagena 1777	1730	667	207	79
Cartagena 1777	1740	1,019	299	60
Colombia 1777	1710	168	265	67
Colombia 1777	1720	254	289	62
Colombia 1777	1730	398	241	72
Colombia 1777	1740	734	299	60
Colombia 1870	1810	254	260	68
Colombia 1870	1820	399	259	68
Colombia 1870	1830	557	251	70
Colombia 1870	1840	1,177	274	65
Colombia 1928	1880	85	288	62
Colombia 1928	1890	203	268	66
Colombia 1928	1900	279	247	70

Country/Region and Census Year	Birth decade	Observations	Whipple	ABCC
Colombia 1964	1900	727,666	175	85
Colombia 1964	1910	1,178,083	160	88
Colombia 1964	1920	1,796,228	142	92
Colombia 1964	1930	2,356,068	156	89
Hidalgo/Guanajuato/ Oaxaca 1740-44	1680	118	343	51
Hidalgo/Guanajuato/ Oaxaca 1740-44	1690	189	299	60
Hidalgo/Guanajuato/ Oaxaca 1740-44	1700	348	279	64
Hidalgo/Guanajuato/ Oaxaca 1740-44	1710	573	279	64
Mexico - Central 1777	1710	550	281	64
Mexico - Central 1777	1720	777	260	68
Mexico - Central 1777	1730	1,437	218	76
Mexico - Central 1777	1740	1,615	266	67
Mexico - City 1777	1710	53	255	69
Mexico - City 1777	1720	86	285	63
Mexico - City 1777	1730	170	274	65
Mexico - City 1777	1740	299	274	65
Mexico - North 1777	1710	70	243	71
Mexico - North 1777	1720	125	244	71
Mexico - North 1777	1730	184	236	73
Mexico - North 1777	1740	326	283	63
Mexico - City 1790	1730	341	305	59
Mexico - City 1790	1740	755	280	64
Mexico - City 1790	1750	1,271	241	72
Mexico - City 1790	1760	1,845	269	66
Guadalajara 1821	1760	1,438	311	58
Guadalajara 1821	1770	3,017	312	58
Guadalajara 1821	1780	4,975	295	61
Guadalajara 1821	1790	7,195	318	56
Coahuila 1823	1760	150	253	69
Coahuila 1823	1770	307	202	80
Coahuila 1823	1780	483	198	80
Coahuila 1823	1790	658	270	66
Mexico 1930	1790	1,432	243	71
Mexico 1930	1800	2,113	250	70
Mexico 1930	1870	514	278	64
Mexico 1930	1880	908	256	69

Country/Region and Census Year	**Birth decade**	**Observations**	**Whipple**	**ABCC**
Mexico 1950	1890	1,147,619	239	72
Mexico 1950	1900	2,028,193	220	76
Mexico 1950	1910	2,855,705	194	81
Mexico 1950	1920	3,902,717	191	82
Lima 1700	1640	274	374	45
Lima 1700	1650	515	354	49
Lima 1700	1660	896	298	60
Lima 1700	1670	1,112	323	55
Lima prison 1866-1909	1820	81	160	88
Lima prison 1866-1909	1830	481	158	88
Lima prison 1866-1909	1840	704	161	88
Lima prison 1866-1909	1850	500	156	89
Lima prison 1866-1909	1860	105	142	92
Peru 1940	1880	287,100	208	78
Peru 1940	1890	441,660	194	81
Peru 1940	1900	698,569	172	86
Peru 1940	1910	942,837	148	90
Lima 1940	1880	36,162	139	92
Lima 1940	1890	62,904	132	94
Lima 1940	1900	104,355	127	95
Lima 1940	1910	149,334	143	91
Montevideo 1772	1710	119	261	68
Montevideo 1772	1720	151	265	67
Montevideo 1772	1730	371	236	73
Montevideo 1772	1740	721	256	69
Montevideo 1791	1740	52	260	68
Montevideo 1791	1750	112	281	64
Montevideo 1791	1760	132	272	66
Soriano/ Maldonado 1834-36	1770	110	286	63
Soriano/ Maldonado 1834-36	1780	245	218	76
Soriano/ Maldonado 1834-36	1790	365	222	76
Soriano/ Maldonado 1834-36	1800	446	281	64
Montevideo prison 1846	1790	130	231	74
Montevideo prison 1846	1800	470	145	91
Montevideo prison 1846	1810	965	196	81

Country/Region and Census Year	**Birth decade**	**Observations**	**Whipple**	**ABCC**
Montevideo prison 1868	1830	130	185	83
Montevideo prison 1868	1840	345	178	84
Montevideo prison 1868	1850	793	178	84
Uruguay 1963	1900	234,244	104	99
Uruguay 1963	1910	297,306	109	98
Uruguay 1963	1920	373,428	105	99
Uruguay 1963	1930	385,341	130	94

4 Gender Equality and Inequality in Numeracy: The Case of Latin America and the Caribbean, 1880-1949

Abstract

This article outlines the development of gender disparities in education for 28 Latin American and Caribbean countries for the period from 1880 to 1949, using age heaping techniques. We explore in particular the hypothesis of a U-shaped development of women's education during economic development, i.e., a decrease in gender equality at lower levels of overall education, and increasing gender equality at higher levels. For the downward sloping part, we find some evidence, although this part is relatively small. The upward sloping part is strongly confirmed. We also find that non-Hispanic Caribbean countries had substantially lower gender inequality rates than Latin American countries. A second major contribution is to document the development of average numerical abilities (of both genders) in these 28 countries.

Gender Equality and Inequality in Numeracy: The Case of Latin America and the Caribbean, 1880-1949[1]

4.1 Introduction

Goldin (1995) argued that female labor force participation follows a U-shaped pattern: At low income levels, women work intensively in the production of goods, such as in today's West, Central, and East Africa. Much of the production takes place in the household and consists of agricultural activities (dairy, poultry, rice, etc.), or proto-industrial cottage work. As market integration increases and incomes start to rise, two separate effects might occur. Firstly, an income effect might lead women to spend more time with children and to do unpaid household work such as cooking and cleaning, especially if women's participation in the new opportunities of manual manufacturing employment is socially stigmatized. Secondly, the relative productivity of traditional home production might decline, as new production techniques in factories become more efficient. Home produced goods are substituted by factory products or those produced on large modern farms. At this second level of development, women's labor force participation might be lower, as Goldin observes in a cross-section for some of today's middle income countries (in Latin America or Southern Africa, for example). The relative social status of women might also decline. Finally, in the third phase of development, women's relative education strongly improves and opens the way to white-collar employment. This type of employment tends to be less stigmatized than manual manufacturing work. In this third phase or level, female participation rises again, confirmed by cross-sectional evidence from Europe, East Asia, North America, and parts of the Asia/Pacific region.

Mammen and Paxson (2000) confirm Goldin's study by estimating the U-shape for a number of years, and compare the absolute and relative education of women.[2] Especially

[1]This chapter is based on an article published in *Revista de Historia Económica: Journal of Iberian and Latin American Economic History*: Manzel and Baten (2009). The concept for the paper was developed jointly, the analyzes and writing was equally shared.

[2]They also included a fixed effects estimation in which the shape of the U is determined by variation within countries over time (1970-1985), rather than cross-sectionally.Relative to the level of development (measured with GDP per capita), the absolute number of women's schooling years increases more or less monotonically, whereas the gap in years of schooling reaches a maximum around 1000 US-$ with gap of about 2 years, and then remains more or less constant, after a modest increase to around 1 year (i.e. overall, the relative gap

important for our study is their finding that the level of female schooling remains mostly stagnant at very low development levels, i.e., for per capita income levels between 400 and 800 US-$. The gap between male and female education increases in this segment, from about one to two years of missing schooling for women. At an income level of 400 US-$, males have received about two years and females one year of formal schooling; at an income level of 800 US-$, males received three years, whereas women still only went to school for one year. In other words, they showed a declining part of the U-shape of education (i.e., increasing gender inequality) for a cross-section of developing countries 1970-1985 in the very low income range (Mammen and Paxon 2000, Figure 1).[3]

In general, female labor force participation tends to correlate with the social status of women. If female employment prospects are good, families might also invest more in girls' education. The main contribution of our study is to test whether the U-shape can also be observed for the relationship between average education and the ratio between female and male education, measured in terms of numerical abilities, in 28 countries of Latin America and the Caribbean during the 1880s-1940s. In earlier research, the strongest evidence for the U-shape came from cross-sectional evidence from rich, middle, and poor countries up until today, since long-run data on the development of gender equality is quite limited.[4] A new measurement strategy, age heaping, allows us to trace the relative numerical abilities of women in Latin American and Caribbean countries back to the birth cohort of the 1880s. Applying this methodology to assess gender equality in such a large number of countries is a substantial contribution, as it opens new avenues for research in this field. We find some evidence on the downward sloping part of the educational U-shape function, although this part is relatively small. In contrast, we find that most Latin American development during this period can be characterized by the upward sloping part of the educational U.

Why is gender inequality in education important? There is a fair amount of evidence

declines).

[3]These countries were at that time as poor or slightly poorer than the Latin American countries studied here, whose GDP per capita ranged between 681 US-$ in 1870 to 1,481 US-$ in 1913 (Maddison 2001).

[4]With the favorable exception of Goldin, who assessed the U.S. case and concluded that evidence on the declining part of the U had to be adjusted by underreporting of female production for the market.

showing an influence of gender inequality on economic growth. Most studies, however, come to different conclusions. Both negative and positive effects of gender inequality on economic growth are detected, although the latter are less numerous (see, for example, Dollar and Gatti 1999; Klasen 2002; Barro and Lee 1994). However, apart from the question of whether gender inequality has a (negative) effect on economic growth, there are more reasons why equity between sexes may be important for a society and should, therefore, be studied in greater detail. Equity in education is, for instance, a necessary precondition for equity of life chances. Better educated women tend to improve nutrition levels and the prevention of illnesses which reduces childhood mortality (Murthi et al. 1995, Hill and King 1993, p. 18). Intra-household distribution models show that income controlled by mothers has a greater positive effect on the health situation of the whole family than income under male control (Thomas 1990). If now the bargaining power of females relative to men increases with their educational level, this also leads to a positive impact on the health status of children.

However, in order to study these effects more closely, more human capital estimates for both genders are needed. Until now, data on the educational system in Latin America and the Caribbean were scarce. Literacy data were available for all countries after 1950, but before this time, only fragmentary information had been published for the larger countries. One important component of human capital is numeracy, the ability to process numbers. In order to measure numeracy, we estimate in this study the degree of age heaping, i.e., the tendency to round up or down one's age. It provides information about numeracy skills or numerical discipline and can be used as a proxy variable for an important component of the educational level of a population. By applying this method, we make a first attempt to estimate and outline the degree and development of gender disparities in numeracy for the period 1880 to 1949.

The Latin American and Caribbean region is not a homogenous one. There are cultural, social and economic development differences as well as historical ones. All these differences - in some cases striking differences, in other cases only subtle nuances - contribute inter alia to the evolution of gender disparities in education. Consequently, we will adopt a generalist approach and underline differences between countries and subgroups of countries without providing much country-specific detail. Further studies may be required to describe gender inequality in education in individual countries in greater detail.

The study is organized as follows. Section 2 presents a review of the literature concerning gender inequality in Latin America. Section 3 describes the methodology used to approximate gender differentials in numeracy, presents our data and discusses possible selectivity issues. Section 4 focuses on the development of numerical abilities and gender disparities in numeracy. Section 5 presents regression results on the determinants of gender inequality and section 6 concludes.

4.2 Education and Gender Related Issues in Latin America and the Caribbean

Today, Latin America has a surprisingly low level of gender inequality in education (Figure 4.1). It is the only region in the developing world, in which girls' secondary attainment equals boys' educational attainment (UN 2005). The ratio from female to male adult literacy rates has around the same value as for Central and Eastern Europe. Nevertheless, there are striking differences in gender inequality within Latin America. Indigenous women in Bolivia still have significantly lower education levels than men from the same ethnic group (De Ferranti et al. 2004, p. 96).

So why did gender inequality in education exist at all in earlier times? Explanations usually focus on two different subjects: Parental discrimination on the one hand and labor market discrimination on the other hand (Kingdon 1997). These two factors are linked to each other. Higher returns for male education than for women, in terms of higher wages for males are common even in today's industrialized countries, although the wage differential is much larger in developing countries. The return for sending a daughter to school is therefore lower, especially if we consider that daughters usually marry and leave home, so that they are not able to care for their parents in old age. In addition to this, in rural areas, long distances to the nearest school make schooling of girls less likely than that of boys. Parents are afraid of sending their daughters to school alone. Therefore, increased availability of schools may have a greater impact on schooling for girls than for boys (Greer 1969).

Emerson and Portela (2003) emphasize a strong persistence of child labor from one generation to the next, but parental schooling influences child labor decisions concerning sons and daughters in different ways. While the father's schooling has a stronger impact on sons' school attendance and child labor, the mother's educational level has a stronger impact on daughters' child labor status.

The social inequality of education is another crucial element, which actually survives until today and which might be correlated with gender inequality. During the colonial period, education was restricted to a small elite and was mainly the church's domain (Kowalewski and Saindon 1992). Engerman and Sokoloff (2005, p. 917) note that the franchise criterion of literacy often used in Latin America might have prevented the ruling elites from extending public schooling too quickly, as the poorer strata of voters would have achieved political power. Independence led to changes in the institutions providing education. The new ideas insisted on the modernization of society via education and this also included female education (Miller 2003, pp. 207; Reimers 2006, p. 434). The church resisted this, but its power was diminishing. One official Chilean church journal in the 1870s predicted that secondary schooling for women is *'nothing more than mere brothels financed by the taxpayers'* (cited in Fisher 1974, pp. 189). This view was not uncommon during the second half of the nineteenth century. While the church worried about female secondary education, only very few women received any education. Even though concern for female education increased, it was never argued that it was desirable for equity reasons. Rather, female education was exclusively intended to create better daughters, wives and mothers (Lavrín 1998, p. 103; Christiansen and Christiansen 2004, p. 47). In order to fulfill these roles and to raise children who would constitute the new society of an independent Latin America, female education could no longer be overlooked.

As one of the earliest countries in Latin America, Chile decreed in the organic law of Primary Education as early as 1860 that in all departments exceeding 2,000 inhabitants at least one school for boys and one for girls had to be established (Schiefelbein and Farrell 1982, p. 229). However such laws were never executed throughout Latin America. Scarce resources and a lack of teachers made female education a difficult task. Discussions about coeducational schools would not rise for decades and few qualified female teachers existed (Kent Besse 1996, p. 133). Domingo Sarmiento, one of the most important leaders in the promotion of education in Argentina, who influenced the educational debate throughout Spanish America, saw this problem and even recruited female school teachers from the United States (Miller 2003, p. 210). Thanks to these and similar measures, female education progressed slowly but surely.

The curriculum focused mainly on religious catechism, reading, writing and arithmetic. Girls were taught less writing and arithmetic, while sewing and household duties were included (Vaughan 1990). In particular, in countries specializing in agriculture, and in rural areas, female education was not seen as an important issue because the relevant knowledge could be learned through informal, oral methods (Stromquist 1992).

Total literacy rates in Spanish America increased from under 10 percent at independence (ca. 1820) to 15 percent around 1850, and to 27 percent in 1900 (Greer 1969). Nevertheless, regional disparities remained large until the end of the 20th century and literacy rates were consistently higher in cities than in urban areas (Mariscal and Sokoloff 2000, Newland 1994). Vaughan (1990) observes for Mexico: *'Whether a region or locality was commercially prosperous [...] was critical to school expansion'*. While 45 percent of the population in northern Mexico around 1910 was literate, in the center and in the south only 27 and 14 percent respectively, knew how to read and write (Vaughan 1990). As expected, gender disparities were considerably higher in the Mexican south and center than in the more prosperous northern regions (Greer 1969).

Mariscal and Sokoloff (2000) explore the reasons for the late investment in education in Latin American countries in contrast with the United States and Canada. Although income levels in the Latin New World were relatively high, wealth has traditionally been concentrated in the hands of the elite. The authors' main finding is that social inequality constrained the introduction of tax-financed compulsory primary education. In Argentina and Uruguay, in contrast, the desire to attract European immigrants resulted in a special interest on the part of the state in improving education. Immigrants demanded better public services and their higher educational level had a positive impact on the educational level of the whole country. Nevertheless, with the exception of these countries, Mariscal and Sokoloff (2000) conclude that social inequality and the concentration of political power in few hands impeded the formation of appropriate institutions to promote education during the 19th and early 20th centuries.

Thorp (1998) studies the gender gap in education for Latin American countries and notes that education usually improves first for boys and then for girls.[5] Therefore, the gender gap will rise initially until female education catches up and the gender gap declines.

Did differences exist between continental Latin America and the Caribbean in terms of gender inequality? Ellis (2003) emphasizes that the belief that non-Hispanic Caribbean societies were matrifocal is misleading, because this would obscure the fact that women also suffer discrimination in this region. However, gender inequality in education was substantially lower than in the Hispanic Caribbean or Latin America (Ellis 2003). Slavery had, in some cases, a leveling effect between the sexes. Race, color and class always played a more important role in this society than gender distinctions. Rich male and female whites enjoyed similar power over the lower classes. Differences between male and female slaves were minor. Both worked and both had been torn away from their cultural roots. Practicing the language or culture of their homelands was strictly forbidden. In this institutional framework, traditional gender roles could not develop as strongly as elsewhere (Wiltshire-Brodber 1999, pp.136-138). Moreover, Caribbean women worked outside the home more often than Latin American women and had a greater economic influence within the family.

Today, these countries even show female education advantages (Ellis 2003, pp. 11) and the expression *'marginalization of Caribbean men'* (Ellis 2003, p. 147) has become famous. Caribbean women contribute significantly to the income of their families. Moreover, males migrated more often in search of employment, leaving wife and children who had to earn

[5]She defines the gender gap as the absolute difference between adult literacy rates of males and females.

their own incomes (Brereton 1999, p. 130). The share of female-headed households in the Caribbean is therefore exceptionally high and these households are not as stigmatized as in Latin American societies. Therefore, we might expect lower gender inequality especially in the non-Hispanic Caribbean.

In sum, Latin American educational development was relatively slow, partly due to social inequality, although education developed more favorably in the southern cone countries. Gender inequality was high in earlier times, especially in continental Latin America and the Hispanic Caribbean. Today gender inequality in education is relatively low, so we might expect a more egalitarian labor force participation in the future (Goldin 1995).

4.3 Data and Methods

Age heaping has been used a number of times recently to measure education levels (Mokyr 1983; Crayen and Baten 2008 and 2009; A'Hearn, Baten, and Crayen 2009; de Moor and van Zanden 2008; Clark 2007; Manzel 2007; Baten, Crayen, and Manzel 2008, see also the applications in Cinnirella 2008; Mironov 2006; O'Grada 2006). It describes the phenomenon that people tend to round up or down their age, mostly in multiples of five, when asked how old they are. The main reasons for this are the lack of knowledge about their real age or the lack of numerical discipline. Consequently, estimating the degree of age heaping gives us information about the educational system as well as about institutions in a society.

As early as the 1950s, Bachi (1951) and Myers (1954) found a correlation between the degree of age heaping and literacy. Mokyr (1983) was the first to apply age heaping as a proxy variable for the educational level of a population in order to investigate whether there was a brain drain from pre-famine Ireland. Studies find a strong negative correlation between age heaping and literacy or schooling, such as Crayen and Baten (2008) for the 19^{th} and 20^{th} centuries, A'Hearn, Baten and Crayen (2009) for the 19^{th} century U.S. and Europe during the early modern period, Manzel and Baten (2008) for Argentina during the 19^{th} century, and Nagi, Stockwell, and Snavley (1973) for African countries of the mid-20th century. To measure the degree of age heaping, various indices can be used. A'Hearn, Baten, and Crayen (2009) show that the Whipple Index is most appropriate for this purpose. It determines the tendency of age heaping on the digits 5 and 0 and is calculated by taking the ratio of the sum of people reporting an age ending on multiples of five and the total sum of people in a certain age range. This ratio is then multiplied by 500. Meaningful interpretations of the index vary between 100 and 500.[6] In the case of 100, no age heaping on multiples of five is present, in the case of 500, the age data contain only digits ending in multiples of five (Hobbs 2004).

$$Wh = \left(\frac{\sum(Age_{25} + Age_{30})}{\frac{1}{5} \cdot \sum(Age_{23} + Age_{24} + ... + Age_{32})} \right) \cdot 100 \tag{4.1}$$

Hence, the Whipple Index (Wh) gives us information about numeracy skills or numerical discipline and can be used as a proxy for an important component of the educational level of a population. The calculation of the Whipple Index requires single age data for ten successive years, so that each terminal digit appears once. Mortality will have the effect that fewer people are alive at age 44 than at age 40, and at age 49 than at age 45, which could bias the Whipple Index downwards (Crayen and Baten 2009). Therefore we choose the age groups 23-32, 33-42, etc. to overcome this problem. We exclude age data for under 23-year olds, because many young males and females married in their early twenties or late teens and had to register as voters, military conscripts, etc. On such occasions, they were repeatedly subject to age requirements, a condition which gave rise to increased age awareness. Moreover, individuals grow physically during this period, which makes it easier to determine their age with a relatively high accuracy.[7]

Age information for over 72-year olds is not included as age statements of older people involve several problems: Age exaggeration, survivor bias, higher mortality of males (Del Popolo 2000), and other household members who report the ages of older persons play a

[6] A Whipple Index of 0 is theoretically possible and would mean an avoidance of ages ending in 5 and 0. However, values below 95-100 are uncommon.

[7] A 17-year-old might round up/down to 18 or 16, but not to 15 or 20. Moreover, children were excluded because of a high likelihood that the parents rather than the child himself answered the question.

more pronounced role than at younger ages.[8]

The Whipple Index is defined inversely, i.e., it represents lack of numeracy rather than numeracy. For an easier interpretation, A'Hearn, Baten, and Crayen (2009) suggested another index, the ABCC index.It transforms the Whipple Index and yields an estimate of the share of individuals who correctly report their age:

$$ABCC = \left(1 - \frac{(Wh - 100)}{400}\right) \cdot 100 \tag{4.2}$$

if $Wh \geq 100$; else $Wh = 100$

The method of approximating educational levels with age heaping behaviour certainly has its deficiencies in measuring human capital, as misreporting of ages may also have political or cultural reasons. The degree to which age heaping is influenced by schooling and the effect of other institutional factors is not easy to disentangle, although Crayen and Baten (2008) assessed this and found that schooling was more important than other factors such as bureaucracy and previous census-taking. We conclude that - at least in the absence of other indicators - age heaping is a valuable instrument to approximate the development of human capital.

4.3.1 Data and Representativeness

We use official census data available from the United Nations Statistical Yearbooks to estimate numeracy levels for 28 Latin American and Caribbean countries from 1880 to 1949 (see the Appendix for a complete list). Our data contain information for all continental Latin American countries with the sole exception of Paraguay.[9] For the Caribbean, we

[8]Studying population enumerations of eight Latin American countries, Del Popolo finds that the share of population with a stated age of 90 and higher is highly correlated with the Whipple Index for 53 to 82-year olds. Thus, countries with stronger age heaping might have more age exaggerations. A further result of her study is that the age error increases with age. Thus, not only does heaping from 72 to 75 play a role, but also heaping from age 72 to 80, 90, or 100. At what age do these effects become too strong to measure age heaping in a reliable way? We do not know this with certainty. In some countries, the effect becomes visible from the age of 70 onwards, in others only from the age of 80. In order to obtain reliable results, we exclude those older than 72 from our analysis.

[9]We decided to exclude Paraguay from an analysis, as data from the censuses of 1962 and 1972 published in the United Nations Demographic Yearbooks not only differed considerably in their heaping behavior, but also gave completely different total population figures. While the census of 1962 gave a total population of 1.7 Mio for the age range 23-72, the census of 1972 covered only around 875,000 inhabitants in the same age range.

have reliable data for 9 countries, including Puerto Rico as a relatively advanced country and Haïti, the poorest country of the region. Based on the number of inhabitants at each age, we calculated Whipple and ABCC Indices for each country and birth decade. If data were available from more than one census in a country, we obtained two different Whipple Indices for a birth decade. In a few cases, the age heaping estimates differed substantially between the two census years. After studying the institutional environment of census-taking we found that in some cases the situation differed. For example, passports had been introduced, so that people could look up their age. This occurred, for instance, in the case of Haïti. While in the census of 1950 pronounced age heaping patterns were observable, in the census of 1971, age heaping had disappeared completely. In order to obtain reliable estimates, we only included censuses if the population was directly asked for their age and passports or similar documents were not widely available (see the appendix concerning the included censuses). If the institutional circumstances changed only very modestly, and the estimated age heaping between an early and a late census differed little, we estimated Whipple Indices on the basis of the earlier census and extrapolated for later birth decades with the growth rates of the later census, but indexing the series on the levels of the earlier census (see the Appendix Table 4.4). However, in the regression analysis in section 4.4, we excluded the estimated values to make sure that we did not introduce biased data. Estimated values are only used in the descriptive figures.

How did the census enumerators obtain their information? Is it possible that we are measuring the numerical abilities of the enumerator or his ability to estimate age? These are legitimate concerns when we try to approximate numeracy with census data. We do not deny that this is a severe problem and may in some cases bias our results. Some enumerators might have taken their duties more seriously than others, and we do not have information on whether all household members were asked individually in all cases. We know that census takers were required to ask each person individually (see, for instance, Ministerio de Economia 1965, p. XII) and information was collected by canvassers (Goyer and Domschke 1983, p. 8). If census takers influenced the results strongly, Whipple indices should vary considerably from one census to the next or within areas enumerated by different census takers. However, we find that this was not the case. Whipple indices for the same countries and birth decades in different census years differed only slightly if the institutional framework did not change. Therefore, our analysis is based on the assumption that census taker errors are uniformly distributed across our samples. For the late 18th and early 19^{th} centuries individual census data for Latin American countries are available. In these sources, census enumerators asked each person individually and did not adjust for obviously erroneous age information (Manzel and Baten 2008).

The reliability of official statistics, including also census statistics, has often been questioned for Latin American countries. So the crucial question is how reliable these population enumerations are. In the cases of Costa Rica and Peru, remote areas of the country were not directly enumerated. This will probably bias our numeracy estimates in these two countries upward, as remote areas with higher shares of indigenous people have fewer schools and therefore have lower educational levels. In Brazil parts of the census schedules of 1950 from Minas Gerais, São Paulo, and Paraná were lost (Goyer and Domschke 1983, p. 85). In the analysis, we will check the sensitivity of results by including and excluding these cases.

We consider censuses taken from 1947 onwards, a period when growing concern about improving official statistics began to arise. The United Nations, especially the Latin American and Caribbean Demographic Center (CELADE), provided technical assistance on how to carry out effective population enumerations and evaluate demographic studies (Goyer and Domschke 1983, p. 278). One or more test censuses were conducted in countries with little experience of census taking in order to train census takers as well as to improve the questionnaires (Goyer and Domschke 1983, p. 37 - 350). Will this have an effect on the accuracy of age statements? Probably not, as the question regarding one's age is a relatively simple one and we would not expect people to know their age more accurately only because they were asked two or three times for their age in a period of three years. Only a very long history of census taking (6 to 7 censuses) may positively influence numerical abilities and discipline in a society, as Crayen and Baten (2008) found out.

In sum, the factors 'underenumeration' and 'pilot census' presented above may potentially influence our results. Therefore, we will check the robustness of our results by excluding countries where underenumeration occurred as well as those who carried out one or more pilot censuses to improve the census quality.

4.3.2 The Development of Numeracy in Latin America and the Caribbean

In appendix Table 4.4, we present the numeracy levels and gender disparities for the birth decades of the 1880s to 1940s and Table 4.1 reports summary statistics. The Whipple and ABCC indices indicate a wide range of numeracy levels. Differences between countries are striking: While as early as 1880, Argentina only showed minor age heaping tendencies (Argentina had a numeracy level of 97.5, the same value as Portugal in 1940, see Crayen and Baten (2008), Ecuador had numeracy rates of only 52 percent in the 1880s. Huge differences remain between these countries until the middle of the 20th century (Figure 4.2 - 4.5). The leading countries in numeracy levels in Latin America are Argentina and Uruguay. Non-Hispanic Caribbean countries also feature very well. An exceptionally rapid improvement in numeracy levels took place in Ecuador, Puerto Rico, and Bolivia. In Ecuador, numeracy levels improved from 52 percent in 1890 to 84 percent in the 1920s and in Bolivia, the share of people who reported exact ages increased from 55 percent in the 1880s to 81 percent in the 1920s. And, very interestingly, Guatemala and Haïti started with values that were not exceptionally low in the 1880s, but obviously suffered major educational development problems in the subsequent period. Therefore, they ended up at relatively low levels of numeracy. Numeracy levels increased during the period under study in all three parts of this region at similar pace (Figure 4.6). However, the non-Hispanic Caribbean countries started at better levels, compared to the Hispanic Caribbean or Latin American countries.

According to their level of numeracy, we can group our countries in 4 categories: Countries with a relatively low level of heaping and those with a moderate, high and an extremely high level of age heaping (Figure 4.7). The countries shaded in dark grey on this map are those with a low numeracy level in 1900. The Southern Cone, Brazil, Costa Rica, Surinam, and Guyana had higher numeracy levels than the Central American countries and Mexico around 1900 (the smaller Caribbean islands are not visible here).

Which factors may contribute to the decline in age heaping? The determinants of improving numeracy are generally an expansion of education, via both formal schooling and informal education at home. This happened quite early especially in the countries with a high share of European immigration. In Argentina and Uruguay, the desire to attract European immigrants resulted in a special interest on the part of the state in improving education. Immigrants demanded better public services and their higher educational level had a positive impact on the educational level of the whole Argentinean population (Mariscal and Sokoloff 2000). Towards the end of the period under consideration, numeracy levels improved considerably in almost all countries. However, in the Domincan Republic, Guatemala, and Nicaragua, numeracy was still at a lower level than in the other countries. Uruguay, Guadeloupe, Trinidad and Tobago, Martinique, Surinam, and the Leeward Islands featured the highest numeracy levels towards the end of the period.

In sum, numerical abilities in the non-Hispanic Caribbean were consistently higher than in Latin America and the Hispanic-Caribbean countries of our sample.By 1940, differences were reduced but still existed. The educational system of the French, Dutch, and British might have led to a high educational level. The regression analysis below will address these differences further taking alternative variables into account.

4.3.3 The Development of Gender Equality in Latin America and the Caribbean

To measure educational equality between the sexes, we define a measure of ‘gender equality’ (GE) as

$$GE = -\left(\frac{(whf - whm)}{whm}\right) \cdot 100 \tag{4.3}$$

where whf and whm are the Whipple indices of females and males, respectively. Thus, the higher our measure of gender equality, the lower the share of women rounding up or down their age in comparison to men rounding up or down in a certain country. A positive (negative) gender equality index implies a female (male) numeracy advantage. Most of the time, the index will be negative. We formulate this as gender equality in order to make it more easily comparable with the literature on female labor force participation rates (Goldin 1995, Mammen and Paxson 2000). Of course, this does not imply that our countries were characterized by gender 'equality' between 1880 and 1949.

Applying our measure of gender equality in numeracy, we find substantial variation between countries (Figure 4.8). As we would have expected, our gender equality index is in most cases negative, indicating that women were less numerate than men during this period (indicated by darker grey tones). Argentina, Uruguay, Surinam, and Guyana had relatively good equality levels, whereas some of the Central American countries were characterized by stronger inequality between the genders.

Latin American countries had typically lower gender equality indices than Caribbean countries during the whole period under consideration (Figure 4.6). In both subregions, the overall trend is characterized by increasing gender equality in numeracy which went hand in hand with economic development. Among the Caribbean countries, even in Haïti - the poorest and least numerate country in the region - there was no evidence for gender inequality in numeracy. Colombia, Guatemala, and the Dominican Republic had relatively low levels of gender equality as well as low levels of overall numeracy (Appendix Table 4.4). In the Dominican Republic, the effect of a long and repressive dictatorship might have strengthened the patriarchic gender relationships. In Argentina, we can find no evidence for gender inequality in numeracy. It is the only country which, as early as in 1880, showed neither evidence for age heaping nor for gender disparities. Until the 1940s, gender equality increased substantially in all Latin American countries. Colombia and Guatemala still had gender equality indices below 10, but this implies a decline to a third of their initial level of inequality.

4.4 The U Hypothesis and Other Potential Determinants of Gender Equality

Until now, we have mostly described the development of numeracy and gender equality in Latin America and the Caribbean. In the following section, we will assess the question whether the temporal development of gender equality in numeracy follows a U-shaped pattern. In the introduction, we explained that female labor force participation has been identified by a U-shape in modern cross-sections by Goldin (1995) and Mammen and Paxson (2000). They argued that at initial levels of development, stigmata against women's work in the factories or the fixed cost of working outside the home might have reduced women's participation. Only as non-stigmatized white-collar employment became available and female education and wages rose, the share of female participation increased again (Goldin stresses mainly the former, Mammen and Paxson the latter factor).

We are interested here in the question whether the first declining and then increasing female labor force participation is also reflected in the equality of education. The economic mechanism might be that higher relative female income expectations motivate parents to send their daughters to school initially. In a second phase, the relative female education might have declined, or at least stagnated, due to factors such as: (a) a replacement of home production with factory production, (b) income effects enabling work at home (c) stigmata effects of married females working in factories. Finally, in the third phase, female equality of numeracy increases again. We actually see this development in some of the poorer countries in our data set, such as Ecuador and Colombia (Figure 4.10 and 4.11). In the other countries, this development cannot be observed. However, there is cross-sectional evidence that some of the poorest countries - such as Haïti - actually had quite low gender inequality. On average, the development of gender equality shows a small initial decline in educational equality in the Hispanic Caribbean, where the equality index declined from -20 to -22 between the 1880s and 1890s, and remained low in the 1900s (Figure 4.9). In Latin America, there was a stagnation between the 1880s and

1890s, whereas in the non-Hispanic Caribbean equality grew. [10]

To test this relationship systematically, we carry out a panel data analysis with gender equality in numeracy as a dependent variable (unbalanced panel, Table 4.2). This allows us to examine the time series and cross-sectional evidence for the U-shape hypothesis at the same time. Apart from the U-shape hypothesis, we need to examine a number of other factors. Firstly, female participation in elections could be a potentially important variable. However, in the case of our countries, between 1880 and 1949, only a few provided electoral rights to women and these rights came quite late. Hence, this dummy variable might pick up some of the time trend. As a second additional variable, democracy favors an equal distribution of resources, therefore perhaps distributing more education also to women. We measure democracy with the POLITY2 variable, which is basically an index of a wide variety of different participation and franchise indicators, ranging from -9 to +10 in our sample. Democracy values were higher in the 1890s and 1900s, whereas during the interwar period, a number of countries became more autocratic than before (for instance, Argentina). Given that at the same time, education increases and gender inequality is gradually reduced, there might be some trend correlation leading to opposite signs. Thirdly, some studies suggest that gender inequality might be high among indigenous tribes. Rosemary Thorp (1998, pp. 38) finds pronounced gender differences in countries with large indigenous populations like Bolivia, Peru, and Guatemala. However, Bustillo (1993) argues that the indigenous culture had egalitarian ideas towards women. Therefore, indigenous population in a society might influence gender equality in either way. Moreover, the language barrier could also play a role here. King and Bellew (1990) emphasize that the language thought and spoken in school was Spanish. As large parts of the population spoke exclusively indigenous languages, especially in rural areas, they were excluded from the schooling system, leading to lower education levels of indigenous people.

To test whether higher gender inequality is present in countries with a higher share

[10] Whether this development was a short trend or a temporary shock, perhaps during the first era of globalization, will have to be explored in further studies.

of indigenous population, we include a dummy variable for these countries. Information on the share of the indigenous population in Latin America and the Caribbean in a historical perspective is not available. Therefore, we will include a dummy variable that takes the value of one if a country has a share of 60 percent or higher of indigenous or part-indigenous population today.

We use a variety of different models to assess the U-shape hypothesis and the other variables (Table 4.2). We start with a fixed effects model, which basically shows that female equality declines at low levels of general education (the linear term of ABCC is negative), but it starts to increase at higher levels (the squared term of ABCC is positive). How steep the declining or increasing portion of this U-shape might be depends on the size of the coefficients. Plotting the predicted ('fitted') values of gender equality against the ABCC index indicates that the declining part of the U is small and the decline is modest (Figure 4.12). In contrast, the upward sloping part is large. This shape does not depend on the squared functional form that we have chosen for the ABCC variable. If we use a LOWESS estimator which does not impose a special functional form, the results are quite similar.[11]

In order to test the robustness of the fixed effects model, we also used a least square dummy variable model with and without dummy variables for birth decades, and find that the results are robust. By including the time dummy variables, the coefficients for the U-shape are still significant, at least at the 10% level of significance. The upward sloping part of the U is also economically significant, as can be seen in Figure 4.12. In contrast, our political variables are insignificant (general democracy) or only sometimes significant (female voting rights). The democracy variable has the opposite sign once (Table 4.2, Col. 2), i.e., democracy reduces gender equality. This might be caused by the fact that democratic values actually declined in the interwar years in some countries, whereas gender equality was growing. Moreover, the number of cases of this control regression might be too small to obtain reliable results. Female voting rights were introduced only towards

[11] Lowess (locally weighted scatterplot smoothing) uses locally-weighted polynomial regression techniques (see Cleveland 1979).

the end of the period. Therefore we cannot fully disentangle its effect from a general trend of increasing gender equality. When time dummies are included, it becomes insignificant due to multicollinearity effects. The share of the indigenous population is insignificant in two of three regressions. In one model it has a significantly negative influence on gender equality, that is, a higher share of indigenous population is associated with a lower level of gender equality (Column 3). Therefore, we can conclude that countries with a high share of indigenous population might show lower gender equality in education, but the effect is not robust.

In general, the relationship between general numeracy and gender equality might be bi-directional, not necessarily causal in only one direction. As we mentioned in the introduction, gender inequality may also hinder development (reverse causality). However, these growth effects might be more long-run in nature. Studying the development from one decade to the next over just seven decades, the effect from the general numeracy level on gender inequality might be stronger than the opposite direction of causality. In order to study this question, we provide some Two Stage Least Square estimates, using instrumental variables in the following section.

What might be good instrumental variables for the potentially endogenous effect of general numeracy? Given our discussion above, the fact of having been a Spanish or Portuguese colony before independence could be a good instrument, as the English, French, and Dutch brought a different educational culture to their colonies, which might have had an impact on gender equality.[12] As for the remaining part of the former Spanish and Portuguese colonies, we observed some differences in educational level to be caused by European immigration. Hence, we generated a dummy variable which is one for the cases of Argentina, Uruguay, and Chile. For the border case of Brazil, we generated a separate instrumental variable which is one for the three southern cone countries plus Brazil.

[12] For example, Browne (2003) and Ellis (2003, p.17-21) argued that female slaves in the French and British Caribbean occupied important economic roles. Therefore gender distinction had less tradition in these countries. In fact, the descriptive analysis above has shown that most non-Spanish-colonized Caribbean countries exhibited lower gender inequality, and that these disparities had been low, at least, since the end of the 19^{th} century. In the Hispanic Caribbean, in contrast, women were more constrained to household work, and formal education had been less important for them.

Good instrumental variables should be correlated with the potentially endogenous variable while not influencing the dependent variable, except via the potentially endogenous variable. The former is clearly true for both instruments, since both are correlated with general numeracy. The correlation of the former Spanish or Portuguese colonies variable for numeracy is -0.51. For the former Spanish or Portuguese colonies, the correlation of both immigration dummies is 0.28, both significant at the 1% level. In a joint regression of numeracy on both variables, both are significant. The latter criterion is also the case here: The effect of general numeracy on gender equality follows the same causal channel. Therefore, we conclude that both instruments are justified. In columns 4 and 5, two versions of IV regressions are displayed. They confirm the U-shape of the relationship studied here.

To test the robustness of our results further, we carried out the same regressions without the countries where pilot censuses were conducted (Table 4.3, Column 2) and in a second step without the countries where underenumeration occurred (Table 4.3, Column 3). The coefficients have the same sign and magnitude. Also, the significance level does not change considerably. The shape of the U might even be steeper using the more restricted samples.[13]Thus, our results remain robust to the inclusion of further variables or slight specification changes, as well as to a changing composition of the data set.

4.5 Conclusion

In this paper, we tested a hypothesis of a U-shaped development of gender equality relative to general numeracy, which was derived from a U-shaped development of female labor force participation relative to the general level of development (Goldin 1995, Mammen and Paxson 2000). The basic economic mechanism was that if relative female labor market prospects were better, the families might have invested slightly more in the education of their female offspring, and vice versa. This investment might have declined in the first phase of development studied here, but the decline turned out to be modest empirically.

[13] The information regarding which countries were excluded for the robustness check regressions can be found in the Appendix.

In contrast, an increase in gender equality (i.e., the upward sloping part of the U-shape) during the period under study can be strongly confirmed.

In order to test this hypothesis, we developed a method to quantify gender equality in numeracy by using the age heaping method. The advantage of this new method is the improved availability of age statistics or census data in order to estimate the education level. Especially for time periods and countries where data is scarce, this method promises new insights into topics that could not be explored yet, due to the lack of adequate statistics. We compiled a new data set for 28 Latin American and Caribbean countries measuring gender disparities in numeracy, covering the decades from 1880 to 1940. We also find evidence for pronounced differences within the region: While South American countries like Argentina and Uruguay already had relatively high gender equality in the late 19^{th} century; Central American countries had traditionally lower levels. Non-Hispanic Caribbean countries performed better in terms of gender equality, as well as in overall numeracy. Gender equality increased considerably during this period, leading to equal numeracy levels of males and females at the end of the period in most countries of our sample.

A second major contribution of this study is to document the development of average numerical abilities (of both genders) in these 28 countries. Some of the countries had already solved their innumeracy problem by the 1880s (Argentina, Guyana). Others experienced strong numeracy growth from initially low levels, but still did not reach 100 percent age numeracy by the birth decade of the 1940s, such as Mexico and Bolivia. And, interestingly, Guatemala and Haïti started with values that were not exceptionally low in the 1880s, but had obviously strong educational development problems in the subsequent period. Therefore, they ended up at relatively low levels of numeracy. In conclusion, this study is a first step to estimate the average numeracy level in these 28 countries, as well as to assess gender equality of numeracy and its determinants.

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4.7 Appendix

4.7.1 Tables

Table 4.1: Summary statistics

Variable	Obs.	Mean	Std. Dev.	Min.	Max.
ABCC	134	84.57	12.73	52.38	100
ABCC squared	134	7,313.47	2,078.71	2,743.53	10,000
Gender Equality	134	-7.35	8.74	-49.65	7.41
Dummy Europ. Immigration incl. Brazil	134	0.15	0.36	0	1.00
Dummy Europ. Immigration	134	0.11	0.32	0	1.00
Dummy Spanish or Portuguese Colony	134	0.61	0.49	0	1.00
Democracy	76	-0.17	4.77	-9.00	10.00
Dummy Female Voting Rights	112	0.04	0.21	0	1.00
Dummy Indigenous $>$ 60%	134	0.16	0.37	0	1.00
Dummy Under-enumeration	134	0.19	0.40	0	1.00
Pilot census	134	0.33	0.47	0	1.00

Notes: Estimated values are not included here. For sources, see Appendix.

Table 4.2: Regressions of gender equality in Latin America (1880-1949)

	(1)	**(2)**	**(3)**	**(4)**	**(5)**
Estimation technique	FE	LSDV	LSDV	IV	IV
Instrument				Col ImBR	Col Im
Constant	22.59	24.01	37.5*		
	(0.31)	(0.29)	(0.09)		
ABCC	-1.10*	-1.16*	-1.17*	-0.75***	-0.72***
	(0.061)	(0.08)	(0.06)	(0.00)	(0.00)
ABCC sq.	0.01*	0.01**	0.01**	0.01***	0.01***
	(0.025)	(0.03)	(0.04)	(0.00)	(0.00)
Democracy	-0.03	-0.04	-0.15		
	(0.6)	(0.83)	(0.37)		
Female Voting Rights	3.21*	3.20*	-0.03		
	(0.078)	(0.09)	(0.99)		
Indigenous	-4.81	-3.08	-18.51***		
	(0.14)	(0.40)	(0.00)		
Country dummies	(FE)	yes	yes	no	no
Time dummies	no	no	yes	no	no
Observations	73	73	69	133	133
Number of countries	16	16	15	28	28
Adj. R^2	0.25	0.84	0.89	0.27	0.29

Notes: Robust p-values in parenthesis. Only non-estimated values included. Col: former Spanish or Portuguese colony. Im: main three immigration countries Uruguay, Chile, and Brazil. Constants are omitted in Columns 4 and 5.

Table 4.3: Regressions excluding cases of underenumeration and pilot censuses

	(1)	**(2)**	**(3)**
Cases included	all	no underenumeration	no pilot census
Constant	52.05*	121.05**	80.05
	(0.082)	(0.048)	(0.14)
ABCC	-1.68**	-3.50**	-2.39*
	(0.038)	(0.032)	(0.096)
ABCC squared	0.01**	0.02**	0.02*
	(0.030)	(0.0288)	(0.087)
Democracy	0.10	-0.49**	0.20
	(0.57)	(0.037)	(0.60)
Female votin rights	3.24	3.08*	0.99
	(0.18)	(0.090)	(0.62)
Indigenous	-6.32*	-6.46	-4.96
	(0.051)	(0.19)	(0.22)
Observations	73	47	38
R^2	0.39	0.46	0.46

Notes: Robust p-values in parentheses. Only non-estimated values included. ***/**/* implies significance at the 1, 5, or 10% level.

4.7.2 Figures

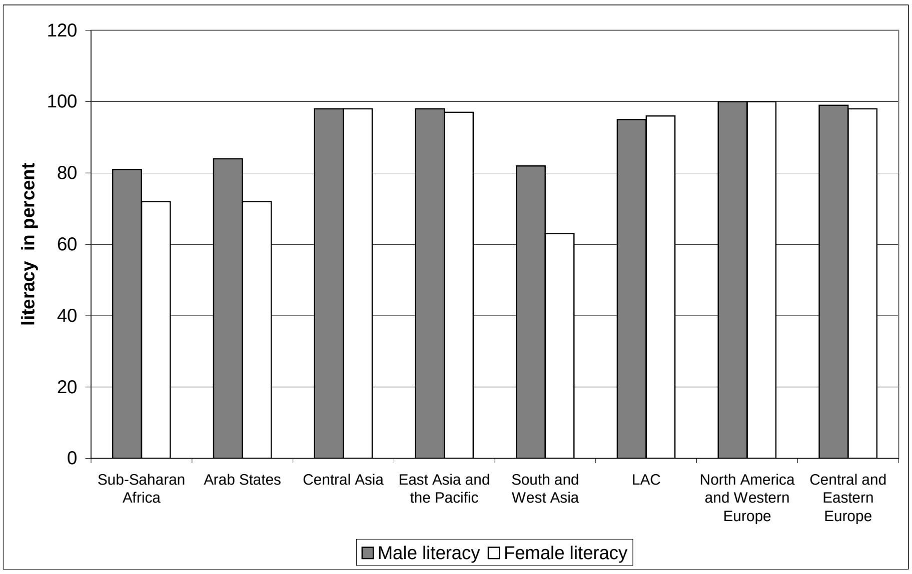

Figure 4.1: Male and female literacy rates, 2000-2004
Source: UNESCO (2004), table 3.9

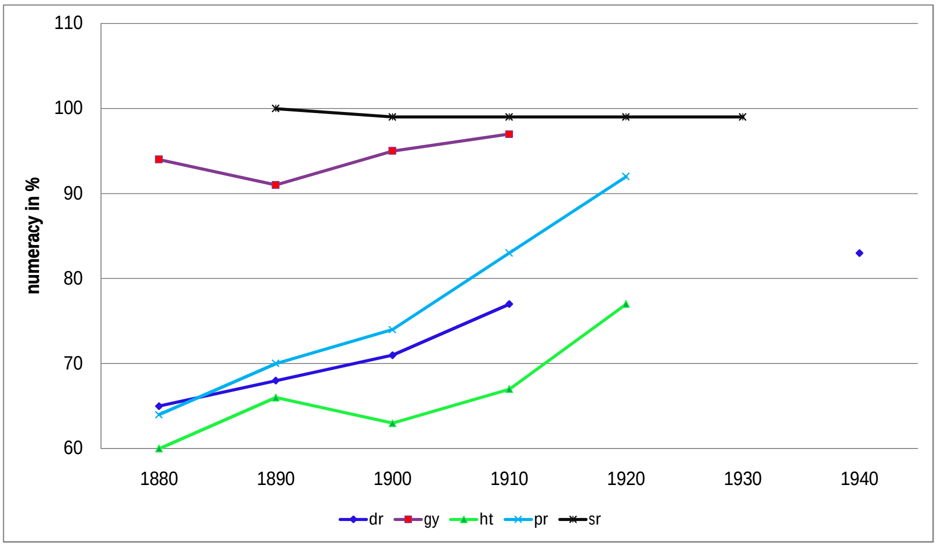

Figure 4.2: Numeracy in percent in the Dominican Republic, Puerto Rico, Haïti, Surinam, and Guyana

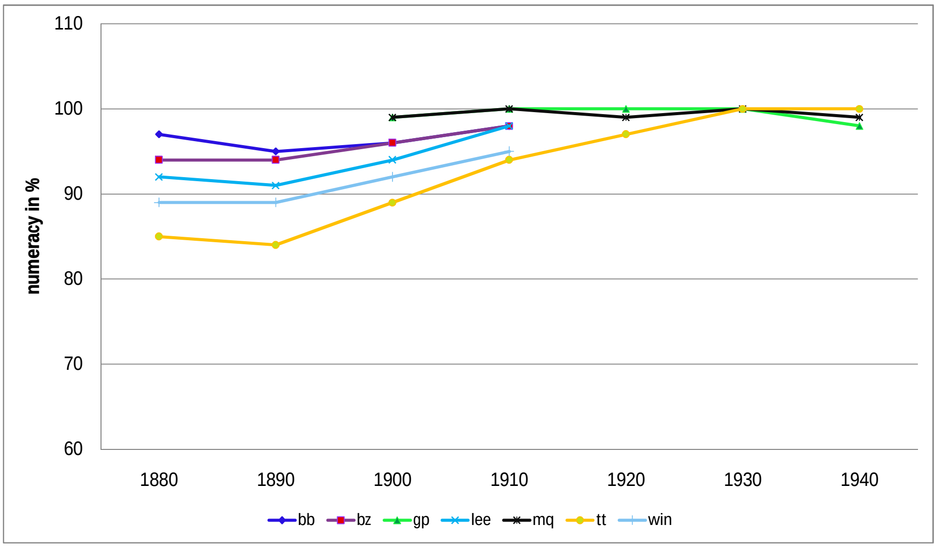

Figure 4.3: Numeracy in percent in Non-Hispanic Caribbean except Haïti, Surinam, and Guyana

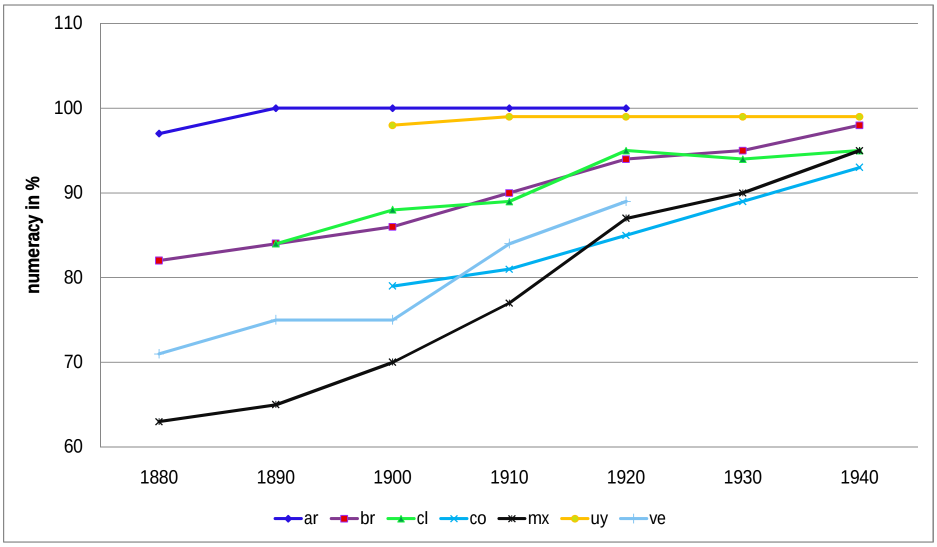

Figure 4.4: Numeracy in percent in Latin America, group I

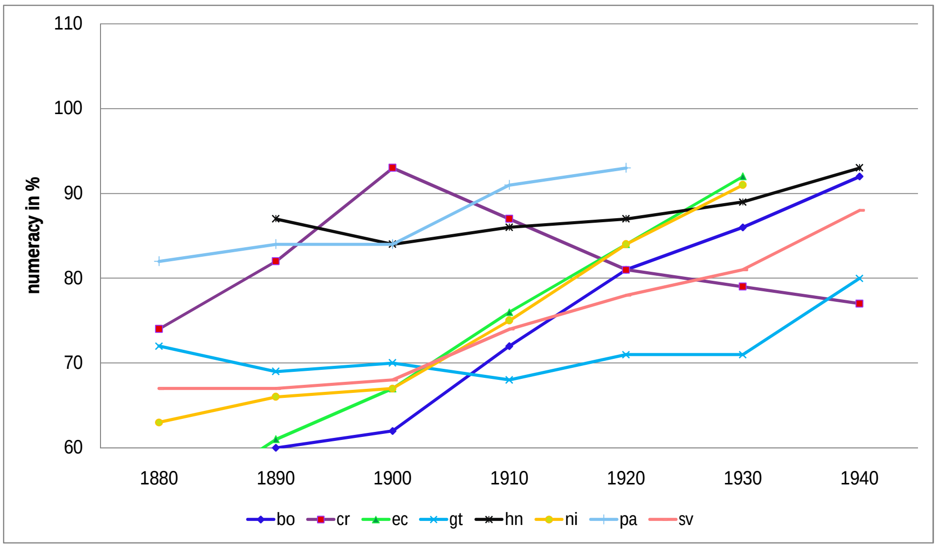

Figure 4.5: Numeracy in percent in Latin America, group II

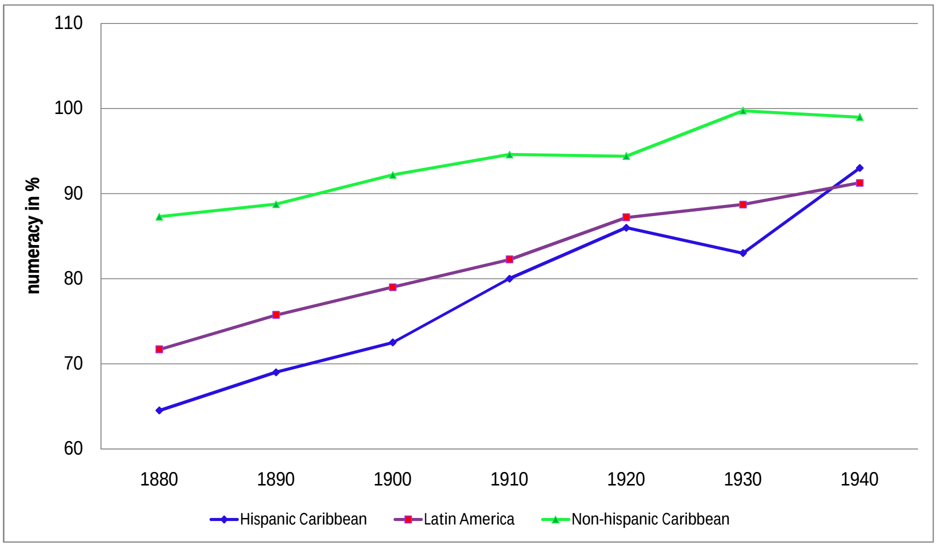

Figure 4.6: Development of numeracy in Latin America and the Caribbean

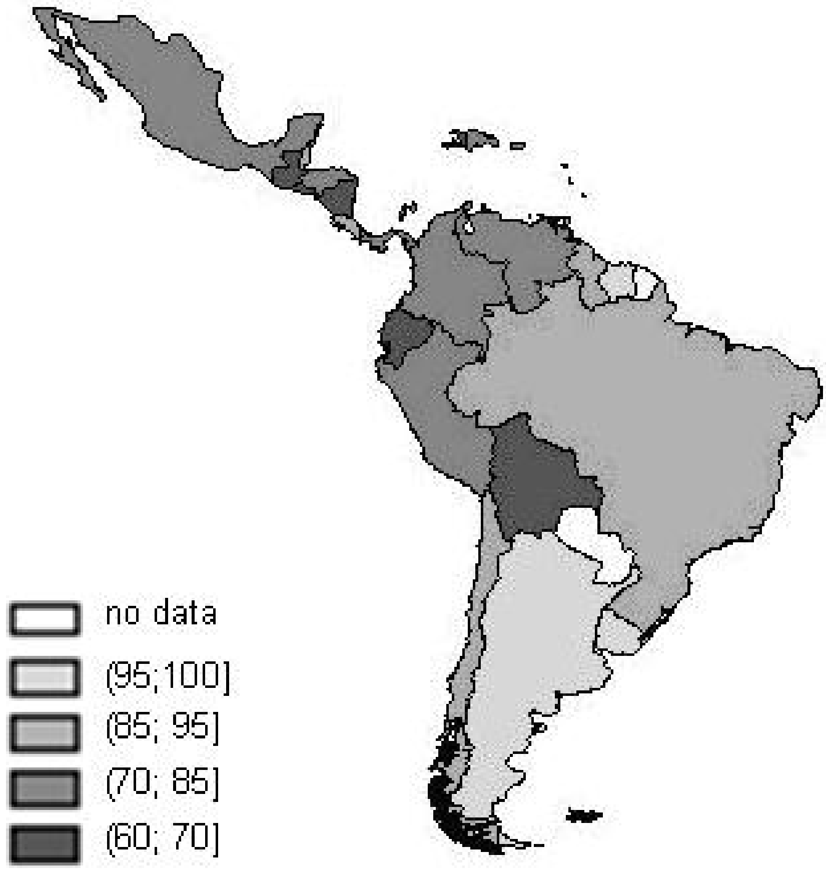

Figure 4.7: Numeracy in Latin American and Caribbean countries, 1900

Figure 4.8: Gender equality indices in Latin American countries, 1900

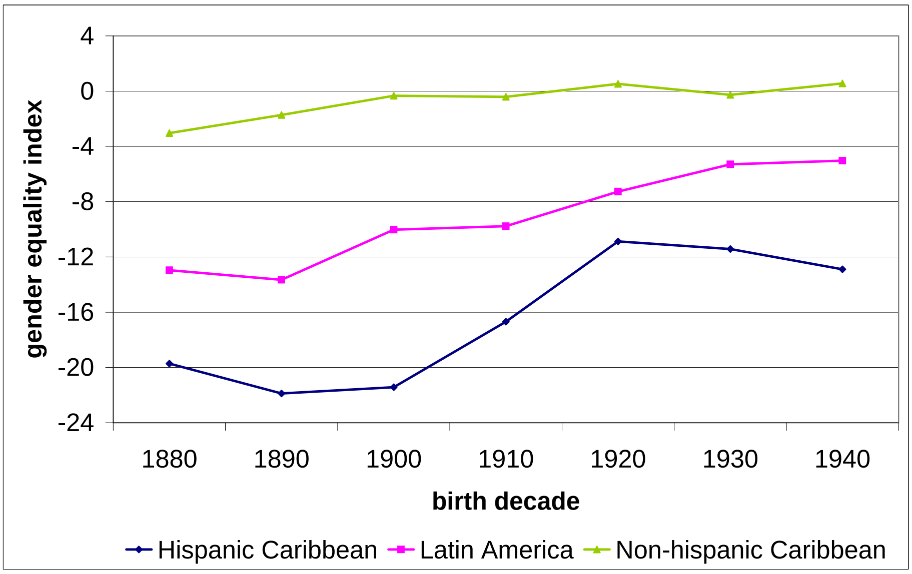

Figure 4.9: Gender equality indices in Latin America and the Caribbean

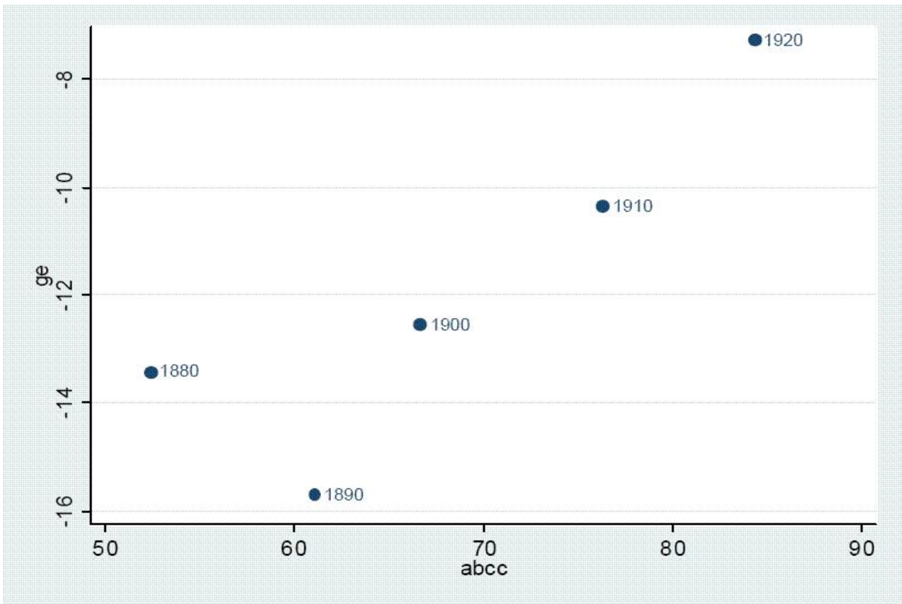

Figure 4.10: Gender equality and numeracy in Ecuador

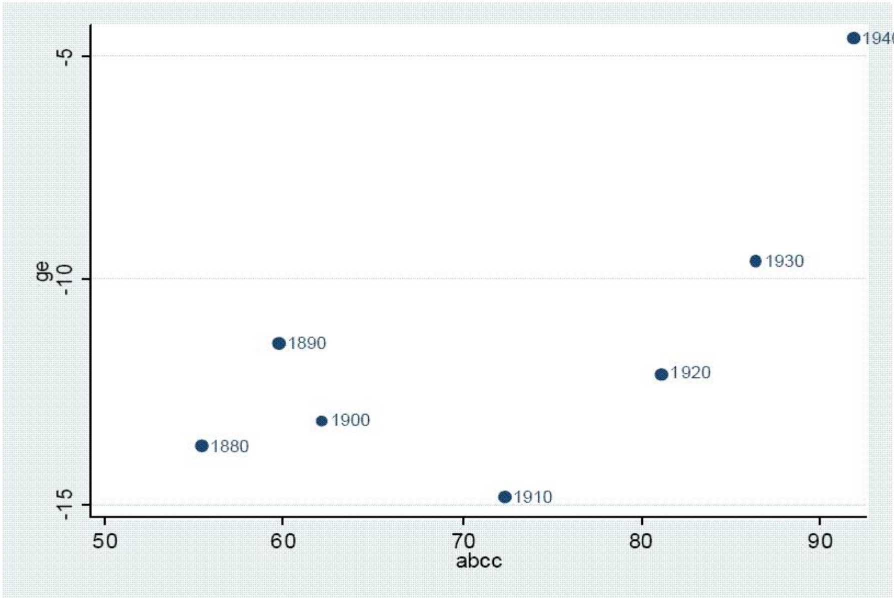

Figure 4.11: Gender equality and numeracy in Colombia

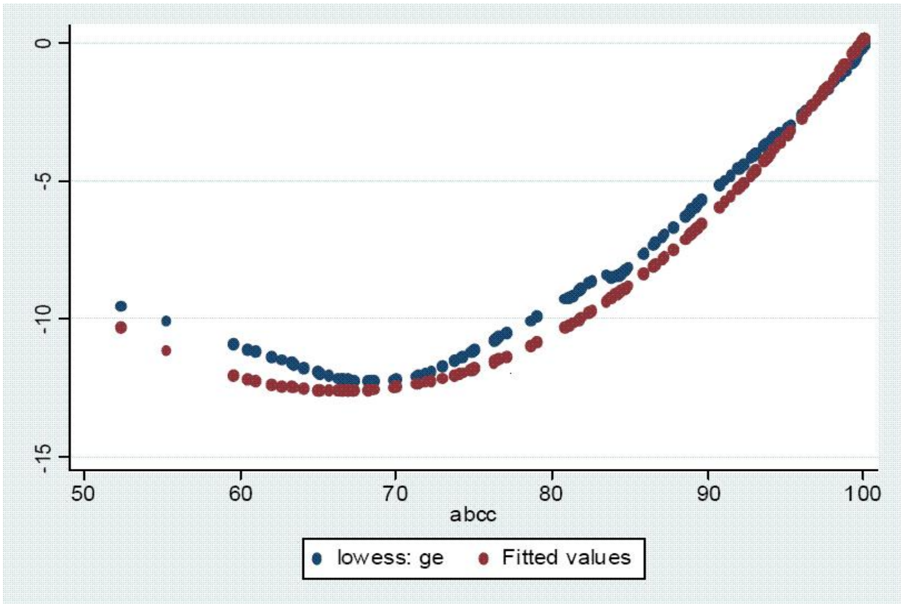

Figure 4.12: U-shaped pattern of gender equality in numeracy

4.7.3 Data Sources and Estimation Decisions

Census Data

1. Latin America

Argentina (ar): Census 1947 for birth decades 1880s-1920s; **Bolivia (bo):** Census 1950 for birth decades 1880s-1920s, birth decades 1930s-1940s estimated using growth rates of census 1976; **Brazil (br):** Census of 1950 for birth decades 1880s-1920s, birth decades 1930s-1940s estimated using growth rates of census 1970; **Chile (cl):** Census 1960 for birth decades 1890s-1930s, 1940s estimated using growth rates of 1970; **Colombia (co):** Census of 1964 for birth decades 1900s-1940s; **Costa Rica (cr):** Census of 1927 for birth decades 1880s-1890s, Census of 1950 for birth decades 1900s-1940s; **Ecuador (ec):** Census of 1950 for birth decades 1880s-1920s, 1930s and 1940s estimated using growth rates from census of 1962; **El Salvador (sv):** Census of 1950 for birth decades 1880s-1910s, 1920-40s estimated using growth rates from census 1971; **Guatemala (gt):** Census of 1950 for birth decades 1880s-1900s, 1910s-40s estimated using growth rates from census of 1973; **Honduras (hn):** Census of 1961 for birth decades 1880s-1930s, 1940s estimated using growth rates from census of 1974; **Mexico (mx):** Census of 1950 for birth decades 1880s-1920s, 1930s-40s estimated using growth rates from census of 1970; **Nicaragua (ni):** Census of 1950 for birth decades 1880s-1920s, 1930s estimated using growth rates from census of 1963 for birth decade 1930s; **Panama (pa):** Census of 1950 for birth decades 1880s-1920s, 1930s estimated using growth rates from census of 1960; **Peru (pe):** Census of 1940 for birth decades 1880s-1910s; **Uruguay (uy):** Census of 1975 for birth decades 1900s-1940s; **Venezuela (ve):** Census of 1950 for birth decades 1880s-1920s, 1930s/40s estimated using growth rates from census of 1961 for birth decades 1930s-1940s.

2. Hispanic-Caribbean

Dominican Republic (dr): Census of 1950 for birth decades 1880s-1910s, 1920s-40s estimated using growth rates from census 1976; **Puerto Rico (pr):** Census of 1950 for birth decades 1880s-1920s

3. Non-Hispanic Caribbean

Barbados (bb): Census 1946 for birth decades 1880s-1910s; **Belize (bz):** Census 1946 for birth decades 1880s-1910s; **Guadeloupe (gp):** Census of 1946 for birth decades 1900s-1940s; **Guayana (gy):** Census of 1946 for birth decades 1880s-1910s; **Haïti (ht):** Census of 1950 for birth decades 1880s-1920s; **Leeward Islands (lee):** Census of 1946 for birth decades 1880s-1910s; **Martinique (mq):** Census of 1967 for birth decades 1900s-1940s; S**urinam (sr):** Census of 1964 for birth decades 1890s-1930s; **Trinidad and Tobago (tt):** Census of 1950 for birth decades 1880s-1910s, census of 1970 for birth decades 1920s-1940s; **Windward Islands (win):** Census of 1946 for birth decades 1880s-1910s.

Data sources:

Census Data:

UN (various issues), Demographic Yearbook, New York, UN. For Costa Rica 1927: Centro Centroamericano de Población: http://ccp.ucr.ac.cr/bvp/censos/1927/index.htm, approached on August 25, 2008.

Indigenous population: http://www.integrando.org.ar/datosdeinteres/indigenas enamerica.htm

Women's suffrage: http://www.ipu.org/wmn-e/suffrage.htm, approached on August 25, 2008. We took only the unrestricted cases.

Democracy: Polity2 index, downloaded from http://www.systemicpeace.org/ polity/ polity4.htm approached on August 25, 2008.

Countries with pilot censuses: Chile, Costa Rica, Dominican Republic, Ecuador, Guatemala, Mexico, Nicaragua, Panama, Venezuela.

Countries with underenumeration: Brazil, Costa Rica, Ecuador, Honduras, Peru.

4.7.4 Data Set

Table 4.4: Data set

Country	Censusyear	Birth decade	Wh	Whm	Whf	GE	ABCC
ar	1947	1880	110	110	110	0.22	97
ar	1947	1890	100	100	100	0.00	100
ar	1947	1900	100	100	100	0.00	100
ar	1947	1910	100	100	100	0.00	100
ar	1947	1920	100	100	100	0.00	100
bb	1946	1880	113	115	112	2.73	97
bb	1946	1890	121	116	125	-7.28	95
bb	1946	1900	115	113	116	-2.78	96
bb	1946	1910	108	107	108	-0.61	98
bz	1946	1880	126	123	129	-4.77	94
bz	1946	1890	125	124	126	-1.58	94
bz	1946	1900	116	111	120	-8.32	96
bz	1946	1910	106	106	106	0.01	98
bo	1950	1880	279	261	296	-13.69	55
bo	1950	1890	261	247	275	-11.39	60
bo	1950	1900	252	235	266	-13.14	62
bo	1950	1910	211	195	224	-14.82	72
bo	1950	1920	176	165	185	-12.08	81
bo	estimated	1930	147	261	161	-9.56	86
bo	estimated	1940	129	261	135	-4.58	92
br	1950	1880	170	158	183	-15.60	82
br	1950	1890	164	156	172	-9.91	84
br	1950	1900	157	151	163	-8.20	86
br	1950	1910	141	138	145	-4.70	90
br	1950	1920	125	123	127	-3.19	94
br	estimated	1930	120	120	120	-0.03	95
br	estimated	1940	109	110	111	-1.13	98
cl	1960	1890	165	130	195	-49.65	84
cl	1960	1900	149	137	160	-16.52	88
cl	1960	1910	143	134	150	-11.90	89
cl	1960	1920	121	113	128	-13.86	95
cl	1960	1930	125	123	126	-2.11	94
cl	estimated	1940	119	117	121	-3.19	95
co	1964	1900	186	164	206	-26.00	79
co	1964	1910	175	158	191	-21.01	81
co	1964	1920	160	148	172	-16.36	85
co	1964	1930	142	135	150	-10.88	89
co	1964	1940	128	120	138	-14.62	93

Country	Censusyear	Birth decade	Wh	Whm	Whf	GE	ABCC
cr	1927	1880	203	193	214	-10.51	74
cr	1927	1890	173	171	175	-2.06	82
cr	1927	1900	129	127	131	-3.55	93
cr	1927	1910	151	147	155	-5.84	87
cr	1927	1920	176	172	180	-4.65	81
cr	1927	1930	184	180	188	-4.50	79
cr	1927	1940	194	185	203	-9.88	77
dr	1950	1880	240	210	270	-28.34	65
dr	1950	1890	226	201	256	-27.20	68
dr	1950	1900	214	191	241	-26.57	71
dr	1950	1910	192	171	214	-25.38	77
dr	estimated	1920	180	166	195	-17.62	80
dr	estimated	1930	167	157	175	-11.43	83
dr	estimated	1940	129	119	135	-12.90	93
ec	1950	1880	290	271	307	-13.42	52
ec	1950	1890	256	237	274	-15.69	61
ec	1950	1900	234	220	247	-12.53	67
ec	1950	1910	195	185	204	-10.35	76
ec	1950	1920	163	157	168	-7.27	84
ec	estimated	1930	134	122	145	-18.27	92
sv	1950	1880	232	220	244	-11.25	67
sv	1950	1890	234	227	240	-5.54	67
sv	1950	1900	227	223	231	-3.74	68
sv	1950	1910	204	202	205	-1.62	74
sv	estimated	1920	189	190	189	0.54	78
sv	estimated	1930	174	177	174	1.61	81
sv	estimated	1940	146	148	144	2.78	88
gp	1967	1900	102	106	100	5.45	99
gp	1967	1910	100	100	100	0.00	100
gp	1967	1920	101	100	105	-5.44	100
gp	1967	1930	100	100	100	0.20	100
gp	1967	1940	107	107	107	0.11	98
gt	1950	1880	212	185	243	-31.15	72
gt	1950	1890	225	199	254	-28.12	69
gt	1950	1900	220	197	243	-23.49	70
gt	estimated	1910	229	207	251	-21.13	68
gt	estimated	1920	218	201	236	-17.39	71
gt	estimated	1880	218	207	231	-11.69	71
gt	estimated	1880	178	170	189	-11.69	80
gy	1946	1880	124	121	126	-3.40	94
gy	1946	1890	136	135	137	-1.58	91

Country	**Censusyear**	**Birth decade**	**Wh**	**Whm**	**Whf**	**GE**	**ABCC**
gy	1946	1900	120	119	121	-1.76	95
gy	1946	1910	111	110	111	-1.30	97
ht	1950	1880	258	254	261	-2.58	60
ht	1950	1890	237	236	238	-1.09	66
ht	1950	1900	247	252	241	4.65	63
ht	1950	1910	231	240	223	7.41	67
ht	1950	1920	193	201	187	7.01	77
hn	1961	1890	152	143	160	-12.44	87
hn	1961	1900	163	157	169	-7.91	84
hn	1961	1910	156	151	161	-6.87	86
hn	1961	1920	153	152	155	-2.19	87
hn	1961	1930	144	143	145	-1.85	89
hn	estimated	1940	130	130	131	-0.73	93
lee	1946	1880	131	125	134	-7.27	92
lee	1946	1890	134	131	136	-3.54	91
lee	1946	1900	124	122	125	-2.37	94
lee	1946	1910	109	108	110	-1.85	98
mq	1967	1900	105	104	105	-0.32	99
mq	1967	1910	100	100	100	0.29	100
mq	1967	1920	102	104	101	3.04	99
mq	1967	1930	100	100	100	-0.13	100
mq	1967	1940	102	104	101	2.26	99
mx	1950	1880	249	231	266	-15.11	63
mx	1950	1890	239	221	257	-15.90	65
mx	1950	1900	220	206	233	-13.26	70
mx	1950	1910	194	181	206	-13.52	77
mx	1950	1920	154	145	162	-11.50	87
mx	estimated	1930	139	134	143	-6.65	90
mx	estimated	1940	122	119	123	-3.05	95
ni	1950	1880	246	234	257	-9.75	63
ni	1950	1890	235	227	242	-6.36	66
ni	1950	1900	231	226	235	-3.83	67
ni	1950	1910	201	197	204	-3.56	75
ni	1950	1920	165	163	167	-2.50	84
ni	estimated	1930	135	137	137	-0.06	91
pa	1950	1880	171	167	175	-4.66	82
pa	1950	1890	165	166	163	1.76	84
pa	1950	1900	165	167	162	2.75	84

Country	Censusyear	Birth decade	Wh	Whm	Whf	GE	ABCC
pa	1950	1910	137	134	140	-3.82	91
pa	1950	1920	128	125	130	-4.33	93
pa	estimated	1930	124	123	124	-1.14	94
pe	1940	1880	172	192	222	-15.50	82
pe	1940	1890	194	178	210	-18.01	76
pe	1940	1900	208	162	183	-12.84	73
pe	1940	1910	232	138	157	-13.54	67
pr	1950	1880	243	231	256	-11.11	64
pr	1950	1890	221	205	239	-16.55	70
pr	1950	1900	205	190	221	-16.30	74
pr	1950	1910	170	163	176	-8.01	83
pr	1950	1920	132	129	135	-4.13	92
sr	1964	1890	100	105	100	4.69	100
sr	1964	1900	103	104	101	2.71	99
sr	1964	1910	102	100	105	-5.15	99
sr	1964	1920	105	104	106	-1.41	99
sr	1964	1930	102	102	103	-0.66	99
tt	1946	1880	161	160	162	-1.02	85
tt	1946	1890	166	164	168	-2.60	84
tt	1946	1900	146	144	148	-2.61	89
tt	1946	1910	123	120	126	-5.07	94
tt	1970	1920	112	112	112	-0.59	97
tt	1970	1930	100	100	100	-0.48	100
tt	1970	1940	100	100	101	-0.70	100
uy	1975	1900	110	107	113	-5.33	98
uy	1975	1910	106	101	110	-9.01	99
uy	1975	1920	105	102	108	-5.91	99
uy	1975	1930	105	105	106	-1.76	99
uy	1975	1940	103	102	104	-2.06	99
ve	1950	1880	215	198	228	-15.16	71
ve	1950	1890	200	183	216	-17.90	75
ve	1950	1900	200	188	213	-13.20	75
ve	1950	1910	162	152	174	-14.60	84
ve	1950	1920	144	138	150	-8.40	89
ve	estimated	1930	134	129	138	-7.24	92
ve	estimated	1940	125	120	128	-7.24	94
win	1946	1880	145	140	147	-4.98	89
win	1946	1890	142	142	143	-0.77	89
win	1946	1900	132	133	131	2.02	92
win	1946	1910	119	120	117	2.19	95

Notes: See list of census data above for abbreviations.

5 Subsistence Crises and the Development of Numeracy in Spain, 1830-1900

Abstract

Several studies state that human capital declines in the presence of economic shocks. This might be because childhood labor increases in the presence of income shocks or because nutritional shortfalls adversely affect cognitive abilities. This study explores the impact of two subsistence crises in Spain during the period 1830 to 1900 on human capital formation. We approximate human capital formation with numerical abilities by applying the age heaping strategy. Our results suggest that provinces facing more severe economic crises in terms of nutritional shortfalls, approximated by the increase in wheat prices, also tend to have a stronger decline in numeracy levels. Moreover, even a subsistence crisis of only two years may lead to a decline in the educational level of the population. This emphasizes the link between economic crises, nutritional problems, and human capital formation.

Subsistence Crises and the Development of Numeracy in Spain, 1830-1900[1]

5.1 Introduction

The revolts in 2008 in several parts of the developing world, for example in Haïti, as a result of the rising food prices have shown clearly that hunger is a problem in our world that has not yet been solved. Innovations and technological progress cannot help the fact that we all rely heavily on agricultural production and that a scaling down of the area under cultivation for foodstuff or the climate change lead, even in today's world, to severe nutritional shortfalls. In this study, we will go a step further and argue that subsistence crises are not only '*morally outrageous and political unacceptable*' (Drèze and Sen 1991, pp.3), but have also a negative impact on human capital formation. To illustrate our hypothesis, we draw on the case of Spain in the 19th century where a subsistence crisis of only two years led to stagnation in numerical abilities of the affected population.

Several studies (Quiroga 2003, Viñado Frago 1990, Núñez 1990, Vilanova and Moreno 1992) trace the development and evolution of human capital in terms of education in Spain.[2] These studies focus predominantly on literacy rates obtained from population censuses. Only from 1860 onwards population censuses contain information on primary schooling. However, less is known about the evolution of human capital formation before this decade.[3] This study aims at shedding light on human capital formation in Spain from 1830 to 1900 with a special focus on the subsistence crises period in the 1840s and 1850s.

Instead of using the literacy rate, we use age misreporting in census data to approximate numerical abilities of the population. We argue that this method has a number of advantages. First of all, it allows for the use of census material that does not explicitly ask whether people could read and write. Second, effects of different languages will be minor, which is a typical problem of literacy censuses and may be especially valid in the case of Spain. Some censuses take into account literacy in various languages, while others

[1] This chapter is based on an article submitted to *Explorations in Economic History*
[2] Benítez (1997) offers a detailed survey of literacy studies for Spain.
[3] Only the Census of 1887 presents information broken down by ages (Benítez 1997) and allows therefore calculating literacy rates for single birth decades.

do not. A further reason is that census data is easily comparable through the application of age heaping indicators, while the definition of literacy rates differs between census years and countries. This is especially true for historical census data, where minimum ages applied in the estimation of literacy levels differ between census years and countries (Hauser and Duncan 1959, p. 368). Using the age heaping strategy does not provide such difficulties and makes numeracy levels easily comparable between different years and regions or countries.

Ó'Gráda (2007) claims that the costs of famines have often been underestimated and malnutrition may negatively affect mental development in early childhood. The present study argues that even a subsistence crisis of only one or two years can already have negative effects on numerical abilities of the population. We are especially interested in inter-provincial differences in numeracy levels in response to these crises. Theoretical models often implicitly assume that human capital formation declines in the presence of economic shocks. Our results suggest that provinces facing more severe economic crises also tend to have a substantial decline in numeracy levels. Further, even a short crisis period of only two years negatively affects the educational level of the population. This emphasizes the link between economic crises, nutritional problems, and human capital formation.

The paper is structured as follows. In the next section, we give a short literature review of the relationship between economic crises and human capital accumulation. Section 3 describes the data and methods used to estimate numeracy levels in the Spanish provinces. Section 4 shows the development of numerical abilities as well as the impact of the subsistence crises on numeracy levels for the period from 1830 to 1900. Section 5 presents a panel-regression to explain provincial differences in numeracy levels and section 6 draws conclusions.

5.2 Subsistence Crises and Human Capital Accumulation

A large amount of literature deals with the implication of malnutrition or famines. Excellent literature on this topic are, for instance, the survey by Ó'Gráda (2007), the works edited by Dyson and Ó'Gráda (2002), or Drèze and Sen (1991). Chronic malnutrition increases mortality, directly through starvation, but also via nutrition related diseases. Additionally, fertility and marriages decrease, while migration increases. This paper, however, scrutinizes mainly the impact of subsistence crises on human capital, a link which has been disregarded so far. Subsistence crises are defined here as a substantial increase in wheat prices originated by bad harvests, wars or distribution problems that cause undernourishment and therefore higher mortality.

Should subsistence crises influence human capital? It seems quite intuitive to assume that the level of schooling in a population will decline in the presence of a subsistence crisis. This may be due to parents not having the ability to afford schooling fees or children have to work. When families are concerned with making ends meet, education loses its immediate importance. Essentially, the opportunity costs of sending children to school will rise and be higher than expected gains from education in the future. In the past, economic crises (subsistence crises are interpreted here as a form of economic crisis) have been frequently associated with a decline in human capital accumulation. In the following, we will focus on two explanations concerning the impact of subsistence crises on human capital formation. The first considers the link between subsistence crises and the amount of schooling, the second focuses on cognitive abilities which are hampered through malnutrition.

5.2.1 Subsistence Crises and the Amount of Schooling

The education choices of households in the presence of transitory shocks (idiosyncratic shocks like parental unemployment or macroeconomic crises like crop failure) may operate in various ways. Theoretical models of child labor like the one presented by Baland and Robinson (2000) assume implicitly that child labor gives rise to a trade-off between current and future earnings. A negative income shock leads to a drop in family income. In the presence of imperfect capital markets, child labor supply will rise to compensate for this decline. Thus, parents use child labor to smooth consumption during transitory shocks (Edmonds 2004, Jensen 2000). This leads to a decline in school attainment and a subsequent decrease in human capital accumulation (Jacoby and Skoufias 1997). Empirical evidence exists on South East Asian and Mexico (Fallon and Lucas 2002), Indonesia (Thomas et al. 2004), Argentina (Rucci 2003), and Cote d'Ivoire (Jensen 2000). Dureyaa, Lam, and Levison (2006) examined the relationship between household shocks and child employment in six Brazilian cities during the 1980s and 1990s. Economic shocks in terms of short-term unemployment of the father increase the probability that the children leave school and enter the labor force themselves or that they fail to advance in school. But transitory shocks may also cause schooling interruption, as Sawada (2003) points out. Further, he argues that the response to transitory shocks may be stronger than to permanent shocks.

Income uncertainty caused by frequent crop shocks can also lead to the result that children never enroll in school. Drawing on the case of Burkina Faso, Kazianga (2005) explains that volatile income streams induce households to build up a buffer stock in order to protect against potential income shortfalls. Thus, even before short term shocks arise, households choose not to send their children to school.

But the effect of macroeconomic shocks can be ambiguous. As wages decrease during crises, wages for children also fall and therefore lower the opportunity costs of schooling. On the other hand, increases in the marginal utility of the children's wage with decreasing family income may lead to increasing child labor and decreasing schooling (Schady 2004, Ferreira and Schady 2008). Increasing school enrollment or school efforts during macroeconomic crises are more likely to be found during longer economic crises and in richer countries (Ferreira and Schady 2008). Following this argument, Goldin (1999) finds increasing secondary enrollment in the United States during the Great Depression. In poorer countries, however, education decreases at least temporary.

Stagnating education during shocks is not restricted only to today's developing countries. Dramatic changes in social and economic settings of the past have been linked to stagnating education (Cipolla 1969, Sanderson 1972, Mitch 1992). In late 18th and 19th centuries Leicester, industrialization relied heavily on child and women labor, preventing the latter from teaching their children. The opportunity costs of sending children to school rose and the educational level of the population declined, as suggested by a higher share of grooms and brides that signed the marriage registers with a cross than in the periods before industrialization started (Brown 2004).

Deteriorating levels of literacy might also be associated with a lower supply of education as a consequence of lower public funds. In a similar vein, social and political struggle can undermine supply and/or demand for education (Cressy 1977).

5.2.2 Malnutrition and Cognitive Abilities

In development economics, nutritional intake and health are important factors in explaining educational outcomes (Pollitt 1990). Malnutrition leads to a poorer health status, a higher susceptibility to disease, and therefore higher absenteeism from school (Behrman 2004). It also diminishes attentiveness (Galler et al. 1983). Therefore, previously malnourished children present frequently worse school outcomes than their better nourished peers (Galler et al. 1990). Further, Glewwe, Jacoby, and King (2001) present evidence for the assumption that better nourished children enroll earlier in school. Thus, malnourished children receive less education.

Nutrition is also a basic requirement for brain development. Protein and micronutrients are essential for cognitive abilities. Three main deficiencies are commonly accepted to have a negative impact on children's cognitive abilities: protein-energy, iron, and iodine. These deficiencies irreversibly affect brain development, learning, and behavior (Scrimshaw 1998). Several studies emphasize the link between nutrition and cognitive abilities, measured by IQ scores, for developing countries (Miller del Rosso and Marek 1996, Glewwe, Jacoby, and King 2001). Although Behrman (1996) has emphasized difficulties assessing the impact of malnutrition on brain development, they agree that early childhood malnutrition as well as infants born to undernourished mothers, present lower cognitive abilities than well nourished children. Gorman and Pollitt (1992) find, for instance, that low weight at birth is associated with retarded cognitive development. Grantham-McGregor and Cumper (1992) study Jamaican children and conclude that early childhood malnutrition is associated with poor school achievements later in life. In a study for Mexico, Cravioto and De Licardie (1975) could show that protein-energy deficiencies give rise to lower intelligence quotients of children who experienced early childhood malnutrition, even after controlling for differences in their psycho-social environment. A study in Nepal has shown that after income, measured as rice and wheat output, the most significant determinant of child enrollment was body size (Mook and Leslie 1986), which is also affected by the nutritional status. Following this research line, Baten, Crayen, and Voth (2007) find that low nutritional levels hampered cognitive ability in industrializing England. Especially the early childhood period, which is the period of rapid brain development, is crucial in this respect (Bryan et al. 2004).

Childhood malnutrition from exposure to the Great Chinese Famine (1959-1961) heavily reduced the health status of the survivors. Meng and Qian (2006) show that this had a significant negative effect on labor supply. They also conclude that educational attainment decreased during this time.

To sum the findings of prolific studies, malnutrition is found to come along with poor cognitive development, lower intelligence (measured by IQ scores or school performance) and poor social and emotional development.[4] Thus, '*children's nutritional intakes must be above a certain threshold to enable them to fully benefit from school education*' (Bhargava 2001).

[4] See Pollitt et al. (1996) for a detailed overview and Barett, Radke-Yarrow, and Klein (1983) on the emotional and social development of malnourished children.

5.3 The Spanish Subsistence Crises and their Impact on Numeracy Levels

Despite increases in agricultural yield throughout the 19th century, there is a long history of production crises in Spain: Crises occurred in 1817, 1823-25, 1837, 1847, 1857, 1868, 1879, 1887 and 1898 (Shubert 1990, p. 25), with the most pronounced effects in 1847 and 1857. However, in general, the production of wheat during the 19th century could keep pace with the population growth. Even exports to Great Britain, France, and Cuba were possible (Díaz 2007).

A scanty harvest in 1846 led to increasing prices of wheat. However, exports of flour and wheat actually still increased. In 1846, more than 426.000 hectoliters of grain were exported and in the following year even more. The 'last European subsistence crisis' (Vanhaute, Paping, and Ó'Gráda 2007) provoked increasing grain prices in the whole of Europe and offered good profit prospects. Furthermore, the Spanish market was closed for imports. Market integration within the country was restricted: Due to the geography of the country, with its mountainous inner parts, transportation rendered difficult. Railway lines connecting the interior with the coastal provinces hardly existed.[5] And it was not until the 1860s when the first railway linking Castile and Leon with the coastal areas opened. For this reason, Herraz (2007) concludes that Spain was a relatively disintegrated economy. This affected the possibility of trade between different regions of the country as well as imports from abroad. The main wheat producing area in Spain was Castile and León located in the interior part of the peninsula. The coastal provinces had a clear advantage of importing food from abroad as maritime transportation costs were considerably lower than those overland (Sánchez-Albornoz 1963, p. 72ff).

Nevertheless, grain imports were restricted. The increase in grain prices in 1847 by 83 percent compared to the prices the year before, led to a significant decline in real wages and living standards.[6] Infant mortality increased as well (Sanz Gimeno and Ramiro

[5]In 1857, only 421 km of railway tracks existed (Sánchez-Albornoz 1963, p. 70ff.).
[6]Calculated from Barquín Gil (2001).

Farinas 2000). Only when the political and social tensions became stronger and parts of the population began to light up windmills and grain silos to advise to their situation, the authorities began to act and allowed grain imports. Municipalities subsidized bread consumption in order to mitigate the negative effects of the crisis (Díaz 2007).

The crisis ten years later was also linked to a bad harvest, although Sánchez-Albornoz (1963, p. 99ff.) sees the reason for the crisis in 1856/57 also as a problem of inventories, distributional problems due to the disintegrated character of the economy, and speculation. In 1856, prices rose from June to June of the next year even up to 84 percent in Segovia, located in Castilla and Leon. This huge increase in grain prices led to severe nutritional shortfalls.

In the following, we will assess the impact of these crises on numeracy levels in Spain. If economic crises in connection with nutritional shortfalls have an impact on school enrollment as well as on cognitive abilities, numeracy levels in Spain should have declined in response to these subsistence crises, assuming that other factors remained constant.

5.4 A Simple Model of Education, Schooling, and Nutrition

From the literature review we conclude that education depends on the amount of schooling as well as on cognitive abilities influenced by nutrition and unobserved factors ϵ. To proxy education we will use numerical abilities (numeracy), as explained above. We do not intend to estimate the model below, as information on various variables does not exist, but the model will help us to explain the main driving forces of a change in numeracy and to derive the hypotheses we will test in the next sections of the paper.

We assume that numeracy (N) in a society, calculated for birth decade t, depends on the following factors:

$$N_t = f[educ_t, nutrition_t, institutions_{t-1}, culturalfactors_{t-1}, \epsilon_t] \tag{5.1}$$

The change in numeracy from one birth decade to the next within one country is consequently given by

$$\begin{aligned}(N_t - N_{t-1}) = f[&(educ_t - educ_{t-1}), (nutr_t - nutr_{t-1}),\\ &(inst_t - inst_{t-1}, cult_t - cult_{t-1}), (\epsilon_t - \epsilon_{t-1})]\end{aligned} \tag{5.2}$$

Assuming that institutions and cultural factors change usually only over a longer time span , this equation reduces to

$$(N_t - N_{t-1}) = f[(educ_t - educ_{t-1}), (nutr_t - nutr_{t-1}), (\epsilon_t - \epsilon_{t-1})] \tag{5.3}$$

Thus, a decrease in numeracy can be attributed to lower school enrollment and/or an inferior nutrition. School enrollment, in turn, is a function of the demand (dem) which in turn is influenced by family income (inc), opportunity costs of schooling (opc), supply (sup) of schools, and unobserved factors ξ:

$$educ_t = f[sup_t, inc_t, opc_t, \xi_t] \tag{5.4}$$

Determinants of nutrition are the regional food production (prod), food imports (imp), proximity effects (prox), and unobserved factors ρ:

$$nutr_t = f[prod_t, netimpors_t, prox_t, \rho_t] \tag{5.5}$$

Ceteris paribus; the closer a province is located to the main food producing areas (in our case wheat production in Castile and Leon), the lower the food prices and the higher will be consumption. Net imports will be higher, the lower relative prices abroad are. Further, transportation costs (trc) play an important role in determining the amount of net food imports. For a given price differential (pd), higher transportation costs lower the amount of food that can be imported:

$$netimports_t = f[pd_t, trc_t] \tag{5.6}$$

Substituting (4) - (6) in (3) yields

$$
\begin{aligned}
(N_t - N_{t-1}) = f[(sup_t - sup_{t-1}), (dem_t - dem_{t-1}), (pd_t - pd_{t-1}),\\
(trc_t - trc_{t-1}), (prox_t - prox_{t-1}), \xi]
\end{aligned}
\tag{5.7}
$$

A decline in numeracy levels can (in our simple model) thus be caused by changes in the demand or supply of schools, income, opportunity costs, price differentials, transportation costs, or proximity effects.

Which factors interact in this model during a subsistence crisis? The amount of schooling is supposed to fall as family income declined and the opportunity costs of sending children to school, i.e., child labor, increase. The supply of schools may remain constant or even decline if the crisis is profound and public expenditure falls. Evidence for Spain, however, suggests that the supply of schools even increased around the 1840s (Carreras and Tafunell 2004). In the presence of a subsistence crisis, regional food production decreases. If net imports remain constant and no ample inventories are available, the amount of food decreases. Schooling as well as nutrition will then fall and lead to a decrease in numeracy.

From this model, we derive the hypotheses that we will test in the following:

1. Subsistence crises have adverse effects on school enrollment as well as on cognitive abilities; therefore numeracy levels will have declined in response to these subsistence crises.
2. In a disintegrated economy like the Spanish during the time under consideration, more remote areas should suffer a stronger decrease in human capital during these crises.

5.5 Data and Methods

5.5.1 Method

In the following, we will use numeracy calculated from census data to proxy education. Modern census data of developing countries or historical census data often present heaping patterns. Most frequently, ages ending in a zero or five, and to a lesser extent in two and eight are preferred (Myers 1954). In recent years, this age misreporting has become popular to approximate numeracy levels (A'Hearn, Baten, and Crayen 2009; Baten, Crayen, and Manzel 2008; de Moor and van Zanden 2008; Clark 2007; Crayen and Baten 2009; Manzel and Baten 2009; Ó'Gráda 2006). Especially for countries or time periods where other data on human capital is missing, this strategy allows the analysis of the evolution of human capital by using various sources that reported singular ages, for example migration registers or census data. Generally, people tend to round their age, when they do not know exactly how old they are or if they lack number discipline. Thus, in societies where time and numbers only play a subordinate role, people are less likely to report their exact age. However, digit preference can also have other economic, social, political or cultural reasons (Nagi, Stockwell, and Snavley 1973, Hauser and Duncan 1959). Military service or pensions (Budd and Guinanne 1991) are, for instance, an incentive to understate or to overstate the age, respectively. In China, for example, census data reveal very low age heaping patterns due to the predominance of the Chinese calendar, which allows interviewers to calculate people's age relatively accurately (Jowett and Li 1992).[7]

Mokyr (1983) was the first to apply the age heaping methodology to approximate the educational level to show that there was no brain drain from pre-famine Ireland. He compares age heaping for those who left the country with those who stayed behind and finds higher age heaping for migrants. Moreover, he finds generally lower age heaping for the better educated. Therefore he rejects the hypothesis that there was brain drain from Ireland before the great Irish famine.

Age heaping is most prevalent in societies with a low educational level (Bachi 1951,

[7]See, however, Baten et al. (2008) on the substantial Chinese heaping during the 19^{th} century.

Shryock and Siegel 1976, p. 115). Myers (1976), for instance, finds a strong negative correlation between age heaping and monthly wages in Saudi Arabia. He argues that higher heaping patterns are more common among people with lower educational status who in turn earn less on average. Nagi, Stockwell, and Snavley (1973) find a negative association between age heaping and literacy as well as a negative link between age heaping and the percentage employed in the non-agricultural sector for African countries. As the level of education in a society rises, age heaping declines (Hauser and Duncan 1959, p. 67). The link between age heaping and literacy has been empirically shown by a number of studies (Duncan-Jones 1990; Nagi, Stockwell, and Snavley 1973; A'Hearn, Baten, and Crayen 2009).

Various indices have been used to estimate the extent of digit preference. Most popular are the Whipple index, the Bachi index and Myer's blended method. A'Hearn, Baten, and Crayen (2009) test for some characteristics of these indexes, concluding that the Whipple index meets the desired assumptions of scale-independence, efficiency, and a linear response to the degree of heaping best. Further, it reliably ranks different samples according to their degree of age heaping. These properties are also met in relatively small samples. For this reason, we apply the Whipple index to estimate numeracy levels of the Spanish society. The Whipple index gives the sum of people at ages ending on the digits zero and five for a special age range containing ten successive ages divided by one fifth of the whole population in the considered range, times hundred. The index varies between 100 and 500. For 500, the whole age distribution contains only ages ending in multiples of five, for 100, exactly 20 percent of the ages end in a zero or a five (Shryock and Siegel 1976).

$$Wh = \left(\frac{\sum(Age_{25} + Age_{30})}{\frac{1}{5} \cdot \sum(Age_{23} + Age_{24} + ... + Age_{32})} \right) \cdot 100 \tag{5.8}$$

In the following, we will calculate Whipple indices for each province and birth decade. The Whipple index of the census of 1900 for the age group 43-52 thus refers to those born in the 1850s, the Whipple index for the age group 53-62 to the birth decade 1840.

This method presumes that the largest amount of education occurs in the first ten years after birth approximately. To spread the preferred ages more evenly within the age range, we use the age groups 23-32, 33-42 etc. up to 63-72. Older and younger age groups are excluded as they involve several problems, among other things that these age statements are not self reported (Manzel and Baten 2009). Studying 126 countries, A'Hearn, Baten, and Crayen (2009) find no age effect on Whipple indices, i.e., with the exception of the youngest age group 23-32, the age group does not influence age heaping behavior. For the youngest age group events like marriage or military service, which require frequent age statements, may attribute to less heaping behavior. The authors propose an adjustment for this age group.

As we dispose of data for 10-year intervals, we will deviate from the general methodology and calculate Whipple indices for the censuses of 1900 to 1960 for all age groups and take the average. This methodology allows us to rule out any possible age effect which is especially important as we are interested in changes of Whipple indices from one birth decade to the next.

A'Hearn, Baten, and Crayen (2009) propose the conversion of the Whipple index to a numeracy index (called ABCC index) that gives the amount of people stating their exact age. A numeracy index of 300, for example, means that (at least) 50 percent of the population stated their age correctly.

$$ABCC = \left(1 - \frac{(Wh - 100)}{400}\right) \cdot 100 \tag{5.9}$$

if $Wh \geq 100$; else $Wh = 100$

We will follow their methodology and calculate ABCC indexes for Spain.

5.5.2 Data Characteristics

The source used to assess numeracy levels in Spain consists of census data for the censuses of 1900-1960.[8]These are used to calculate Whipple indexes for the birth decades from 1830 to 1900. This is a large time horizon which allows us to assess differences in numeracy levels and the influence of the two subsistence crises in Spain. The census data cover the whole Spanish peninsula as well as the Canary Islands and the Baleares.[9]The interviewees were asked to provide their age, their profession, and whether or not they possessed the ability to read and write. Nevertheless, definitions of the profession are broad and not skill-specific. For example, the definitions sum up all people working in agriculture without difference between land owners or day laborers. For this reason, this information is not useful for our survey on numeracy levels in the Spanish provinces. Our data also lack information on the province of birth, which may be a possible source of bias. Barcelona, Madrid, and Biscay have been regions with high attraction to migrants, while Aragón, Asturias, Islas Baleares, Northern Castile, and Galicia had traditionally higher shares of emigrants (Rosés and Sánchez-Alonso 2002). We have to assume that migration did not play an important role, which might not be too restrictive migration only began to play an important role at the beginning of the 20th century (Rosés and Sánchez-Alonso 2002). Summary statistics of the data set for the whole country are shown in Table 5.1.

Unfortunately, we do not have information about the census coverage. The censuses attempted to capture the entire de facto population, but under-representation of some isolated rural municipalities is possible. Carreras and Tafunell (2004, p. 106) question especially the reliability of the census of 1940, but give no concrete reason for this. Literacy information is expected to give only a rough measure for the literacy level as Franco imposed monolingualism in Spain and it is therefore likely that literate Basks and other minorities were counted as illiterates.

[8]Age heaping decreases over the course of socioeconomic development. However, the average numeracy levels do not change substantially if we exclude the Censuses after 1940, 1950, or 1960.

[9]From 1930 onwards the censuses also contain age information on the Spanish colonies in Africa and the cities of Ceuta and Melilla. Nevertheless, the case number is too small to include them in the quantitative analysis.

5.6 Development and Regional Disparities in Numeracy Levels

5.6.1 Overall Trends and Regional Disparities in Spanish Education

Spanish numeracy, as measured by the ABCC index, increases over the course of socioeconomic development (Figure 5.1). The scatterplot in Figure 5.2 shows a strong correlation between numeracy and literacy on a provincial level in Spain. [10] The development of numeracy coincides with an increase in primary school enrollment (Figure 5.3). However, we observe stagnation in overall numeracy levels for those born in the 1840s and 1850s. After this point in time, there is a steady increase. Comparing these results with education data, we find no decrease or stagnation in enrollment rates in the 1850s that could explain stagnating numeracy levels. The death of Fernando VII in 1833 marked the beginning of the liberal regime which carried out extensive educational reforms. Especially after 1840, the number of public primary schools increased considerably. In the following, we will argue that the observed stagnation in numeracy may be attributed to the subsistence crises in 1847 and 1857 which had a negative impact on the educational level of the population through the channels we explained above.

The Spanish peninsula is characterized by differences in climate, soils, social and economic conditions; therefore we also would expect numeracy levels to vary within the country. Trade oriented regions exhibited high levels of numeracy (Brown 2004), probably because it would seem that people in trading regions would need to read, write, and calculate more frequently. This presumption is tested in the next section. Figures 5.4 and 5.5 show the distribution of numeracy in the Spanish provinces for the birth decades 1830 and 1900, with darker shaded areas indicating lower numeracy. Numeracy levels actually differed remarkably between the autonomous regions. The Communities of Andalusia, Murcia, Extremadura, and Galicia had considerably lower levels than the rest of the country. We find high numeracy levels (or low Whipple indices) in the communities of Asturias, Basque Country, Madrid, and Castile and Leon. These findings correspond with

[10] Data on literacy stems from Carreras and Tafunell (2005) and is available for the birth decades 1860, 1870, 1880, and 1900.

Cipolla's (1969, p.83) who mentions a '*corridor of literacy*' from Madrid towards Alava in the north. Studies by Vilanova and Moreno (1992) and Núñez (1990) show that regions with high literacy rates throughout the 19th and 20th century have been the northern provinces and the interior, regions with low literacy the southern provinces and Galicia. The economically more dynamic regions in the north had lower age heaping than other regions, as well in the 1830s as at the turn of the 19th century. A higher share of day laborers working on the *latifundios* may be responsible for more pronounced age heaping patterns in the southern part of Spain (Nuñez 1990).[11]

The interior features relatively high ABCC indexes. The Basque, which were strongly involved in trade, also presented high numeracy levels. This result is interesting for two reasons: First, numeracy levels in the Basque Country in 1830 were already as high as they were eighty years later (!) in Galicia: In 1830 the average numeracy in the Basque Country was 95 percent, while average numeracy in Galicia was not at this value until 1910.[12] Second, estimations of literacy rates in 1860 do not yield such favorable results for the Basque. These results indicate that the effects of a different language likely played an important role when measuring literacy rates. Surprisingly, Cataluña, which became '*Spain's factory*' in the second half of the 19th century (Nadal 1985) shows only moderate numeracy levels. Rosés (1998) offers an interesting explanation for this. A great part of education took place informally in the plants; children entered the job market at age eight and a few years later they were able to supervise their own work group. This 'training-on-the-job' did not favor literacy or numeracy, but led to skilled industrial workers. In 1900, differences between regions had become minor, although Andalusia and Galicia still had relatively low numeracy levels.

[11] Núñez (1993) finds that widespread analphabetism in the southern part of Spain led to low geographical and occupational mobility. Mainly the better educated from the north migrated to those regions where skilled workers were requested. Thus, migration is not responsible for lower educational levels in the south.

[12] For comparison: The overall ABCC index in Spain was at 88 in 1830 and at 98 in 1910. Numeracy data is available until the 1930s; however, we decided to focus mainly on the period until 1900 to study the effects of numeracy levels during the subsistence crises in detail.

5.6.2 The Subsistence Crises Puzzle

In a next step, we focus on the dynamic nature of the evolution of the ABCC index. We are especially interested in which provinces suffered most during the subsistence crises of 1846/47 and 1856/57. To study this question, we plot the change in numeracy indexes from one decade to the next. All provinces which experienced a deterioration or stagnation of numeracy levels are colored dark grey. As Figure 5.6 shows, in the 1840s, most provinces experienced stagnation in numeracy levels in comparison with the 1830s. We have stated above that Spain suffered a subsistence crisis and political problems during this period. The bad harvest of wheat led to increasing grain prices, severe nutritional problems, and riots. During this time, numeracy levels deteriorated or stagnated in almost all provinces. Those which experienced no stagnation in numeracy levels are predominantly allocated in the center.[13] Interestingly, this region was specialized in wheat cultivation. This fact could lead to the assumption that, although wheat prices also raised in the interior, the increase was less pronounced than in other Spanish regions.[14]

However, when we look at the change in ABCC indexes for the birth cohorts born in the 1840s and 1850s (Figure 5.7), the reverse happened. While most coastal provinces could improve their performance in numeracy levels, the northern Meseta as well as the Balears experienced a decline or stagnation. Nevertheless, several authors (Núñez 1992, Moreno Lázaro 2001, p. 185) state that Castile and Leon developed very favorably economically in the second half of the 19th century. Several events stand out in 1850's Spain. The Crimean war in 1853 led to a rise in wheat exports and therefore also to increasing domestic grain prices. The northern Meseta, Spain's granary, should have benefited from this situation. But in 1856/57, again, a bad yield of wheat, stock and distribution problems (Sánchez-Albornoz 1963, p.99) caused a subsistence crisis. During both crises. starvation and excess mortality could be observed, especially among the lower social strata of the society (Díaz Marín 2003, 2007).

To shed more light on this, we verify what happened exactly during the subsistence

[13]Mainly Castilla la Mancha and Castile and Leon, in the following: the northern Meseta.

[14]In this context, we use the increase in wheat prices as an indicator for the severity of the crises.

crisis in the 1840s and 1850s by means of the model developed in section 5.4 of this paper. Nutritional intake declined during both subsistence crises due to a fall in regional wheat production. Nevertheless, if the same amount of food had been imported, there would have been no nutritional shortfalls. Coastal regions exhibited an advantage in terms of lower transportation costs for imports, but a disadvantage due to the fact they were located further away from home production. During both crises, after some riots, the Spanish authorities allowed to import wheat from abroad (Díaz Marín 2003). To a certain extent, this could reduce the adverse effects of the crisis. Nevertheless, as in the '*hungry forties*' the whole of Europe experienced harvest problems, imports were small, therefore the coastal areas could not benefit much from grain imports. In Castile and Leon, however, given the proximity to production, grain prices increased less.

In the 1850s, in contrast, grain imports from Europe could mitigate the bad harvest in some parts of the country. Net imports could rise and relieve the lower regional production especially in the easily accessible coastal areas of the peninsula. Castile and Leon's geographic situation in the mountainous inner part of the country rendered transportation more difficult, especially before the railway came, leading to a lower supply and higher wheat prices. Thus, nutritional problems were higher in the isolated interior provinces than in coastal regions. This explains a higher nutritional level of the interior in 1846/47, but a lower nutritional level during the subsistence crisis in 1856/57. Through the nutrition link presented above, the crisis may have had a negative effect on numeracy levels in Castile and Leon. It is very likely that schooling also declined during this time, even though enrollment rates show an increase in the number of children enrolled in primary schools. However, schooling statistics are usually comprised of all students registered at the beginning of the school year and not only of those who actually attended school. For this reason, numeracy levels as an outcome indicator offer a better possibility to judge educational progress or stagnation.

Our hypothesis is supported by the development of wheat prices, approximating the severity of the crises, in the considered decades. While in the 1840s wheat prices increased to higher levels in the coastal zones of Spain as compared to the interior, during the crisis in the 1850s this relationship reversed. The percent increase in prices in the interior in the 1850s is 60 percent as compared to only 14 percent in the coastal zones (Figure 5.8).

This development explains also the increase in infant mortality rates in 1850s Central Spain (Sanz Gimeno and Ramiro Fariñas 2000, Figure 5.9) as well as a decrease in the biological standard of living measured by the average height of recruits in Castile and Leon born in this decade (Martínez-Carrión and Moreno-Lázaro 2007, Figure 10). Nutrition and the disease environment in the first years after birth greatly influence adult height. The average height of recruits in Castile and Leon fell for the birth cohorts of 1856-1860 to a greater extent than in the rural South East. In the 1840s however, heights in the rural South East declined while they even improved in Castile and Leon. Thus, the data on the biological standard of living shows that Castile and Leon suffered severe nutritional shortfalls during the subsistence crisis of 1856/57. In the 1840s, we cannot observe a similar decrease. From this evidence, we can deduce that the bad harvests in 1840s and 1850s Spain led to a fall in cognitive abilities because of protein-energy and micronutrient deficiencies caused through malnutrition. Increasing grain prices led to declining household income (Díaz Marín 2007) as reflected by lower heights of recruits. Child labor possibly increased leading to lower school attendance.

5.7 Explaining Disparities in Numeracy Levels

5.7.1 The Determinants of Disparities in Numeracy Levels

Studies of education in Spain have concluded that literacy was more widespread in the urbanized, northern parts, Galicia being the only exception, while in the rural south analphabetism was more prevalent (Núñez 1993). They also state that a higher amount of day laborers working on *latifundios* in southern Spain were responsible for these disparities. Isolation and the lack of communication systems probably impeded the spread of literacy (Bello 1929). Further, Viñao Frago (1990) argues that literacy in Spain depended more strongly on the amount of schooling provided and on urbanization than in other countries. He sees the reason in the predominance of the Catholic religion which is based more on oral and visual tradition than the Protestant confession. Furthermore, the predominance of the Catholic Church offered no competition incentive to force literacy, like it did in countries where Protestants and Catholics lived nearby each other and competed (Tortella 2000). Priests taught not how to read the catechism, but preferred to read it to their community, in contrast to the protestant church which attached more importance to the self-study of the Bible.

Another important fact Viñao Frago (1990) mentions, is that governmental action in education was limited to the time of the liberal regime (1838-1860). Basic educational costs in primary education were a municipal matter until the 20th century. This could have had a negative impact on the supply of schools, especially in rural areas or poorer municipalities. Moreover, schools have long been viewed as imposed from the central government and therefore strengthened the resistance against schools.

After having assessed the development of numeracy levels in Spain, in a next step we determine the factors that generated the differences in numeracy levels between the Spanish provinces and compare our results to previous studies. As in the section before, we are especially interested in the link between grain prices and numeracy levels. For this purpose, we estimate a panel regression model.

5.7.2 Explanatory Variables

On the basis of Whipple and ABCC indexes used in the first part of this paper, we construct a panel data set with 49 provinces to study determinants of numeracy levels. The dependent variable is the ABCC index per province and birth decade.[15]

Initial Level of Numeracy

We include this variable to control for the initial level of education. We would expect that provinces which experienced a lower level of numeracy in 1830 also experienced lower levels in subsequent decades.

[15] Santa Cruz de Tenerife and Las Palmas are counted as one province due to the lack of detailed other data on these provinces. We have information about wheat prices for 31 provinces.

Port

Trade centers might have higher numeracy levels due to the fact that the population in these places is more often faced with money, numbers, dates, or bookkeeping. For this reason we include a dummy variable for ports as an approximation for trading places. The variable is dichotomous and takes the value of one if the province has an economically important port and zero otherwise. We expect higher numeracy levels in provinces with an economically important port due to the fact that these provinces were more integrated in international trade. Furthermore, as we explained above, costal provinces were able to import foodstuffs more easily and with lower costs from overseas which might have had positive effects on the provision of foodstuffs.

Production of Export Crops

In a similar vein as the dummy variable for ports, this variable tries to capture the effect of international trade on numeracy levels. The variable takes the value one for provinces which produced export crops and zero otherwise. Due to the lack of detailed export statistics on provincial level, it has to be admitted that the definition of this variable is relatively rough. Information on the production of export crops in the Spanish provinces has been collected from Morilla Critz, Olmstead, and Rhode (1999), whereas the information on the most important export products for 1827, 1855-1859, and 1890 comes from Tortella (2000).[16]

Latifundism

This variable is also dichotomous and takes the value one for provinces with a high share of latifundios. In theses provinces, we expect exceptionally high shares of day laborers. For them, formal education in terms of literacy or numeracy might have been less important, so that low levels of numeracy were more widespread among day laborers. Hence, we expect a negative link between numeracy levels and the prevalence of latifundism in a

[16]Only export products with a share of 5 percent or higher have been included.

province. Data on latifundism stems from Malefakis (1970) who reports information on land tenure from the cadastre surveys conducted since 1906. Provinces with a share of 40 percent or higher of large holdings (over 250 hectares) are assumed to have a high share of latifundios.

Share of Urban Population

Scholars (Núñez 1990, Cipolla 1969) commonly state that literacy in cities increased more rapidly than in rural areas due to the lower average fixed costs of schools. Therefore, we would expect numeracy levels to be inversely related to the share of urban population. The data comes from Carreras and Tafunell (2005). Information is available for 1860 to 1900.

Wheat Prices

To assess the link between education and subsistence crises, we include nominal wheat prices for each province as an indicator for the intensity of the crises. Wheat prices stem from 1830 to 1883 from Barquín Gil (2001) and are reported in reales per fanega. [17]As our proxy for education is on a ten year basis, we calculate 10-year averages for 1830 to 1880. The author reports prices for 16 different Spanish cities which we use as a proxy for wheat prices within the corresponding province. For lacking provinces we carried out a cluster analysis that calculates the degree of similarity between the Spanish provinces controlling for the distance to the most important trade centers in 19 th century Spain, i.e., Madrid, Bilbao, Barcelona, Seville, and Cádiz, the altitude, wheat prices for the period 1856-1865 and 1866-1875 (this wheat price series is not comparable with the series by Barquín Gil), a dummy variable for provinces with a port, and the share of urban population in the 1860s. The results are the used to approximate wheat prices for the other provinces. [18]

[17] 1 real = 0,25 pesetas; 1 fanega = 0,55501 hectolitres (see Barquín Gil 2001).
[18] See appendix for a more detailed discussion of the methodology and the results of the cluster analysis.

5.7.3 Regression Results

We use a random effects regression to test for the factors influencing numeracy levels on a provincial level in Spain. The regression results are presented in table 5.2.[19] All specifications show that wheat prices were related negatively to the numeracy level of the population. The influence is statistically significant even if we control with interaction variables of different decades for inflation effects. The dummy variables for ports had no significant impact on numeracy levels between 1830 and 1880, while, in contrast to our expectations, the dummy variable for latifundism is related positively to the level of numeracy. The dummy variable for provinces producing export crops (oranges, cotton, etc.) shows a significant positive effect on numeracy levels. We have to admit, that this variable is only a rough proxy, as we lack detailed import and export statistics on a provincial level. All variables remain robust to specification changes. The dummy variables for birth decades have been included to account for unobserved time effects.

Numeracy levels at the beginning of the period are an important determinant of numeracy levels throughout the considered time lapse. Thus, the ranking of numeracy between the provinces has not changed much during the time considered. Provinces presenting high numeracy levels in 1830 also presented high levels in 1880. This could be a hint that further factors that influenced initial numeracy levels are important in explaining the development of numeracy levels, for instance, institutional factors. The high Rš is caused by the inclusion of the ABCC index in 1830 which is highly correlated with the dependent variable as can be seen in specification 4, where the numeracy index in 1830 is excluded. According to the variance inflation factor, no strong multicollinearities between the other explanatory variables exist.

Our regression results suggest that factors usually applied to explain differences in education between regions, such as the share of urban population or the share of day laborers, can explain disparities in numeracy levels only to certain extent. As was explained in the first part of this research paper, wheat prices may have had an impact on numeracy levels.

[19] The results of the Hausman Test suggest that it is reasonable to estimate random effects.

Further, provinces producing export products had higher numeracy levels, emphasizing as well the importance of economic integration for human capital accumulation.

5.8 Conclusion

This paper has developed a new data set which allowed scrutinizing the development of numeracy levels in Spain from the pre-industrial era up to 1900. Remarkable disparities of numeracy levels existed between the different regions. While generally numeracy levels were higher in the central-northern parts, the south and Galicia presented lower levels. This relationship remains stable over the considered period. Interestingly, the Basque country had very high numeracy levels, although literacy estimates do not yield such favorable results for the Basque.

Further, this paper has surveyed the relationship between subsistence crises and numeracy levels providing the example of Spain during the 1840s and 1850s. The analysis has shown that numeracy levels declined in provinces which experienced economic problems in terms of nutritional shortfalls. Thus, we find further evidence that economic crises had a negative impact on school enrollment and/or cognitive abilities. Even a short subsistence crisis of only one or two years can have serious negative effects on the human capital development and therefore on future growth perspectives. This emphasizes the link between economic crises, nutritional problems, and human capital formation.

Tracing in detail the development of numerical abilities in Spain, we find that the interior and the coastal provinces followed different paths during the subsistence crises in 1846/47 and 1856/57. While the subsistence crisis in the 1840s hit predominantly the coastal provinces of the peninsula, the crises in the 1850s affected mainly the major wheat producing northern Meseta due to the difficulties of transporting imported wheat from abroad to the interior. In both cases, these crises are reflected in slightly declining or stagnating numeracy levels.

Beyond the more well-known negative effects during subsistence crises, these crises also have a negative impact on the development of human capital through lower schooling/ and or lower cognitive abilities and even short crises are likely to slow human capital development.

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5.10 Appendix

5.10.1 Tables

Table 5.1: Summary statistics

Birth decade	**Whipple Index.**	**ABCC Index**	**Census Year**
1830	149.08	87.73	1900
1840	151.19	87.20	1900-1910
1850	150.44	87.39	1900-1920
1860	143.78	89.06	1900-1930
1870	133.34	91.67	1900-1940
1880	128.92	92.77	1910-1950
1890	117.30	95.67	1920-1960
1900	113.21	96.70	1930-1970

Notes: Census data stems from www.ine.es.

Table 5.2: Random effects regressions: Determinants of numeracy levels in Spain (1830-80)

Variable	**(1)**	**(2)**	**(3)**	**(4)**
Constant	20.24***	26.86***	25.28***	97.03***
	(5.49)	(7.62)	(7.49)	(36.43)
Initial ABCC	0.80***	0.77***	0.76***	-
	(23.25)	(22.42)	(23.39)	
Wheat Price	-0.11***	-0.12***	-0.10***	-0.23***
	(-3.81)	(-4.03)	(-3.54)	(-4.25)
Log Urban population	0.23	0.67	0.57*	-0.52
	(1.04)	(-3.12)	(2.82)	(-0.88)
D_Port	0.85	-	-	-
	(0.93)			
D_Latifundism	1.57***	-	-	-
	(3.44)			
D_Export Products	1.87***	-	1.62***	-
	(4.60)		(3.99)	
D_1840	2.46	3.50*	3.27	6.55**
	(1.23)	(1.68)	(1.62)	(2.55)
D_1850	3.50	5.30*	4.49	9.99**
	(1.17)	(1.71)	(1.49)	(2.56)
D_1860	3.56	6.36*	4.78	11.83***
	(1.15)	(2.00)	(1.54)	(2.89)
D_1870	4.00	6.82*	5.24	12.31***
	(1.24)	(2.05)	(1.61)	(2.89)
D_1880	-0.18	2.44*	0.94	9.69**
	(-0.05)	(0.67)	(0.27)	(2.06)
Wheat_1840	-0.09***	-0.12*	-0.11**	-0.20***
	(-1.66)	(-2.16)	(-2.09)	(-3.01)
Wheat_1850	-0.08	-0.12*	-0.10	-0.21**
	(-1.13)	(-1.67)	(-1.46)	(-2.36)
Wheat_1860	-0.01	-0.07	-0.04	-0.15**
	(-0.15)	(-1.03)	(-0.57)	(-1.83)
Wheat_1870	-0.01	-0.07	-0.04	-0.16**
	(-0.11)	(-0.97)	(-0.52)	(-1.75)
Wheat_1880	0.12	0.06	0.09	-0.05
	(-1.64)	(0.87)	(-1.28)	(-0.52)
Panel Observations	216	216	216	216
Provinces	40	40	40	40
Overall R^2	0.87	0.86	0.87	0.43

Notes: Wheat prices from Barquín Gil are only available until the 1880s. ***/**/* implies significance at 1; 5 or 10% significance level, respectively. We have only included variables that remain robust to different specifications. There are no strong multicollinearities according to the variance inflation factor. Estimation with robust standard errors. Reference category: birth decade 1830, wheat prices 1830.

5.10.2 Figures

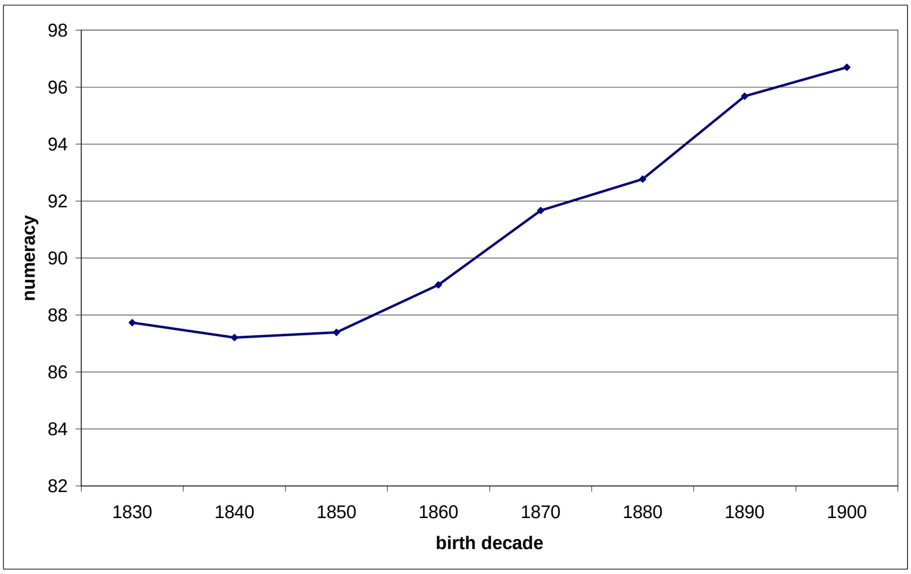

Figure 5.1: Evolution of numeracy in Spain (1830-1900)

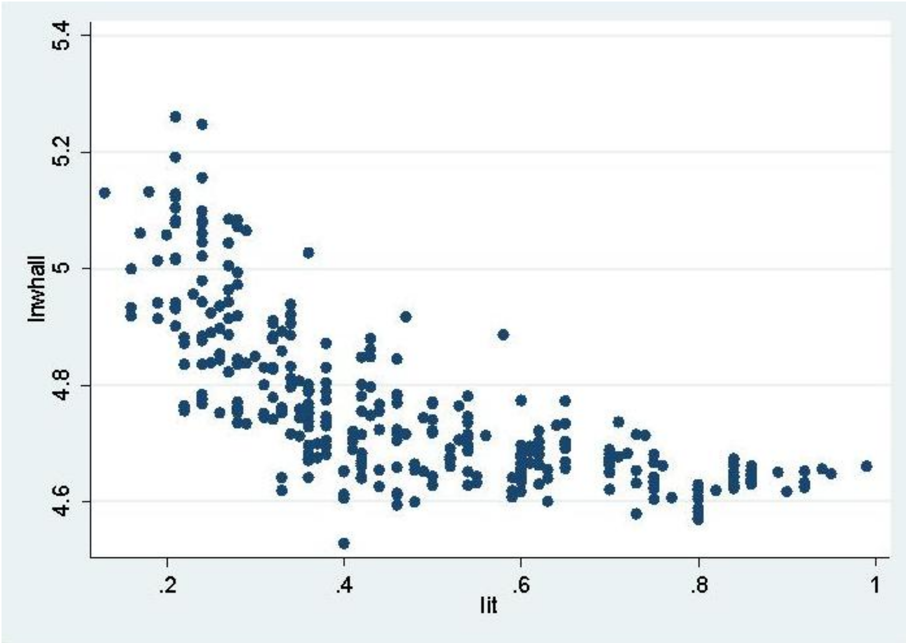

Figure 5.2: Scatterplot: Numeracy and literacy

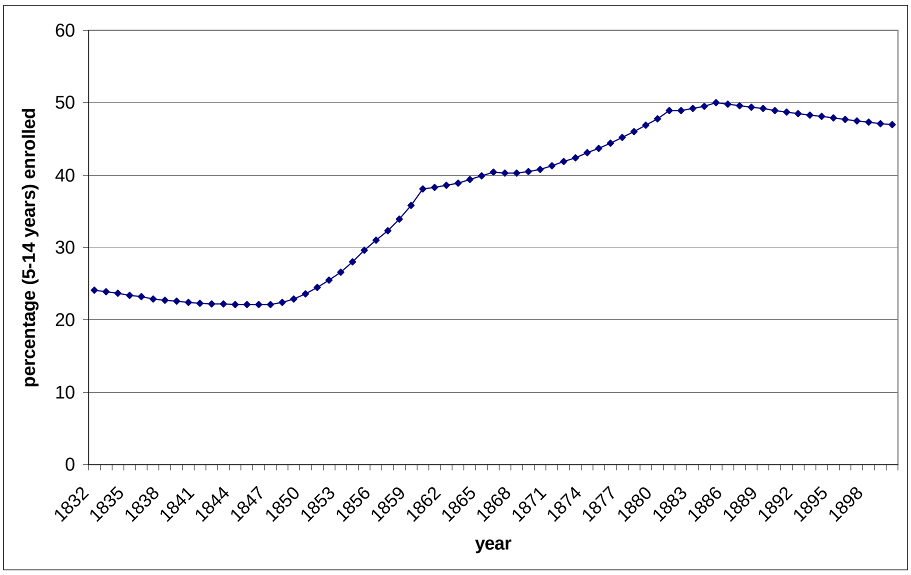

Figure 5.3: Development of enrolment ratios in Spain (1830-1890)

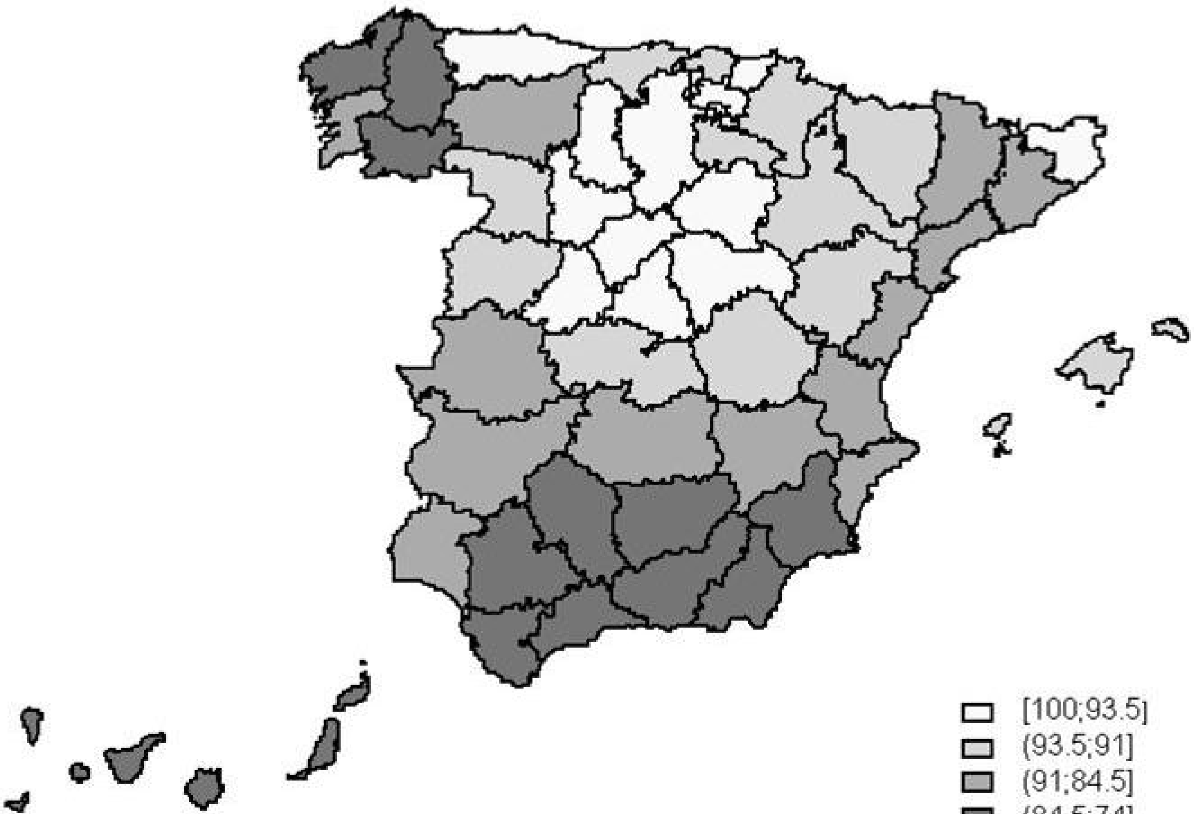

Figure 5.4: Numeracy in Spanish provinces, 1830

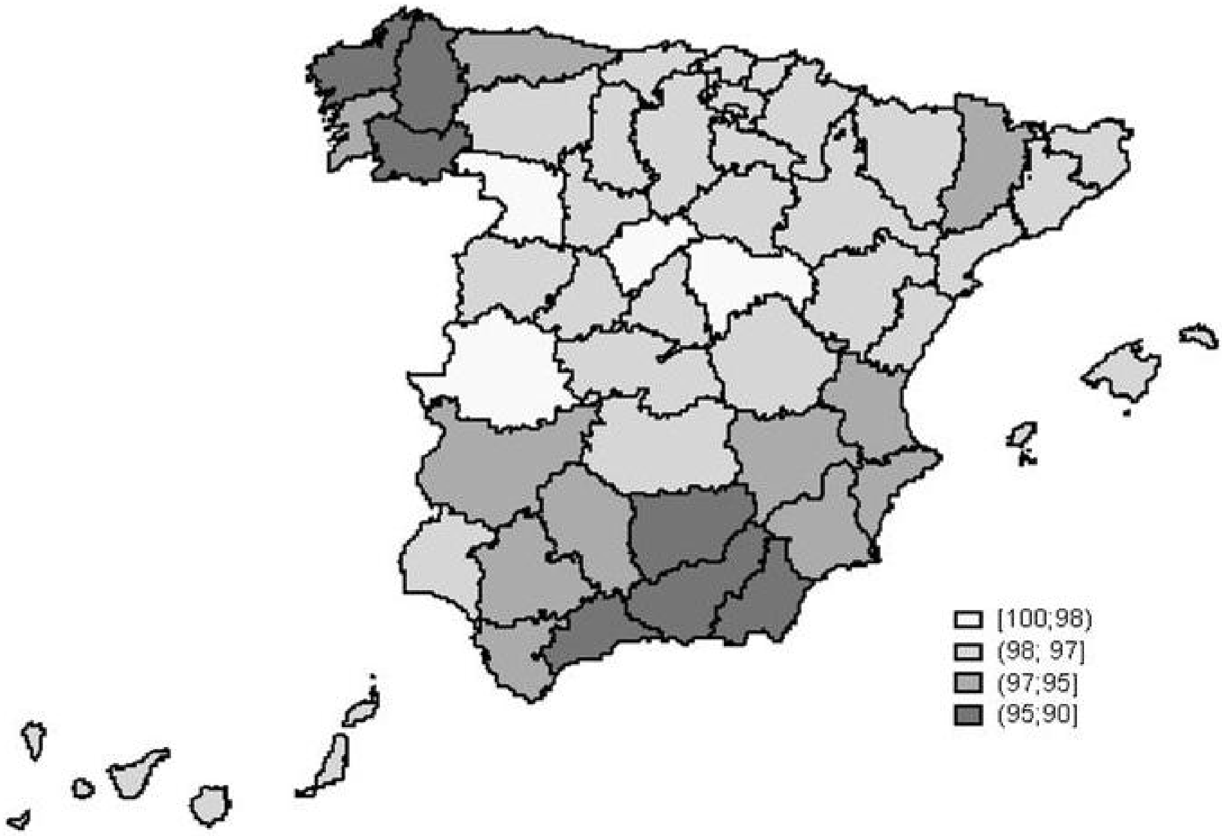

Figure 5.5: Numeracy in Spanish provinces, 1900

Figure 5.6: Change in numeracy, 1830-1840

Figure 5.7: Change in numeracy, 1840-1850

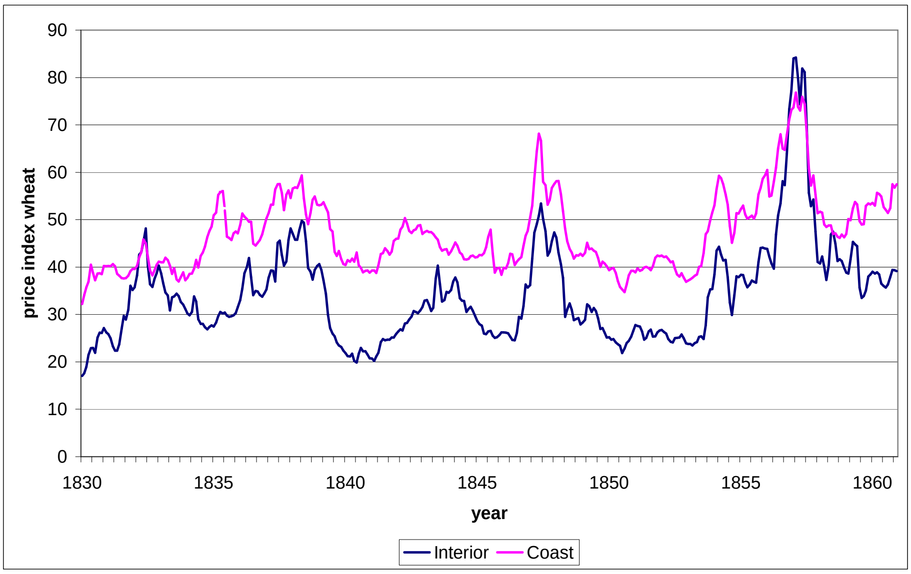

Figure 5.8: Development of nominal wheat prices in peripherical and central Spain (1830-1860)
Source: Rafael Barquín (2001): Precios de trigo e índices de consumo en España, 1765-1883. The author does not state which provinces he classifies as belonging to the interior and which to the coast.

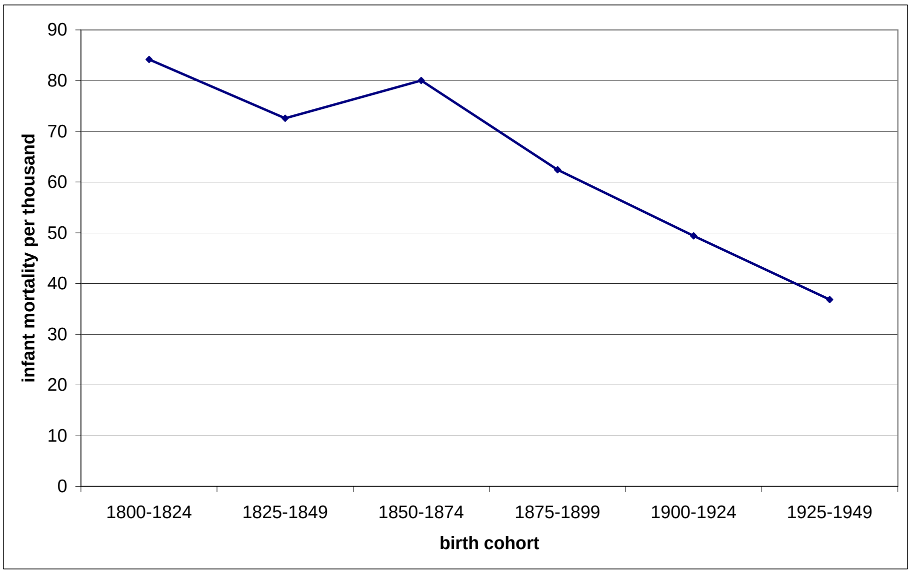

Figure 5.9: Infant mortality rates (age 0-1) in Central Spain (1800-1949)
Source: Data comes from Sanz Gimeno and Ramiro Fariñas (2000), Table 3. Central Spain: Cáceres, Toledo, Madrid, and Guadalajara.

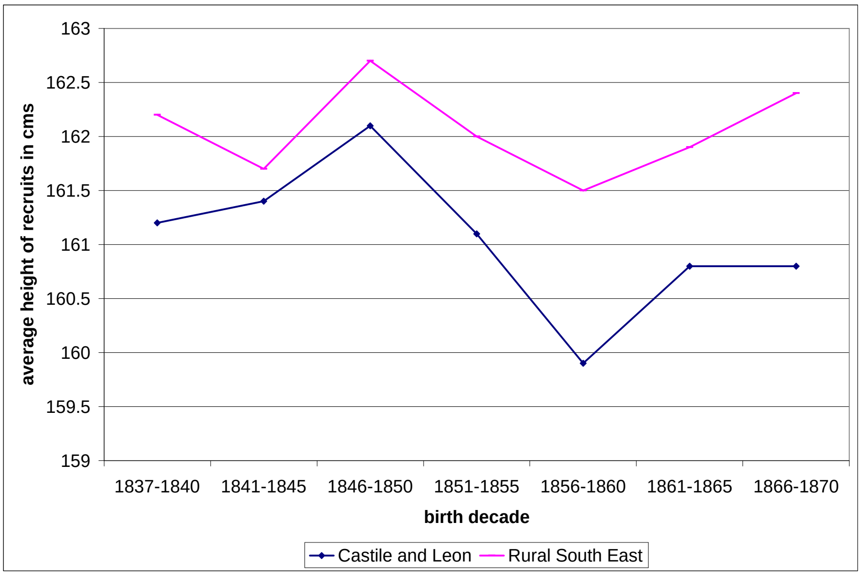

Figure 5.10: Development of average height of recruits in Castile and Leon (1837-1870)
Source: Data comes from Martínez-Carrión and Moreno-Lázaro (2007), appendix A.

5.10.3 Explanatory Variables

Wheat Prices from Barquín Gil (2001) available for 16 cities

Table 5.3: Wheat prices from Barquín Gil (2001)

City	Province
La Coruña	La Coruña
Oviedo	Asturias
Santander	Cantabria
Tolosa	Guipuzcoa
Pamplona	Navarre
Tudela	Navarre
Lleida	Lleida
Zaragoza	Zaragoza
Girona	Girona
Segovia	Segovia
Medina	Valladolid
León	León
Burgos	Burgos
Vitoria	Alava
Murcia	Murcia
Granada	Granada

Dummy Variable Port One for Barcelona, Cantabria, Cadiz, Malaga, Seville, Valencia and Biscay.

Dummy Variable Latifundios One for Albacete, Badajoz, Ciudad Real, Caceres, Cadiz, Córdoba, Granada, Jaen, Murcia, Seville and Toledo.

Dummy Variable Export Crops Export Crops: cotton, oranges, wine. One for Alava, Albacete, Alicante, Almería, Ávila, Barcelona, Burgos, Cantabria, Castellón, Ciudad Real, Cuenca, Cádiz, Córdoba, Girona, Granada, Guadalajara, Guipuzcoa, Huelva, Huesca, Jaen, León, Lleida, Málaga, Navarre, Palencia, La Rioja, Salamanca, Segovia, Seville, Soria, Tarragona, Teruel, Toledo, Valencia, Valladolid, Viscay, Zamora, Zaragoza.

5.10.4 Cluster Analysis

A cluster analysis quantifies differences and similarities between the different observations. To determine the similarity between the provinces, the Euclidean distance is calculated for a set of variables. The distance between province x and y is, for example, given by

$$Distance_{x,y} = \sqrt{\sum_{i=1}^{n}(x_i - y_i)} \tag{5.10}$$

The results for each combination of provinces can then be shown in a distance matrix. Low values indicate similarity between two provinces. The set of variables used to detect similarities are average wheat prices for the period 1856-65, average wheat prices for the period 1866-75, a dummy variable for provinces with a port, a dummy variable for provinces situated at the coast or frontier, altitude, and the nearest distance to the most important trade centers.[20] All these variables attempt to capture the economic structure of the provinces and are available for a large number of provinces.

To account for the fact that these variables are measured on different scales, the Euclidean distances are standardized. For each value, its mean is first subtracted and then divided by its standard variation. As a result, each variable possesses a mean of zero and a standard deviation of one and influences the Euclidean distance with the same weight. The results of five different specifications are shown in tables 5.4, 5.5, 5.6, 5.7 and 5.8. Further specifications were tested, but the results did not deviate from the results presented here. Table 5.9 shows the average of the calculated differences. In a last step, the missing wheat prices are filled in with data from the most similar province:[21] Albacete: Granada; Alicante: Murcia; Almería: Coruña; Ávila: Álava; Badajoz: Navarre; Baleares: Granada; Cáceres: Granada; Castellón: Saragoza; Ciudad real: Granada; Córdoba: Gerona; Cuenca: Burgos; Guadalajara: Álava; Huelva: Gerona; Huesca: Navarre; Jaen: Granada; Lugo: Coruña; Orense: Coruña, Palencia: Burgos; Pontevedra: Murcia; Rioja (La): Navarre; Salamanca: Valladolid; Soria: Valladolid; Tarragona: Lerida; Teruel: León; Toledo: Álava; Viscaya: Guipuzcoa; Zamora: León.

[20]The series of wheat prices stems from Sánchez-Albornoz and is not comparable with the series by Barquín Gil (2001). The latter series covers a bigger time span, but is only available for sixteen provinces, while the series by Sánchez-Albornoz starts only in 1856, but covers almost all Spanish provinces.

[21]In cases wit ED>8, the differences between the provinces were esteemed too large and no data points have been filled in.

Abbreviations for tables: 1: Álava, **2:** Albacete, **3:** Alicante, **4:** Almería, **5:** Asturias, **6:** Ávila, **7:** Badajoz, **8:** Baleares, **9:** Barcelona, **10:** Burgos, **11:** Cáceres, **12:** Cádiz, **14:** Cantabria, **15:** Castellón, **16**: Ciudad Real, **17:** Córdoba, **18:** Coruña, **19:** Cuenca, **20:** Gerona, **21:** Granada, **22:** Guadalajara, **23:** Guipuzcoa, **24:** Huelva, **25:** Huesca, **26:** Jaen, **27:** Leon, **28:** Lerida, **29:** Lugo, **30:** Madrid, **31:** Málaga, **32:** Murcia, **33:** Navarre, **34:**Orense, **35:** Palencia, **36:** Pontevedra, **37:** Rioja (La), **38:** Salamanca, **39:** Segovia, **40:** Sevilla, **41:** Soria, **42:** Tarragona, **43:** Teruel, **44:** Toledo, **45:** Valencia, **46:** Valladolid, **47:** Vizcaya, **48:** Zamora, **49:** Zaragoza.

Table 5.4: Results of a cluster analysis using the standardized Euclidean distance, specification 1

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44
1	0	1.68	3.67	3.57	2.63	1.30	1.18	2.83	3.98	1.35	1.87	4.83	3.24	2.17	2.08	2.64	3.73	1.50	1.83	2.16	0.19	1.89	2.65	1.64	1.76	2.18	2.34	2.68	4.18	4.42	0.67	1.60	0.69	1.57	1.73	4.38	2.58	2.79	0.69	3.97	1.20	3.20	3.17	1.90
2	1.68	0	2.63	2.54	1.67	2.33	1.61	2.21	4.10	1.86	1.12	4.77	3.53	1.88	1.34	2.43	2.81	1.81	2.16	0.80	2.08	2.38	2.61	1.14	0.79	1.77	2.21	2.83	3.79	3.26	1.50	1.77	1.70	1.90	2.46	4.45	2.49	1.99	1.37	3.45	1.61	3.77	2.37	1.84
3	3.67	2.63	0	1.02	3.79	3.50	2.16	1.14	4.03	4.30	2.45	4.44	3.83	1.86	2.75	2.36	1.84	4.28	2.60	2.50	4.32	2.77	2.45	2.82	2.48	3.88	2.41	4.12	3.13	1.39	3.38	4.00	3.43	4.22	4.96	4.31	2.31	3.88	3.10	2.90	3.86	4.26	3.60	2.77
4	3.57	2.54	1.02	0	3.53	3.21	2.34	1.73	4.54	3.97	2.05	5.14	3.83	1.80	3.06	2.97	0.83	3.94	2.67	2.61	4.07	2.80	2.80	2.35	2.59	3.34	2.44	4.57	3.58	1.99	3.13	3.55	3.22	3.83	4.67	4.91	2.74	3.29	3.11	3.05	3.58	4.33	2.87	2.39
5	2.63	1.67	3.79	3.53	0	3.36	3.24	3.61	5.18	2.19	1.91	5.93	4.34	3.40	2.78	3.97	3.66	1.81	3.25	1.65	2.46	3.45	3.53	2.06	2.40	1.82	2.97	4.02	4.74	4.50	2.58	2.20	2.85	2.35	2.56	5.65	3.53	1.98	2.52	4.53	2.49	4.60	2.75	3.21
6	1.30	2.33	3.50	3.21	3.36	0	1.89	2.73	4.15	2.12	1.91	5.12	3.00	1.82	2.86	2.90	3.22	2.27	1.56	2.85	1.69	1.44	2.57	1.68	2.41	2.51	2.17	3.60	4.21	4.40	1.03	2.02	0.92	2.13	2.58	4.63	2.58	3.10	1.43	3.84	1.87	3.06	3.15	1.56
7	1.81	1.61	2.16	2.34	3.24	1.89	0	1.27	3.36	2.70	1.84	3.96	3.13	0.75	1.41	1.22	2.73	2.86	1.56	1.92	2.64	1.71	2.11	1.81	1.12	2.88	2.07	2.47	3.28	2.75	1.64	2.60	1.58	2.68	3.27	3.61	1.89	3.16	1.38	2.96	2.14	3.27	3.14	1.40
8	2.83	2.21	1.14	1.73	3.61	2.73	1.27	0	3.31	3.72	2.16	3.82	3.27	1.20	2.09	1.37	2.41	3.76	1.71	2.12	3.60	1.89	1.67	2.47	1.89	3.64	1.82	3.24	2.83	2.05	2.67	3.55	2.67	3.71	4.33	3.61	1.43	3.82	2.23	2.80	3.26	3.54	3.70	2.31
9	3.98	4.10	4.03	4.54	5.18	4.15	3.36	3.31	0	4.95	4.32	1.33	2.23	3.65	3.61	2.93	5.05	5.04	3.41	3.98	4.65	3.49	3.29	4.48	3.75	5.35	3.71	3.63	1.56	4.44	4.16	5.06	4.09	5.07	5.29	0.92	3.14	5.66	3.61	2.45	4.62	2.04	5.76	4.30
10	1.35	1.86	4.30	3.97	2.19	2.12	2.70	3.72	4.95	0	2.12	5.79	3.98	2.94	2.61	3.67	3.94	0.48	2.96	2.50	0.91	3.03	3.75	1.66	2.22	1.26	3.25	3.37	4.99	4.91	1.26	0.66	1.43	0.46	0.70	5.33	3.70	1.88	1.84	4.51	0.75	4.04	2.51	2.22
11	1.87	1.12	2.45	2.05	1.91	1.91	1.84	2.16	4.32	2.12	0	5.17	3.26	1.70	2.30	2.86	2.16	1.99	1.77	1.48	2.14	1.92	2.32	0.68	1.67	1.72	1.64	3.72	3.81	3.43	1.50	1.83	1.71	2.11	2.78	4.82	2.32	2.05	1.57	3.44	1.99	3.60	2.20	1.69
12	4.83	4.77	4.44	5.14	5.93	5.12	3.96	3.82	1.33	5.79	5.17	0	3.52	4.33	3.97	3.19	5.74	5.91	4.32	4.57	5.57	4.43	4.08	5.33	4.27	6.19	4.61	3.71	2.27	4.50	5.03	5.90	4.94	5.89	6.11	0.65	3.86	6.42	4.44	3.11	5.38	3.35	6.49	5.04
13	3.24	3.53	3.83	3.83	4.34	3.00	3.13	3.27	2.23	3.98	3.26	3.52	0	3.10	3.78	3.51	4.04	3.99	2.72	3.65	3.63	2.71	3.00	3.38	3.53	4.16	2.92	4.39	2.11	4.67	3.22	3.93	3.20	4.04	4.36	3.02	3.01	4.55	3.03	2.16	3.79	0.72	4.59	3.41
14	2.17	1.88	1.86	1.80	3.40	1.82	0.75	1.20	3.65	2.94	1.70	4.33	3.10	0	2.04	1.76	2.10	3.07	1.59	2.24	2.89	1.67	2.19	1.70	1.61	2.87	2.00	3.21	3.34	2.60	1.81	2.68	1.77	2.84	3.57	3.97	2.03	3.11	1.79	2.86	2.39	3.36	2.89	1.15
15	2.08	1.34	2.75	3.06	2.78	2.86	1.41	2.09	3.61	2.61	2.30	3.97	3.78	2.04	0	1.58	3.51	2.73	2.52	1.45	2.77	2.75	2.81	2.26	0.66	2.89	2.82	1.66	3.61	2.96	2.13	2.68	2.16	2.67	3.07	3.71	2.56	3.04	1.74	3.41	2.15	3.87	3.31	2.27
16	2.64	2.43	2.36	2.97	3.97	2.90	1.22	1.37	2.93	3.67	2.86	3.19	3.51	1.76	1.58	0	3.57	3.82	2.13	2.40	3.53	2.30	2.21	2.97	1.79	3.98	2.59	2.06	3.07	2.66	2.71	3.69	2.62	3.72	4.15	2.97	1.88	4.22	2.14	3.16	3.14	3.54	4.24	2.58
17	3.73	2.81	1.84	0.83	3.66	3.22	2.73	2.41	5.05	3.94	2.16	5.74	4.04	2.10	3.51	3.57	0	3.91	3.04	3.06	4.11	3.11	3.36	2.31	2.96	3.14	2.86	5.04	4.12	2.59	3.18	3.42	3.28	3.72	4.63	5.45	3.33	3.04	3.40	3.35	3.57	4.58	2.45	2.32
18	1.50	1.81	4.28	3.94	1.81	2.27	2.86	3.76	5.04	0.48	1.99	5.91	3.99	3.07	2.73	3.82	3.91	0	2.95	2.36	0.95	3.03	3.67	1.63	2.31	1.15	3.12	3.59	4.99	4.98	1.45	0.82	1.67	0.80	0.88	5.47	3.65	1.81	1.89	4.58	1.14	4.09	2.53	2.44
19	1.83	2.16	2.60	2.67	3.25	1.56	1.56	1.71	3.41	2.96	1.77	4.32	2.72	1.59	2.52	2.13	3.04	2.95	0	2.23	2.47	0.29	1.01	2.07	2.18	3.20	0.86	3.37	3.30	3.71	1.85	2.93	1.84	3.08	3.46	3.97	1.04	3.68	1.31	3.43	2.73	2.82	3.77	2.23
20	2.16	0.80	2.50	2.61	1.65	2.85	1.92	2.12	3.98	2.50	1.48	4.57	3.65	2.24	1.45	2.40	3.06	2.36	2.23	0	2.58	2.50	2.36	1.80	1.15	2.42	2.08	2.88	3.58	3.17	2.15	2.50	2.33	2.62	3.02	4.34	2.23	2.60	1.68	3.52	2.35	3.88	3.00	2.52
21	0.91	2.08	4.32	4.07	2.46	1.69	2.64	3.60	4.65	0.91	2.14	5.57	3.63	2.89	2.77	3.53	4.11	0.95	2.47	2.58	0	2.50	3.27	1.85	2.41	1.90	2.82	3.36	4.80	5.12	1.13	1.32	1.25	1.25	1.09	5.11	3.27	2.60	1.46	4.54	1.28	3.60	3.15	2.40
22	1.89	2.38	2.77	2.80	3.45	1.44	1.71	1.89	3.49	3.03	1.92	4.43	2.71	1.67	2.75	2.30	3.11	3.03	0.29	2.50	2.50	0	1.18	2.17	2.39	3.29	1.03	3.53	3.42	3.89	1.89	2.99	1.86	3.14	3.51	4.06	1.24	3.79	1.45	3.52	2.80	2.79	3.86	2.26
23	2.65	2.61	2.45	2.80	3.53	2.57	2.11	1.67	3.29	3.75	2.32	4.08	3.00	2.19	2.81	2.21	3.36	3.67	1.01	2.36	3.27	1.18	0	2.80	2.60	3.91	0.85	3.62	3.04	3.62	2.75	3.75	2.77	3.90	4.23	3.87	0.33	4.32	2.02	3.55	3.55	3.12	4.44	3.06
24	1.64	1.14	2.82	2.35	2.06	1.68	1.81	2.47	4.48	1.66	0.68	5.33	3.38	1.70	2.26	2.97	2.31	1.63	2.07	1.80	1.85	2.17	2.80	0	1.61	1.24	2.17	3.61	4.10	3.62	1.10	1.25	1.32	1.54	2.35	4.92	2.76	1.64	1.56	3.54	1.43	3.68	1.77	1.24
25	1.76	0.79	2.48	2.59	2.40	2.41	1.12	1.89	3.75	2.22	1.67	4.27	3.53	1.61	0.66	1.79	2.96	2.31	2.18	1.15	2.41	2.39	2.60	1.61	0	2.33	2.43	2.22	3.58	2.89	1.65	2.18	1.73	2.23	2.78	3.97	2.40	2.52	1.41	3.25	1.75	3.70	2.74	1.74
26	2.18	1.77	3.88	3.34	1.82	2.51	2.88	3.64	5.35	1.26	1.72	6.19	4.16	2.87	2.89	3.98	3.14	1.15	3.20	2.42	1.90	3.29	3.91	1.24	2.33	0	3.25	4.11	5.02	4.50	1.75	0.76	1.99	1.04	1.82	5.76	3.89	0.74	2.39	4.34	1.42	4.43	1.42	2.10
27	2.34	2.21	2.41	2.44	2.97	2.17	2.07	1.82	3.71	3.25	1.64	4.61	2.92	2.00	2.82	2.59	2.86	3.12	0.86	2.08	2.82	1.03	0.85	2.17	2.43	3.25	0	3.87	3.30	3.67	2.32	3.17	2.40	3.38	3.77	4.34	1.04	3.67	1.78	3.53	3.13	3.15	3.80	2.67
28	2.68	2.83	4.12	4.57	4.02	3.60	2.47	3.24	3.63	3.37	3.72	3.71	4.39	3.21	1.66	2.06	5.04	3.59	3.37	2.88	3.36	3.53	3.62	3.61	2.22	4.11	3.87	0	4.26	4.18	3.02	3.68	2.94	3.52	3.55	3.48	3.34	4.38	2.54	4.31	2.96	4.21	4.72	3.40
29	4.18	3.79	3.13	3.58	4.74	4.21	3.28	2.83	1.56	4.99	3.81	2.27	2.11	3.34	3.61	3.07	4.12	4.99	3.30	3.58	4.80	3.42	3.04	4.10	3.58	5.02	3.30	4.26	0	3.63	4.18	4.93	4.18	5.05	5.47	2.11	2.93	5.20	3.71	1.54	4.67	2.41	5.19	4.08
30	4.42	3.26	1.39	1.99	4.50	4.40	2.75	2.05	4.44	4.91	3.43	4.50	4.67	2.60	2.96	2.66	2.59	4.98	3.71	3.17	5.12	3.89	3.62	3.62	2.89	4.50	3.67	4.18	3.63	0	4.12	4.62	4.15	4.78	5.56	4.45	3.40	4.33	3.92	3.19	4.37	5.06	3.98	3.31
31	0.67	1.50	3.38	3.13	2.58	1.03	1.64	2.67	4.16	1.26	1.50	5.03	3.22	1.81	2.13	2.71	3.18	1.45	1.85	2.15	1.13	1.89	2.75	1.10	1.65	1.75	2.32	3.02	4.18	4.12	0	1.22	0.28	1.29	1.83	4.56	2.69	2.33	0.96	3.75	0.39	3.31	2.59	1.31
32	1.60	1.77	4.00	3.55	2.20	2.02	2.60	3.55	5.06	0.66	1.83	5.90	3.93	2.68	2.68	3.69	3.42	0.82	2.93	2.50	1.32	2.99	3.75	1.25	2.18	0.76	3.17	3.68	4.93	4.62	1.22	0	1.41	0.36	1.28	5.44	3.71	1.40	1.98	4.30	0.78	4.10	1.90	1.83
33	0.69	1.70	3.43	3.22	2.85	0.92	1.58	2.67	4.09	1.43	1.71	4.94	3.20	1.77	2.16	2.62	3.28	1.67	1.84	2.33	1.25	1.86	2.77	1.32	1.73	1.99	2.40	2.94	4.18	4.15	0.28	1.41	0	1.44	1.94	4.47	2.70	2.56	1.00	3.75	1.03	3.25	2.75	1.28
34	1.57	1.90	4.22	3.83	2.35	2.13	2.68	3.71	5.07	0.46	2.11	5.89	4.04	2.84	2.67	3.72	3.72	0.80	3.08	2.62	1.25	3.14	3.90	1.54	2.23	1.04	3.38	3.52	5.05	4.78	1.29	0.36	1.44	0	1.01	5.42	3.85	1.62	2.03	4.44	0.63	4.15	2.15	1.98
35	1.73	2.46	4.96	4.67	2.56	2.58	3.27	4.33	5.29	0.70	2.78	6.11	4.36	3.57	3.07	4.15	4.63	0.88	3.46	3.02	1.09	3.51	4.23	2.35	2.78	1.82	3.77	3.55	5.47	5.56	1.83	1.28	1.94	1.01	0	5.65	4.19	2.40	2.30	5.04	1.30	4.33	3.09	2.85
36	4.38	4.45	4.31	4.91	5.65	4.63	3.61	3.61	0.92	5.33	4.82	0.65	3.02	3.97	3.71	2.97	5.45	5.47	3.97	4.34	5.11	4.06	3.87	4.92	3.97	5.76	4.34	3.48	2.11	4.45	4.46	5.44	4.47	5.42	5.65	0	3.65	6.02	4.04	2.78	4.92	2.81	6.09	4.59
37	2.58	2.49	2.31	2.74	3.53	2.58	1.89	1.43	3.14	3.70	2.32	3.86	3.01	2.03	2.56	1.88	3.33	3.65	1.04	2.23	3.27	1.24	0.33	2.76	2.40	3.89	1.04	3.34	2.93	3.40	2.69	3.71	2.70	3.85	4.19	3.65	0	4.27	1.93	3.42	3.45	3.11	4.39	2.59
38	2.79	1.99	3.88	3.29	1.98	3.10	3.16	3.82	5.66	1.88	2.05	6.42	4.55	3.11	3.04	4.22	3.04	1.81	3.68	2.60	2.60	3.79	4.32	1.64	2.52	0.74	3.67	4.38	5.20	4.33	2.33	1.40	2.56	1.62	2.40	6.02	4.27	0	2.92	4.41	1.91	4.89	0.97	2.35
39	0.69	1.37	3.10	3.11	2.52	1.43	1.38	2.23	3.61	1.84	1.57	4.44	3.03	1.79	1.74	2.14	3.40	1.89	1.31	1.68	1.46	1.45	2.02	1.56	1.41	2.39	1.78	2.54	3.71	3.92	0.96	1.98	1.00	2.03	2.30	4.04	1.93	2.92	0	3.62	1.62	3.05	3.25	1.89
40	3.97	3.45	2.90	3.05	4.53	3.84	2.96	2.80	2.45	4.51	3.44	3.11	2.16	2.86	3.41	3.16	3.35	4.58	3.43	3.52	4.54	3.52	3.55	3.54	3.25	4.34	3.53	4.31	1.54	3.19	3.75	4.30	3.75	4.44	5.04	2.78	3.42	4.41	3.62	0	4.09	2.64	4.21	3.31
41	1.20	1.61	3.86	3.58	2.49	1.87	2.14	3.26	4.62	0.75	1.99	5.38	3.79	2.39	2.15	3.14	3.57	1.14	2.73	2.35	1.28	2.80	3.55	1.43	1.75	1.42	3.13	2.96	4.67	4.37	0.93	0.78	1.03	0.63	1.30	4.92	3.45	1.91	1.62	4.09	0	3.87	2.31	1.62
42	3.20	3.77	4.26	4.33	4.60	3.06	3.27	3.54	2.04	4.04	3.60	3.35	0.72	3.36	3.87	3.54	4.58	4.09	2.82	3.88	3.60	2.79	3.12	3.68	3.70	4.43	3.15	4.21	2.41	5.06	3.31	4.10	3.25	4.15	4.33	2.81	3.11	4.89	3.05	2.64	3.87	0	5.00	3.66
43	3.17	2.37	3.60	2.87	2.75	3.15	3.14	3.70	5.75	2.51	2.20	6.49	4.59	2.89	3.31	4.24	2.45	2.53	3.77	3.00	3.15	3.86	4.44	1.77	2.74	1.42	3.80	4.72	5.19	3.98	2.59	1.90	2.75	2.15	3.09	6.09	4.39	0.97	3.25	4.21	2.31	5.00	0	2.10
44	1.90	1.84	2.77	2.39	3.21	1.56	1.40	2.31	4.30	2.22	1.69	5.04	3.41	1.15	2.27	2.58	2.32	2.44	2.23	2.52	2.40	2.26	3.06	1.24	1.74	2.10	2.67	3.40	4.08	3.31	1.31	1.83	1.28	1.98	2.85	4.59	2.95	2.35	1.89	3.31	1.62	3.66	2.10	0

Notes: Variables included in the analysis are wheat prices 1856-65, dummy variable for provinces with a port, share of the urban population, altitude of the capital of each province, and the distance to the most important trade centers.

Table 5.5: Results of a cluster analysis using the standardized Euclidean distance, specification 2

	1	2	3	4	5	6	7	8	9	10	11	12	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	30	31	32	33	35	37	38	39	40	42	43	44	45	46	47	48	49
1	0	1.68	4.18	4.09	2.63	2.38	2.69	3.46	3.54	1.35	2.74	4.48	2.68	2.95	2.08	2.64	4.23	1.50	2.71	2.94	0.91	2.75	3.31	2.58	1.76	2.18	3.08	2.68	3.77	4.85	2.11	1.60	0.69	2.54	1.73	3.45	3.26	2.79	0.69	3.53	1.20	2.64	3.75	1.90
2	1.68	0	3.30	3.23	1.67	3.07	2.56	2.97	3.68	1.86	2.29	4.41	3.03	2.74	1.34	2.43	3.44	1.81	2.94	2.15	2.08	3.11	3.29	2.30	0.79	1.77	2.98	2.83	3.32	3.82	2.50	1.77	1.70	2.76	2.46	3.54	3.19	1.99	1.37	2.93	1.61	3.29	3.10	1.84
3	4.18	3.30	0	1.02	4.28	3.50	2.16	1.14	2.98	4.74	2.45	3.53	2.72	1.86	3.40	3.09	1.84	4.72	2.60	2.50	4.76	2.77	2.45	2.82	3.18	4.37	2.41	4.58	1.57	1.39	3.38	4.47	3.97	4.22	5.35	3.90	2.31	4.36	3.69	1.06	4.34	3.29	3.60	3.41
4	4.09	3.23	1.20	0	4.06	3.21	2.34	1.73	3.64	4.45	2.05	4.37	2.71	1.80	3.65	3.58	0.83	4.41	2.67	2.61	4.54	2.80	2.80	2.35	3.27	3.89	2.44	4.99	2.35	1.99	3.13	4.08	3.79	3.83	5.08	4.55	2.74	3.85	3.70	1.41	4.10	3.39	2.87	3.11
5	2.63	1.67	4.28	4.06	0	3.91	3.80	4.12	4.85	2.19	2.76	5.64	3.94	3.95	2.78	3.97	4.17	1.81	3.81	2.59	2.46	3.98	4.06	2.87	2.40	1.82	3.58	4.02	4.37	4.92	3.26	2.20	2.85	3.08	2.56	4.96	4.06	1.98	2.52	4.15	2.49	4.22	3.40	3.21
6	2.38	3.07	3.50	3.21	3.91	0	1.89	2.73	3.15	2.91	1.91	4.35	1.31	1.82	3.49	3.52	3.22	3.02	1.56	2.85	2.61	1.44	2.57	1.68	3.13	3.21	2.17	4.12	3.22	4.40	1.03	2.84	2.20	2.13	3.26	4.25	2.58	3.69	2.46	2.73	2.74	1.42	3.15	2.53
7	2.69	2.56	2.16	2.34	3.80	1.89	0	1.27	2.00	3.36	1.84	2.90	1.57	0.75	2.44	2.34	2.73	3.49	1.56	1.92	3.31	1.71	2.11	1.81	2.29	3.51	2.07	3.18	1.86	2.75	1.64	3.27	2.54	2.68	3.83	3.11	1.89	3.74	2.43	1.22	2.93	1.84	3.14	2.44
8	3.46	2.97	1.14	1.73	4.12	2.73	1.27	0	1.92	4.22	2.16	2.69	1.84	1.20	2.89	2.42	2.41	4.26	1.71	2.12	4.12	1.89	1.67	2.47	2.75	4.15	1.82	3.80	0.83	2.05	2.67	4.08	3.33	3.71	4.77	3.12	1.43	4.31	2.99	0.73	3.82	2.28	3.70	3.05
9	3.54	3.68	2.98	3.64	4.85	3.15	2.00	1.92	0	4.61	3.37	1.33	2.23	2.46	3.12	2.29	4.27	4.70	2.09	2.92	4.27	2.21	1.88	3.57	3.28	5.03	2.55	3.14	1.56	3.52	3.16	4.72	3.66	4.29	4.96	2.20	1.59	5.36	3.12	2.45	4.24	2.04	5.08	3.89
10	1.35	1.86	4.74	4.45	2.19	2.91	3.36	4.22	4.61	0	2.91	5.49	3.53	3.55	2.61	3.67	4.41	0.48	3.57	3.20	0.91	3.63	4.24	2.59	2.22	1.26	3.81	3.37	4.65	5.30	2.36	0.66	1.43	2.05	0.70	4.59	4.20	1.88	1.84	4.13	0.75	3.61	3.21	2.22
11	2.74	2.29	2.45	2.05	2.76	1.91	1.84	2.16	3.37	2.91	0	4.41	1.82	1.70	3.04	3.49	2.16	2.82	1.77	1.48	2.93	1.92	2.32	0.68	2.60	2.63	1.64	4.22	2.68	3.43	1.50	2.71	2.63	2.11	3.42	4.46	2.32	2.86	2.54	2.12	2.82	2.38	2.20	2.62
12	4.48	4.41	3.53	4.37	5.64	4.35	2.90	2.69	1.33	5.49	4.41	0	3.52	3.38	3.52	2.61	5.06	5.62	3.36	3.69	5.26	3.51	3.05	4.59	3.87	5.92	3.74	3.23	2.27	3.60	4.24	5.62	4.59	5.24	5.84	2.10	2.75	6.15	4.04	3.11	5.06	3.35	5.90	4.70
14	2.68	3.03	2.72	2.71	3.94	1.31	1.57	1.84	2.23	3.53	1.82	3.52	0	1.52	3.32	3.00	3.01	3.55	0.34	2.45	3.14	0.18	1.30	2.04	3.03	3.74	1.11	4.00	2.11	3.81	1.75	3.49	2.63	3.01	3.96	3.62	1.33	4.17	2.42	2.16	3.33	0.72	3.71	2.88
15	2.95	2.74	1.86	1.80	3.95	1.82	0.75	1.20	2.46	3.55	1.70	3.38	1.52	0	2.85	2.66	2.10	3.66	1.59	2.24	3.51	1.67	2.19	1.70	2.56	3.49	2.00	3.78	1.97	2.60	1.81	3.34	2.66	2.84	4.09	3.52	2.03	3.69	2.68	0.94	3.11	2.00	2.89	2.30
16	2.08	1.34	3.40	3.65	2.78	3.49	2.44	2.89	3.12	2.61	3.04	3.52	3.32	2.85	0	1.58	4.04	2.73	3.21	2.46	2.77	3.39	3.45	3.01	0.66	2.89	3.45	1.66	3.12	3.57	2.92	2.68	2.16	3.33	3.07	2.54	3.25	3.04	1.74	2.88	2.15	3.42	3.86	2.27
17	2.64	2.43	3.09	3.58	3.97	3.52	2.34	2.42	2.29	3.67	3.49	2.61	3.00	2.66	1.58	0	4.09	3.82	2.92	3.12	3.53	3.05	2.97	3.57	1.79	3.98	3.27	2.06	2.47	3.33	3.36	3.69	2.62	4.22	4.15	1.24	2.74	4.22	2.14	2.58	3.14	3.03	4.69	2.58
18	4.23	3.44	1.84	0.83	4.17	3.22	2.73	2.41	4.27	4.41	2.16	5.06	3.01	2.10	4.04	4.09	0	4.39	3.04	3.06	4.57	3.11	3.36	2.31	3.57	3.72	2.86	5.42	3.10	2.59	3.18	3.96	3.84	3.72	5.05	5.13	3.33	3.64	3.94	1.98	4.09	3.70	2.45	3.06
19	1.50	1.81	4.72	4.41	1.81	3.02	3.49	4.26	4.70	0.48	2.82	5.62	3.55	3.66	2.73	3.82	4.39	0	3.56	3.09	0.95	3.63	4.18	2.58	2.31	1.15	3.70	3.59	4.65	5.36	2.46	0.82	1.67	2.15	0.88	4.76	4.16	1.81	1.89	4.20	1.14	3.66	3.22	2.44
20	2.71	2.94	2.60	2.67	3.81	1.56	1.56	1.71	2.09	3.57	1.77	3.36	0.34	1.59	3.21	2.92	3.04	3.56	0	2.23	3.18	0.29	1.01	2.07	2.95	3.77	0.86	3.91	1.89	3.71	1.85	3.54	2.72	3.08	3.99	3.52	1.04	4.18	2.39	2.11	3.38	0.82	3.77	2.99
21	2.94	2.15	2.50	2.61	2.59	2.85	1.92	2.12	2.92	3.20	1.48	3.69	2.45	2.24	2.46	3.12	3.06	3.09	2.23	0	3.26	2.50	2.36	1.80	2.30	3.14	2.08	3.51	2.34	3.17	2.15	3.20	3.07	2.62	3.62	3.94	2.23	3.27	2.61	2.26	3.09	2.78	3.00	3.21
22	0.91	2.08	4.76	4.54	2.46	2.61	3.31	4.12	4.27	0.91	2.93	5.26	3.14	3.51	2.77	3.53	4.57	0.95	3.18	3.26	0	3.20	3.83	2.72	2.41	1.90	3.45	3.36	4.44	5.49	2.29	1.32	1.25	2.36	1.09	4.33	3.83	2.60	1.46	4.15	1.28	3.10	3.73	2.40
23	2.75	3.11	2.77	2.80	3.98	1.44	1.71	1.89	2.21	3.63	1.92	3.51	0.18	1.67	3.39	3.05	3.11	3.63	0.29	2.50	3.20	0	1.18	2.17	3.12	3.85	1.03	4.06	2.10	3.89	1.89	3.59	2.73	3.14	4.04	3.63	1.24	4.29	2.47	2.26	3.44	0.69	3.86	3.02
24	3.31	3.29	2.45	2.80	4.06	2.57	2.11	1.67	1.88	4.24	2.32	3.05	1.30	2.19	3.45	2.97	3.36	4.18	1.01	2.36	3.83	1.18	0	2.80	3.28	4.39	0.85	4.13	1.40	3.62	2.75	4.25	3.42	3.90	4.68	3.41	0.33	4.76	2.84	2.31	4.07	1.55	4.44	3.66
25	2.58	2.30	2.82	2.35	2.87	1.68	1.81	2.47	3.57	2.59	0.68	4.59	2.04	1.70	3.01	3.57	2.31	2.58	2.07	1.80	2.72	2.17	2.80	0	2.56	2.35	2.17	4.13	3.09	3.62	1.10	2.36	2.39	1.54	3.08	4.57	2.76	2.58	2.53	2.29	2.46	2.50	1.77	2.35
26	1.76	0.79	3.18	3.27	2.40	3.13	2.29	2.75	3.28	2.22	2.60	3.87	3.03	2.56	0.66	1.79	3.57	2.31	2.95	2.30	2.41	3.12	3.28	2.56	0	2.33	3.14	2.22	3.09	3.51	2.59	2.18	1.73	2.99	2.78	2.90	3.12	2.52	1.41	2.69	1.75	3.22	3.39	1.74
27	2.18	1.77	4.37	3.89	1.82	3.21	3.51	4.15	5.03	1.26	2.63	5.92	3.74	3.49	2.89	3.98	3.72	1.15	3.77	3.14	1.90	3.85	4.39	2.35	2.33	0	3.82	4.11	4.68	4.92	2.66	0.76	1.99	2.25	1.82	5.09	4.37	0.74	2.39	3.94	1.42	4.04	2.45	2.10
28	3.08	2.98	2.41	2.44	3.58	2.17	2.07	1.82	2.55	3.81	1.64	3.74	1.11	2.00	3.45	3.27	2.86	3.70	0.86	2.08	3.45	1.03	0.85	2.17	3.14	3.82	0	4.36	1.89	3.67	2.32	3.75	3.12	3.38	4.27	3.93	1.04	4.18	2.68	2.28	3.71	1.61	3.80	3.33
30	2.68	2.83	4.58	4.99	4.02	4.12	3.18	3.80	3.14	3.37	4.22	3.23	4.00	3.78	1.66	2.06	5.42	3.59	3.91	3.51	3.36	4.06	4.13	4.13	2.22	4.11	4.36	0	3.85	4.63	3.62	3.68	2.94	4.05	3.55	2.19	3.89	4.38	2.54	3.91	2.96	3.80	5.12	3.40
31	3.77	3.32	1.57	2.35	4.37	3.22	1.86	0.83	1.56	4.65	2.68	2.27	2.11	1.97	3.12	2.47	3.10	4.65	1.89	2.34	4.44	2.10	1.40	3.09	3.09	4.68	1.89	3.85	0	2.42	3.19	4.59	3.76	4.27	5.15	2.91	1.14	4.87	3.23	1.54	4.30	2.41	4.43	3.65
32	4.85	3.82	1.39	1.99	4.92	4.40	2.75	2.05	3.52	5.30	3.43	3.60	3.81	2.60	3.57	3.33	2.59	5.36	3.71	3.17	5.49	3.89	3.62	3.62	3.51	4.92	3.67	4.63	2.42	0	4.12	5.04	4.60	4.78	5.91	4.06	3.40	4.77	4.40	1.70	4.80	4.28	3.98	3.87
33	2.11	2.50	3.38	3.13	3.26	1.03	1.64	2.67	3.16	2.36	1.50	4.24	1.75	1.81	2.92	3.36	3.18	2.46	1.85	2.15	2.29	1.89	2.75	1.10	2.59	2.66	2.32	3.62	3.19	4.12	0	2.34	2.02	1.29	2.70	4.19	2.69	3.07	2.21	2.61	2.20	1.90	2.59	2.39
35	1.60	1.77	4.47	4.08	2.20	2.84	3.27	4.08	4.72	0.66	2.71	5.62	3.49	3.34	2.68	3.69	3.96	0.82	3.54	3.20	1.32	3.59	4.25	2.36	2.18	0.76	3.75	3.68	4.59	5.04	2.34	0	1.41	2.03	1.28	4.72	4.21	1.40	1.98	3.90	0.78	3.67	2.76	1.83
37	0.69	1.70	3.97	3.79	2.85	2.20	2.54	3.33	3.66	1.43	2.63	4.59	2.63	2.66	2.16	2.62	3.84	1.67	2.72	3.07	1.25	2.73	3.42	2.39	1.73	1.99	3.12	2.94	3.76	4.60	2.02	1.41	0	2.46	1.94	3.55	3.35	2.56	1.00	3.28	1.03	2.69	3.40	1.28
38	2.54	2.76	4.22	3.83	3.08	2.13	2.68	3.71	4.29	2.05	2.11	5.24	3.01	2.84	3.33	4.22	3.72	2.15	3.08	2.62	2.36	3.14	3.90	1.54	2.99	2.25	3.38	4.05	4.27	4.78	1.29	2.03	2.46	0	2.24	5.11	3.85	2.57	2.84	3.52	2.09	3.16	2.15	2.81
39	1.73	2.46	5.35	5.08	2.56	3.26	3.83	4.77	4.96	0.70	3.42	5.84	3.96	4.09	3.07	4.15	5.05	0.88	3.99	3.62	1.09	4.04	4.68	3.08	2.78	1.82	4.27	3.55	5.15	5.91	2.70	1.28	1.94	2.24	0	4.96	4.64	2.40	2.30	4.70	1.30	3.93	3.68	2.85
40	3.45	3.54	3.90	4.55	4.96	4.25	3.11	3.12	2.20	4.59	4.46	2.10	3.62	3.52	2.54	1.24	5.13	4.76	3.52	3.94	4.33	3.63	3.41	4.57	2.90	5.09	3.93	2.19	2.91	4.06	4.19	4.72	3.55	5.11	4.96	0	3.17	5.38	3.00	3.42	4.11	3.45	5.81	3.71
42	3.26	3.19	2.31	2.74	4.06	2.58	1.89	1.43	1.59	4.20	2.32	2.75	1.33	2.03	3.25	2.74	3.33	4.16	1.04	2.23	3.83	1.24	0.33	2.76	3.12	4.37	1.04	3.89	1.14	3.40	2.69	4.21	3.35	3.85	4.64	3.17	0	4.72	2.78	2.10	3.99	1.55	4.39	3.56
43	2.79	1.99	4.36	3.85	1.98	3.69	3.74	4.31	5.36	1.88	2.86	6.15	4.17	3.69	3.04	4.22	3.64	1.81	4.18	3.27	2.60	4.29	4.76	2.58	2.52	0.74	4.18	4.38	4.87	4.77	3.07	1.40	2.56	2.57	2.40	5.38	4.72	0	2.92	4.02	1.91	4.54	2.22	2.35
44	0.69	1.37	3.69	3.70	2.52	2.46	2.43	2.99	3.12	1.84	2.54	4.04	2.42	2.68	1.74	2.14	3.94	1.89	2.39	2.61	1.46	2.47	2.84	2.53	1.41	2.39	2.68	2.54	3.23	4.40	2.21	1.98	1.00	2.84	2.30	3.00	2.78	2.92	0	3.13	1.62	2.44	3.81	1.89
45	3.53	2.93	1.06	1.41	4.15	2.73	1.22	0.73	2.45	4.13	2.12	3.11	2.16	0.94	2.88	2.58	1.98	4.20	2.11	2.26	4.15	2.26	2.31	2.29	2.69	3.94	2.28	3.91	1.54	1.70	2.61	3.90	3.28	3.52	4.70	3.42	2.10	4.02	3.13	0	3.66	2.64	3.22	2.76
46	1.20	1.61	4.34	4.10	2.49	2.74	2.93	3.82	4.24	0.75	2.82	5.06	3.33	3.11	2.15	3.14	4.09	1.14	3.38	3.09	1.28	3.44	4.07	2.46	1.75	1.42	3.71	2.96	4.30	4.80	2.20	0.78	1.03	2.09	1.30	4.11	3.99	1.91	1.62	3.66	0	3.42	3.05	1.62
47	2.64	3.29	3.29	3.39	4.22	1.42	1.84	2.28	2.04	3.61	2.38	3.35	0.72	2.00	3.42	3.03	3.70	3.66	0.82	2.78	3.10	0.69	1.55	2.50	3.22	4.04	1.61	3.80	2.41	4.28	1.90	3.67	2.69	3.16	3.93	3.45	1.55	4.54	2.44	2.64	3.42	0	4.20	3.17
48	3.75	3.10	3.60	2.87	3.40	3.15	3.14	3.70	5.08	3.21	2.20	5.90	3.71	2.89	3.86	4.69	2.45	3.22	3.77	3.00	3.73	3.86	4.44	1.77	3.39	2.45	3.80	5.12	4.43	3.98	2.59	2.76	3.40	2.15	3.68	5.81	4.39	2.22	3.81	3.22	3.05	4.20	0	2.89
49	1.90	1.84	3.41	3.11	3.21	2.53	2.44	3.05	3.89	2.22	2.62	4.70	2.88	2.30	2.27	2.58	3.06	2.44	2.99	3.21	2.40	3.02	3.66	2.35	1.74	2.10	3.33	3.40	3.65	3.87	2.39	1.83	1.28	2.81	2.85	3.71	3.56	2.35	1.89	2.76	1.62	3.17	2.89	0

Notes: Variables included in the analysis are wheat prices 1856-65, dummy variable for provinces with a cost or frontier, share of the urban population, altitude of the capital of each province, and the distance to the most important trade centers.

Table 5.6: Results of a cluster analysis using the standardized Euclidean distance, specification 3

	1	2	3	4	5	6	7	8	9	10	11	12	14	15	16	17	18	19	20	21	22	23	24	25
1	0	1.45	3.01	3.02	1.78	0.36	1.05	2.07	3.32	0.84	1.66	3.52	2.98	1.41	1.15	1.31	3.13	0.69	1.26	1.89	0.31	2.20	2.20	1.45
2	1.45	0	1.60	1.57	0.39	1.36	0.40	0.88	3.37	1.54	0.21	3.49	2.98	0.22	0.39	0.90	1.76	1.24	1.10	0.75	1.67	1.77	1.77	0.60
3	3.01	1.60	0	0.66	1.24	2.96	1.97	1.05	3.84	3.12	1.42	3.83	3.60	1.73	1.86	1.94	1.31	2.83	2.15	1.21	3.26	2.07	2.07	1.97
4	3.02	1.57	0.66	0	1.31	2.89	1.97	1.39	4.12	2.95	1.36	4.15	3.72	1.62	1.92	2.19	0.65	2.69	2.41	1.49	3.22	2.56	2.56	1.75
5	1.78	0.39	1.24	1.31	0	1.73	0.73	0.53	3.36	1.94	0.29	3.43	3.03	0.58	0.63	0.91	1.63	1.63	1.13	0.44	2.02	1.59	1.59	0.93
6	0.36	1.36	2.96	2.89	1.73	0	1.00	2.10	3.48	0.50	1.56	3.69	3.04	1.27	1.14	1.45	2.93	0.35	1.45	1.93	0.35	2.41	2.41	1.22
7	1.05	0.40	1.97	1.97	0.73	1.00	0	1.12	3.27	1.26	0.61	3.41	2.90	0.43	0.19	0.75	2.15	0.95	0.89	0.95	1.29	1.73	1.73	0.69
8	2.07	0.88	1.05	1.39	0.53	2.10	1.12	0	3.25	2.38	0.82	3.27	3.06	1.09	0.96	0.90	1.87	2.06	1.10	0.18	2.35	1.21	1.21	1.45
9	3.32	3.37	3.84	4.12	3.36	3.48	3.27	3.25	0	3.79	3.45	0.35	0.99	3.47	3.20	2.97	4.45	3.61	2.91	3.19	3.49	2.89	2.89	3.67
10	0.84	1.54	3.12	2.95	1.94	0.50	1.26	2.38	3.79	0	1.71	4.01	3.24	1.39	1.44	1.86	2.88	0.32	1.89	2.22	0.69	2.84	2.84	1.21
11	1.66	0.21	1.42	1.36	0.29	1.56	0.61	0.82	3.45	1.71	0	3.55	3.05	0.32	0.59	1.03	1.56	1.41	1.25	0.72	1.87	1.83	1.83	0.64
12	3.52	3.49	3.83	4.15	3.43	3.69	3.41	3.27	0.35	4.01	3.55	0	1.28	3.60	3.32	3.05	4.52	3.82	2.99	3.24	3.70	2.86	2.86	3.83
14	2.98	2.98	3.60	3.72	3.03	3.04	2.90	3.06	0.99	3.24	3.05	1.28	0	3.02	2.87	2.82	3.92	3.11	2.82	2.99	3.09	3.06	3.06	3.14
15	1.41	0.22	1.73	1.62	0.58	1.27	0.43	1.09	3.47	1.39	0.32	3.60	3.02	0	0.51	1.07	1.73	1.10	1.26	0.97	1.60	1.98	1.98	0.38
16	1.15	0.39	1.86	1.92	0.63	1.14	0.19	0.96	3.20	1.44	0.59	3.32	2.87	0.51	0	0.58	2.15	1.12	0.75	0.78	1.41	1.55	1.55	0.84
17	1.31	0.90	1.94	2.19	0.91	1.45	0.75	0.90	2.97	1.86	1.03	3.05	2.82	1.07	0.58	0	2.54	1.55	0.22	0.74	1.62	1.00	1.00	1.41
18	3.13	1.76	1.31	0.65	1.63	2.93	2.15	1.87	4.45	2.88	1.56	4.52	3.92	1.73	2.15	2.54	0	2.67	2.76	1.93	3.28	3.07	3.07	1.71
19	0.69	1.24	2.83	2.69	1.63	0.35	0.95	2.06	3.61	0.32	1.41	3.82	3.11	1.10	1.12	1.55	2.67	0	1.60	1.90	0.67	2.54	2.54	0.97
20	1.26	1.10	2.15	2.41	1.13	1.45	0.89	1.10	2.91	1.89	1.25	2.99	2.82	1.26	0.75	0.22	2.76	1.60	0	0.94	1.57	0.96	0.96	1.58
21	1.89	0.75	1.21	1.49	0.44	1.93	0.95	0.18	3.19	2.22	0.72	3.24	2.99	0.97	0.78	0.74	1.93	1.90	0.94	0	2.17	1.18	1.18	1.34
22	0.31	1.67	3.26	3.22	2.02	0.35	1.29	2.35	3.49	0.69	1.87	3.70	3.09	1.60	1.41	1.62	3.28	0.67	1.57	2.17	0	2.51	2.51	1.57
23	1.12	1.13	2.28	2.51	1.22	1.33	0.87	1.23	2.92	1.78	1.30	3.02	2.81	1.27	0.75	0.33	2.84	1.49	0.16	1.07	1.43	1.09	1.09	1.57
24	2.20	1.77	2.07	2.56	1.59	2.41	1.73	1.21	2.89	2.84	1.83	2.86	3.06	1.98	1.55	1.00	3.07	2.54	0.96	1.18	2.51	0	0	2.35
25	1.45	0.60	1.97	1.75	0.93	1.22	0.69	1.45	3.67	1.21	0.64	3.83	3.14	0.38	0.84	1.41	1.71	0.97	1.58	1.34	1.57	2.35	2.35	0
26	1.28	0.17	1.77	1.74	0.54	1.19	0.23	1.00	3.34	1.40	0.38	3.47	2.95	0.23	0.28	0.84	1.91	1.09	1.03	0.85	1.50	1.78	1.78	0.58
27	1.69	1.24	2.48	2.12	1.56	1.37	1.27	2.09	4.07	1.11	1.27	4.26	3.42	1.02	1.44	2.02	1.89	1.03	2.16	1.98	1.70	2.98	2.98	0.64
28	1.94	1.26	1.67	2.09	1.07	2.08	1.28	0.71	2.96	2.48	1.31	2.97	2.96	1.48	1.09	0.63	2.58	2.16	0.70	0.66	2.24	0.52	0.52	1.85
29	2.59	1.45	1.80	1.24	1.51	2.33	1.75	1.94	4.34	2.19	1.31	4.47	3.72	1.32	1.83	2.34	0.81	2.03	2.55	1.92	2.68	3.09	3.09	1.14
30	0.60	1.65	3.05	3.19	1.88	0.96	1.26	2.03	3.08	1.45	1.85	3.24	2.92	1.68	1.27	1.14	3.40	1.27	1.00	1.85	0.84	1.82	1.82	1.84
31	3.73	3.22	3.14	3.42	3.08	3.82	3.28	2.91	1.35	4.07	3.21	1.24	1.47	3.34	3.19	3.03	3.78	3.85	3.06	2.93	3.94	2.89	2.89	3.55
32	3.34	1.89	0.61	0.37	1.59	3.23	2.29	1.56	4.24	3.31	1.68	4.25	3.89	1.96	2.22	2.42	0.89	3.05	2.64	1.70	3.56	2.66	2.66	2.11
33	0.57	1.18	2.78	2.67	1.56	0.26	0.85	1.97	3.52	0.44	1.36	3.73	3.05	1.06	1.02	1.42	2.69	0.15	1.46	1.80	0.61	2.41	2.41	0.98
34	2.74	1.42	1.35	0.76	1.35	2.54	1.79	1.68	4.25	2.48	1.23	4.34	3.71	1.37	1.81	2.25	0.40	2.28	2.47	1.71	2.89	2.88	2.88	1.32
35	1.28	1.46	2.93	2.66	1.84	0.92	1.30	2.34	3.98	0.52	1.57	4.20	3.36	1.26	1.50	2.01	2.50	0.59	2.10	2.20	1.19	3.02	3.02	0.96
36	4.38	2.95	1.37	1.52	2.60	4.31	3.33	2.40	4.78	4.43	2.75	4.71	4.58	3.05	3.23	3.30	1.92	4.15	3.49	2.56	4.62	3.23	3.23	3.24
37	0.52	1.34	2.94	2.84	1.72	0.17	1.01	2.12	3.56	0.35	1.53	3.77	3.09	1.22	1.17	1.53	2.84	0.19	1.55	1.95	0.48	2.51	2.51	1.13
38	1.23	1.66	3.17	2.92	2.05	0.88	1.46	2.53	4.02	0.40	1.79	4.26	3.41	1.47	1.65	2.13	2.76	0.61	2.19	2.38	1.09	3.13	3.13	1.20
39	0.93	2.01	3.61	3.46	2.40	0.73	1.69	2.81	3.90	0.52	2.19	4.15	3.39	1.88	1.85	2.18	3.40	0.78	2.16	2.64	0.65	3.12	3.12	1.72
40	3.24	3.33	3.86	4.11	3.33	3.39	3.22	3.25	0.17	3.69	3.41	0.52	0.86	3.42	3.15	2.95	4.42	3.52	2.89	3.19	3.39	2.92	2.92	3.61
41	1.33	1.65	3.13	2.85	2.03	0.98	1.48	2.53	4.07	0.51	1.77	4.30	3.44	1.46	1.67	2.17	2.67	0.68	2.25	2.38	1.20	3.17	3.17	1.16
42	2.12	1.68	2.03	2.50	1.51	2.33	1.64	1.14	2.89	2.76	1.75	2.86	3.03	1.89	1.46	0.92	3.01	2.46	0.87	1.10	2.43	0.09	0.09	2.26
43	2.29	1.56	2.41	1.92	1.78	1.98	1.72	2.29	4.40	1.71	1.51	4.58	3.72	1.36	1.86	2.43	1.52	1.64	2.60	2.22	2.31	3.33	3.33	1.02
44	0.61	1.09	2.52	2.63	1.33	0.81	0.71	1.53	3.08	1.28	1.29	3.23	2.83	1.14	0.71	0.71	2.85	1.01	0.66	1.35	0.91	1.61	1.61	1.33
45	3.49	2.88	2.97	2.96	2.83	3.44	2.99	2.88	2.18	3.52	2.84	2.30	1.50	2.90	2.97	3.08	3.08	3.36	3.18	2.89	3.63	3.36	3.36	2.98
46	1.02	1.53	3.08	2.86	1.92	0.66	1.29	2.39	3.88	0.20	1.67	4.10	3.30	1.36	1.48	1.94	2.76	0.40	1.99	2.23	0.89	2.94	2.94	1.12
47	2.95	3.24	4.02	4.17	3.32	3.07	3.08	3.35	0.91	3.30	3.34	1.26	0.64	3.28	3.06	2.95	4.38	3.19	2.90	3.26	3.04	3.17	3.17	3.40
48	2.86	2.08	2.67	2.09	2.25	2.54	2.28	2.73	4.84	2.23	2.00	5.01	4.11	1.90	2.40	2.97	1.55	2.19	3.15	2.69	2.86	3.83	3.83	1.58
49	1.50	1.17	2.52	2.21	1.52	1.17	1.15	2.04	3.96	0.92	1.24	4.16	3.34	0.96	1.33	1.89	2.03	0.83	2.03	1.92	1.50	2.87	2.87	0.59

	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49
1	1.28	1.69	1.94	2.59	0.60	3.73	3.34	0.57	2.74	1.28	4.38	0.52	1.23	0.93	3.24	1.33	2.12	2.29	0.61	3.49	1.02	2.95	2.86	1.50
2	0.17	1.24	1.26	1.45	1.65	3.22	1.89	1.18	1.42	1.46	2.95	1.34	1.66	2.01	3.33	1.65	1.68	1.56	1.09	2.88	1.53	3.24	2.08	1.17
3	1.77	2.48	1.67	1.80	3.05	3.14	0.61	2.78	1.35	2.93	1.37	2.94	3.17	3.61	3.86	3.13	2.03	2.41	2.52	2.97	3.08	4.02	2.67	2.52
4	1.74	2.12	2.09	1.24	3.19	3.42	0.37	2.67	0.76	2.66	1.52	2.84	2.92	3.46	4.11	2.85	2.50	1.92	2.63	2.96	2.86	4.17	2.09	2.21
5	0.54	1.56	1.07	1.51	1.88	3.08	1.59	1.56	1.35	1.84	2.60	1.72	2.05	2.40	3.33	2.03	1.51	1.78	1.33	2.83	1.92	3.32	2.25	1.52
6	1.19	1.37	2.08	2.33	0.96	3.82	3.23	0.26	2.54	0.92	4.31	0.17	0.88	0.73	3.39	0.98	2.33	1.98	0.81	3.44	0.66	3.07	2.54	1.17
7	0.23	1.27	1.28	1.75	1.26	3.28	2.29	0.85	1.79	1.30	3.33	1.01	1.46	1.69	3.22	1.48	1.64	1.72	0.71	2.99	1.29	3.08	2.28	1.15
8	1.00	2.09	0.71	1.94	2.03	2.91	1.56	1.97	1.68	2.34	2.40	2.12	2.53	2.81	3.25	2.53	1.14	2.29	1.53	2.88	2.39	3.35	2.73	2.04
9	3.34	4.07	2.96	4.34	3.08	1.35	4.24	3.52	4.25	3.98	4.78	3.56	4.02	3.90	0.17	4.07	2.89	4.40	3.08	2.18	3.88	0.91	4.84	3.96
10	1.40	1.11	2.48	2.19	1.45	4.07	3.31	0.44	2.48	0.52	4.43	0.35	0.40	0.52	3.69	0.51	2.76	1.71	1.28	3.52	0.20	3.30	2.23	0.92
11	0.38	1.27	1.31	1.31	1.85	3.21	1.68	1.36	1.23	1.57	2.75	1.53	1.79	2.19	3.41	1.77	1.75	1.51	1.29	2.84	1.67	3.34	2.00	1.24
12	3.47	4.26	2.97	4.47	3.24	1.24	4.25	3.73	4.34	4.20	4.71	3.77	4.26	4.15	0.52	4.30	2.86	4.58	3.23	2.30	4.10	1.26	5.01	4.16
14	2.95	3.42	2.96	3.72	2.92	1.47	3.89	3.05	3.71	3.36	4.58	3.09	3.41	3.39	0.86	3.44	3.03	3.72	2.83	1.50	3.30	0.64	4.11	3.34
15	0.23	1.02	1.48	1.32	1.68	3.34	1.96	1.06	1.37	1.26	3.05	1.22	1.47	1.88	3.42	1.46	1.89	1.36	1.14	2.90	1.36	3.28	1.90	0.96
16	0.28	1.44	1.09	1.83	1.27	3.19	2.22	1.02	1.81	1.50	3.23	1.17	1.65	1.85	3.15	1.67	1.46	1.86	0.71	2.97	1.48	3.06	2.40	1.33
17	0.84	2.02	0.63	2.34	1.14	3.03	2.42	1.42	2.25	2.01	3.30	1.53	2.13	2.18	2.95	2.17	0.92	2.43	0.71	3.08	1.94	2.95	2.97	1.89
18	1.91	1.89	2.58	0.81	3.40	3.78	0.89	2.69	0.40	2.50	1.92	2.84	2.76	3.40	4.42	2.67	3.01	1.52	2.85	3.08	2.76	4.38	1.55	2.03
19	1.09	1.03	2.16	2.03	1.27	3.85	3.05	0.15	2.28	0.59	4.15	0.19	0.61	0.78	3.52	0.68	2.46	1.64	1.01	3.36	0.40	3.19	2.19	0.83
20	1.03	2.16	0.70	2.55	1.00	3.06	2.64	1.46	2.47	2.10	3.49	1.55	2.19	2.16	2.89	2.25	0.87	2.60	0.66	3.18	1.99	2.90	3.15	2.03
21	0.85	1.98	0.66	1.92	1.85	2.93	1.70	1.80	1.71	2.20	2.56	1.95	2.38	2.64	3.19	2.38	1.10	2.22	1.35	2.89	2.23	3.26	2.69	1.92
22	1.50	1.70	2.24	2.68	0.84	3.94	3.56	0.61	2.89	1.19	4.62	0.48	1.09	0.65	3.39	1.20	2.43	2.31	0.91	3.63	0.89	3.04	2.86	1.50
23	1.04	2.12	0.86	2.58	0.84	3.13	2.75	1.35	2.53	2.02	3.63	1.44	2.10	2.03	2.89	2.15	1.01	2.59	0.52	3.22	1.89	2.87	3.15	1.98
24	1.78	2.98	0.52	3.09	1.82	2.89	2.66	2.41	2.88	3.02	3.23	2.51	3.13	3.12	2.92	3.17	0.09	3.33	1.61	3.36	2.94	3.17	3.83	2.87
25	0.58	0.64	1.85	1.14	1.84	3.55	2.11	0.98	1.32	0.96	3.24	1.13	1.20	1.72	3.61	1.16	2.26	1.02	1.33	2.98	1.12	3.40	1.58	0.59
26	0	1.21	1.29	1.55	1.49	3.26	2.06	1.02	1.56	1.35	3.12	1.18	1.54	1.86	3.29	1.54	1.69	1.59	0.94	2.92	1.39	3.17	2.13	1.11
27	1.21	0	2.49	1.13	2.21	3.98	2.49	1.12	1.50	0.63	3.64	1.22	0.89	1.60	3.98	0.79	2.89	0.61	1.79	3.21	0.94	3.67	1.16	0.20
28	1.29	2.49	0	2.57	1.69	2.86	2.24	2.04	2.36	2.58	2.94	2.16	2.72	2.81	2.97	2.75	0.45	2.81	1.33	3.11	2.54	3.13	3.31	2.40
29	1.55	1.13	2.57	0	2.97	3.89	1.58	2.08	0.49	1.76	2.69	2.22	2.01	2.70	4.29	1.92	3.02	0.72	2.45	3.07	2.04	4.12	0.87	1.29
30	1.49	2.21	1.69	2.97	0	3.58	3.47	1.14	3.05	1.86	4.42	1.12	1.83	1.48	3.02	1.93	1.76	2.78	0.56	3.58	1.62	2.83	3.36	2.02
31	3.26	3.98	2.86	3.89	3.58	0	3.46	3.77	3.69	4.11	3.79	3.86	4.23	4.34	1.43	4.24	2.88	4.15	3.37	1.45	4.11	1.93	4.49	3.94
32	2.06	2.49	2.24	1.58	3.47	3.46	0	3.02	1.10	3.03	1.15	3.18	3.28	3.82	4.25	3.22	2.61	2.28	2.92	3.07	3.23	4.36	2.41	2.58
33	1.02	1.12	2.04	2.08	1.14	3.77	3.02	0	2.29	0.73	4.11	0.16	0.75	0.84	3.44	0.83	2.32	1.73	0.86	3.33	0.54	3.12	2.29	0.93
34	1.56	1.50	2.36	0.49	3.05	3.69	1.10	2.29	0	2.10	2.21	2.45	2.36	3.00	4.21	2.28	2.80	1.19	2.50	2.98	2.36	4.13	1.33	1.63
35	1.35	0.63	2.58	1.76	1.86	4.11	3.03	0.73	2.10	0	4.17	0.76	0.26	0.98	3.88	0.20	2.93	1.21	1.57	3.42	0.33	3.51	1.71	0.47
36	3.12	3.64	2.94	2.69	4.42	3.79	1.15	4.11	2.21	4.17	0	4.28	4.42	4.93	4.82	4.36	3.21	3.40	3.89	3.64	4.36	5.07	3.47	3.72
37	1.18	1.22	2.16	2.22	1.12	3.86	3.18	0.16	2.45	0.76	4.28	0	0.72	0.68	3.47	0.81	2.42	1.83	0.93	3.42	0.50	3.13	2.39	1.02
38	1.54	0.89	2.72	2.01	1.83	4.23	3.28	0.75	2.36	0.26	4.42	0.72	0	0.75	3.92	0.13	3.04	1.44	1.62	3.56	0.22	3.51	1.92	0.73
39	1.86	1.60	2.81	2.70	1.48	4.34	3.82	0.84	3.00	0.98	4.93	0.68	0.75	0	3.79	0.88	3.04	2.18	1.51	3.84	0.66	3.35	2.68	1.42
40	3.29	3.98	2.97	4.29	3.02	1.43	4.25	3.44	4.21	3.88	4.82	3.47	3.92	3.79	0	3.97	2.92	4.33	3.02	2.15	3.77	0.74	4.76	3.88
41	1.54	0.79	2.75	1.92	1.93	4.24	3.22	0.83	2.28	0.20	4.36	0.81	0.13	0.88	3.97	0	3.08	1.33	1.69	3.54	0.32	3.56	1.80	0.65
42	1.69	2.89	0.45	3.02	1.76	2.88	2.61	2.32	2.80	2.93	3.21	2.42	3.04	3.04	2.92	3.08	0	3.24	1.53	3.32	2.85	3.14	3.75	2.78
43	1.59	0.61	2.81	0.72	2.78	4.15	2.28	1.73	1.19	1.21	3.40	1.83	1.44	2.18	4.33	1.33	3.24	0	2.32	3.26	1.53	4.05	0.57	0.81
44	0.94	1.79	1.33	2.45	0.56	3.37	2.92	0.86	2.50	1.57	3.89	0.93	1.62	1.51	3.02	1.69	1.53	2.32	0	3.27	1.40	2.87	2.89	1.61
45	2.92	3.21	3.11	3.07	3.58	1.45	3.07	3.33	2.98	3.42	3.64	3.42	3.56	3.84	2.15	3.54	3.32	3.26	3.27	0	3.50	2.14	3.48	3.22
46	1.39	0.94	2.54	2.04	1.62	4.11	3.23	0.54	2.36	0.33	4.36	0.50	0.22	0.66	3.77	0.32	2.85	1.53	1.40	3.50	0	3.39	2.04	0.75
47	3.17	3.67	3.13	4.12	2.83	1.93	4.36	3.12	4.13	3.51	5.07	3.13	3.51	3.35	0.74	3.56	3.14	4.05	2.87	2.14	3.39	0	4.47	3.56
48	2.13	1.16	3.31	0.87	3.36	4.49	2.41	2.29	1.33	1.71	3.47	2.39	1.92	2.68	4.76	1.80	3.75	0.57	2.89	3.48	2.04	4.47	0	1.36
49	1.11	0.20	2.40	1.29	2.02	3.94	2.58	0.93	1.63	0.47	3.72	1.02	0.73	1.42	3.88	0.65	2.78	0.81	1.61	3.22	0.75	3.56	1.36	0

Notes: Variables included in the analysis are wheat prices 1856-65, dummy variable for provinces with a port, and the distance to the most important trade centers.

Table 5.7: Results of a cluster analysis using the standardized Euclidean distance, specification 4

	1	2	3	4	5	6	7	8	9	10	11	12	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49
1	0	1.52	3.43	3.27	2.47	0.36	1.06	2.52	3.59	1.03	1.66	3.91	3.18	1.54	1.27	1.49	3.75	0.79	2.03	2.21	0.63	1.49	2.73	1.52	1.58	1.73	2.62	2.71	0.87	4.12	3.53	0.67	2.91	1.31	5.87	0.66	1.49	1.23	3.38	1.96	2.93	2.34	0.72	3.56	1.05	3.13	2.86	1.57
2	1.52	0	1.99	1.76	1.30	1.43	0.54	1.31	3.49	1.88	0.48	3.70	3.05	0.26	0.40	0.93	2.37	1.50	1.57	1.01	1.96	1.24	2.11	0.60	0.49	1.49	1.81	1.49	1.65	3.47	2.01	1.44	1.50	1.65	4.53	1.60	2.12	2.38	3.37	2.53	2.29	1.83	1.09	2.88	1.70	3.28	2.17	1.50
3	3.43	1.99	0	0.76	1.24	3.37	2.49	1.07	3.85	3.85	2.14	3.83	3.63	2.01	2.16	2.16	1.37	3.48	2.15	1.31	3.93	2.37	2.07	2.31	1.91	3.18	1.68	1.99	3.21	3.14	0.79	3.42	1.52	3.51	2.64	3.58	4.03	4.36	3.92	4.39	2.06	3.22	2.82	3.13	3.62	4.06	3.21	3.29
4	3.27	1.76	0.76	0	1.39	3.14	2.28	1.40	4.12	3.49	1.83	4.18	3.72	1.75	2.05	2.26	1.03	3.15	2.43	1.50	3.70	2.53	2.58	1.92	1.78	2.66	2.15	1.32	3.25	3.46	0.39	3.12	0.82	3.08	3.05	3.29	3.60	4.03	4.13	3.93	2.61	2.59	2.77	3.02	3.25	4.18	2.51	2.80
5	2.47	1.30	1.24	1.39	0	2.41	1.76	0.60	3.38	3.01	1.70	3.43	3.08	1.24	1.33	1.36	1.67	2.65	1.14	0.72	3.03	1.42	1.59	1.57	0.96	2.59	1.07	1.76	2.17	3.08	1.69	2.59	1.54	2.72	3.40	2.73	3.27	3.47	3.42	3.75	1.54	2.83	1.88	3.02	2.76	3.39	2.91	2.65
6	0.36	1.43	3.37	3.14	2.41	0	1.00	2.53	3.72	0.80	1.56	4.05	3.24	1.40	1.26	1.60	3.57	0.53	2.14	2.22	0.67	1.64	2.89	1.29	1.49	1.42	2.71	2.46	1.13	4.19	3.42	0.46	2.71	0.98	5.80	0.46	1.23	1.10	3.52	1.76	3.06	2.04	0.88	3.50	0.73	3.23	2.54	1.27
7	1.06	0.54	2.49	2.28	1.76	1.00	0	1.73	3.50	1.45	0.62	3.76	3.07	0.66	0.47	0.95	2.90	1.06	1.73	1.40	1.45	1.24	2.29	0.77	0.85	1.35	2.09	1.88	1.36	3.67	2.51	0.97	1.98	1.37	5.05	1.13	1.74	1.92	3.33	2.14	2.52	1.82	0.76	3.04	1.35	3.21	2.29	1.28
8	2.52	1.31	1.07	1.40	0.60	2.53	1.73	0	3.25	3.13	1.61	3.28	3.07	1.36	1.30	1.16	1.97	2.74	1.11	0.34	3.07	1.31	1.22	1.75	1.12	2.74	0.78	2.03	2.18	2.93	1.59	2.66	1.74	2.91	3.44	2.81	3.40	3.59	3.28	3.83	1.28	2.98	1.86	2.99	2.93	3.37	3.15	2.79
9	3.59	3.49	3.85	4.12	3.38	3.72	3.50	3.25	0	4.26	3.69	0.49	1.01	3.55	3.30	3.04	4.51	4.00	2.92	3.20	3.97	2.94	2.91	3.78	3.37	4.41	2.99	4.37	3.16	1.41	4.25	3.91	4.27	4.31	5.42	3.97	4.58	4.45	0.42	4.94	2.97	4.77	3.23	2.29	4.20	0.96	5.06	4.36
10	1.03	1.88	3.85	3.49	3.01	0.80	1.45	3.13	4.26	0	1.82	4.62	3.67	1.85	1.84	2.27	3.92	0.39	2.90	2.82	0.69	2.38	3.60	1.60	2.07	1.14	3.42	2.60	1.89	4.70	3.74	0.50	2.93	0.60	6.32	0.40	0.47	0.56	4.00	0.99	3.80	1.71	1.61	3.74	0.38	3.68	2.28	0.93
11	1.66	0.48	2.14	1.83	1.70	1.56	0.62	1.61	3.69	1.82	0	3.92	3.23	0.66	0.78	1.23	2.55	1.47	1.99	1.32	1.96	1.61	2.42	0.76	0.97	1.33	2.16	1.52	1.94	3.64	2.01	1.42	1.54	1.61	4.75	1.59	1.99	2.35	3.53	2.31	2.64	1.59	1.34	2.91	1.70	3.48	2.01	1.33
12	3.91	3.70	3.83	4.18	3.43	4.05	3.76	3.28	0.49	4.62	3.92	0	1.40	3.76	3.51	3.21	4.54	4.35	2.99	3.28	4.33	3.10	2.86	4.03	3.55	4.72	2.97	4.56	3.41	1.24	4.29	4.25	4.41	4.65	5.21	4.32	4.96	4.84	0.90	5.33	2.88	5.07	3.48	2.52	4.55	1.42	5.34	4.68
14	3.18	3.05	3.63	3.72	3.08	3.24	3.07	3.07	1.01	3.67	3.23	1.40	0	3.07	2.93	2.86	4.03	3.45	2.85	2.99	3.52	2.81	3.10	3.21	2.95	3.73	3.03	3.74	2.96	1.60	3.89	3.39	3.71	3.65	5.35	3.44	3.94	3.90	0.88	4.29	3.16	4.05	2.93	1.57	3.58	0.65	4.29	3.70
15	1.54	0.26	2.01	1.75	1.24	1.40	0.66	1.36	3.55	1.85	0.66	3.76	3.07	0	0.52	1.07	2.25	1.48	1.59	1.10	1.98	1.32	2.21	0.41	0.39	1.41	1.87	1.34	1.68	3.52	2.03	1.44	1.41	1.56	4.49	1.60	2.07	2.36	3.43	2.52	2.35	1.75	1.16	2.90	1.62	3.31	2.04	1.44
16	1.27	0.40	2.16	2.05	1.33	1.26	0.47	1.30	3.30	1.84	0.78	3.51	2.93	0.52	0	0.60	2.63	1.45	1.29	0.98	1.78	0.87	1.88	0.84	0.48	1.70	1.63	1.85	1.27	3.41	2.30	1.36	1.86	1.71	4.66	1.51	2.15	2.29	3.18	2.59	2.08	2.12	0.73	2.97	1.69	3.10	2.50	1.66
17	1.49	0.93	2.16	2.26	1.36	1.60	0.95	1.16	3.04	2.27	1.23	3.21	2.86	1.07	0.60	0	2.88	1.88	0.92	0.86	2.04	0.44	1.36	1.43	0.87	2.27	1.23	2.34	1.14	3.21	2.46	1.77	2.26	2.24	4.60	1.89	2.63	2.64	2.96	3.05	1.61	2.70	0.78	3.08	2.17	2.97	3.08	2.22
18	3.75	2.37	1.37	1.03	1.67	3.57	2.90	1.97	4.51	3.92	2.55	4.54	4.03	2.25	2.63	2.88	0	3.61	2.80	2.14	4.19	3.04	3.11	2.35	2.22	3.06	2.59	1.49	3.69	3.80	1.28	3.61	1.17	3.43	2.66	3.76	4.00	4.44	4.56	4.40	3.01	2.96	3.31	3.38	3.61	4.50	2.69	3.23
19	0.79	1.50	3.48	3.15	2.65	0.53	1.06	2.74	4.00	0.39	1.47	4.35	3.45	1.48	1.45	1.88	3.61	0	2.53	2.43	0.69	2.02	3.23	1.27	1.69	1.03	3.04	2.35	1.62	4.39	3.40	0.15	2.46	4.60	5.96	0.20	0.77	0.89	3.77	1.27	3.43	1.64	1.26	3.51	0.41	3.49	2.21	0.84
20	2.03	1.57	2.15	2.43	1.14	2.14	1.73	1.11	2.92	2.90	1.99	2.99	2.85	1.59	1.29	0.92	2.80	2.53	0	1.05	2.66	0.63	0.96	1.95	1.22	2.91	0.72	2.67	1.39	3.07	2.68	2.43	2.55	2.82	4.19	2.53	3.28	3.23	2.96	3.77	0.97	3.33	1.38	3.31	2.73	2.95	3.59	2.88
21	2.21	1.01	1.31	1.50	0.72	2.22	1.40	0.34	3.20	2.82	1.32	3.28	2.99	1.10	0.98	0.86	2.14	2.43	1.05	0	2.75	1.08	1.27	1.51	0.87	2.48	0.91	1.95	1.92	2.99	1.70	2.34	1.72	2.62	3.77	2.49	3.10	3.27	3.19	3.51	1.41	2.75	1.55	2.93	2.64	3.26	2.97	2.50
22	0.63	1.96	3.93	3.70	3.03	0.67	1.45	3.07	3.97	0.69	1.96	4.33	3.52	1.98	1.78	2.04	4.19	0.69	2.66	2.75	0	2.09	3.31	1.86	2.10	1.71	3.22	3.01	1.44	4.56	3.93	0.64	3.26	1.22	6.41	0.50	1.13	0.69	3.71	1.50	3.54	2.31	1.30	3.83	0.93	3.43	2.89	1.50
23	1.49	1.24	2.37	2.53	1.42	1.64	1.24	1.31	2.94	2.38	1.61	3.10	2.81	1.32	0.87	0.44	3.04	2.02	0.63	1.08	2.09	0	1.26	1.66	1.04	2.51	1.16	2.58	0.91	3.22	2.76	1.90	2.53	2.39	4.66	2.00	2.78	2.70	2.89	3.24	1.45	2.98	0.80	3.23	2.27	2.87	3.34	2.45
24	2.73	2.11	2.07	2.58	1.59	2.89	2.29	1.22	2.91	3.60	2.42	2.86	3.10	2.21	1.88	1.36	3.11	3.23	0.96	1.27	3.31	1.26	0	2.62	1.90	3.57	0.54	3.20	2.07	2.89	2.70	3.11	2.95	3.57	3.96	3.22	3.98	3.94	3.00	4.41	0.41	3.93	2.03	3.50	3.49	3.22	4.21	3.54
25	1.52	0.60	2.31	1.92	1.57	1.29	0.77	1.75	3.78	1.60	0.76	4.03	3.21	0.41	0.84	1.43	2.35	1.27	1.95	1.51	1.86	1.66	2.62	0	0.75	1.03	2.27	1.20	1.85	3.78	2.22	1.27	1.41	1.22	4.73	1.52	1.76	2.13	3.64	2.22	2.75	1.39	1.33	2.98	1.34	3.45	1.69	1.09
26	1.58	0.49	1.91	1.78	0.96	1.49	0.85	1.12	3.37	2.07	0.97	3.55	2.95	0.39	0.48	0.87	2.22	1.60	1.22	0.87	2.10	1.04	1.90	0.75	0	1.76	1.54	1.55	1.52	3.36	2.07	1.63	1.56	1.82	4.31	1.78	2.34	2.54	3.29	2.82	2.01	2.12	1.08	2.93	1.84	3.17	2.38	1.78
27	1.73	1.49	3.18	2.66	2.59	1.42	1.35	2.74	4.41	1.14	1.33	4.72	3.73	1.41	1.70	2.27	3.06	1.03	2.91	2.48	1.71	2.51	3.57	1.03	1.76	0	3.27	1.62	2.42	4.50	2.90	1.12	1.99	0.63	5.60	1.23	1.01	1.66	4.19	1.35	3.74	0.62	1.93	3.37	0.94	3.93	1.18	0.23
28	2.62	1.81	1.68	2.15	1.07	2.71	2.09	0.78	2.99	3.42	2.16	2.97	3.03	1.87	1.63	1.23	2.59	3.04	0.72	0.91	3.22	1.16	0.54	2.27	1.54	3.27	0	2.74	2.03	2.86	2.32	2.94	2.49	3.30	3.64	3.06	3.77	3.80	3.08	4.22	0.51	3.60	1.92	3.30	3.25	3.22	3.81	3.27
29	2.71	1.49	1.99	1.32	1.76	2.46	1.88	2.03	4.37	2.60	1.52	4.56	3.74	1.34	1.85	2.34	1.49	2.35	2.67	1.95	3.01	2.58	3.20	1.20	1.55	1.62	2.74	0	2.98	4.00	1.62	2.38	0.51	2.07	4.11	2.53	2.60	3.15	4.29	2.95	3.25	1.47	2.48	3.08	2.31	4.13	1.28	1.81
30	0.87	1.65	3.21	3.25	2.17	1.13	1.36	2.18	3.16	1.89	1.94	3.41	2.96	1.68	1.27	1.14	3.69	1.62	1.39	1.92	1.44	0.91	2.07	1.85	1.52	2.42	2.03	2.98	0	3.75	3.51	1.50	3.07	2.08	5.50	1.52	2.35	2.06	3.03	2.83	2.24	3.00	0.61	3.58	1.85	2.86	3.44	2.30
31	4.12	3.47	3.14	3.46	3.08	4.19	3.67	2.93	1.41	4.70	3.64	1.24	1.60	3.52	3.41	3.21	3.80	4.39	3.07	2.99	4.56	3.22	2.89	3.78	3.36	4.50	2.86	4.00	3.75	0	3.51	4.31	3.77	4.59	4.36	4.42	4.96	5.03	1.64	5.31	2.90	4.71	3.63	1.81	4.57	2.06	4.86	4.51
32	3.53	2.01	0.79	0.39	1.69	3.42	2.51	1.59	4.25	3.74	2.01	4.29	3.89	2.03	2.30	2.46	1.28	3.40	2.68	1.70	3.93	2.76	2.70	2.22	2.07	2.90	2.32	1.62	3.51	3.51	0	3.37	1.11	3.35	3.00	3.54	3.83	4.28	4.26	4.12	2.76	2.79	3.02	3.11	3.52	4.36	2.72	3.03
33	0.67	1.44	3.42	3.12	2.59	0.49	0.97	2.66	3.91	0.50	1.42	4.25	3.39	1.44	1.36	1.77	3.61	0.15	2.43	2.34	0.64	1.90	3.11	1.27	1.63	1.12	2.94	2.38	1.50	4.31	3.37	0	2.64	0.74	5.92	0.17	0.90	0.95	3.68	1.37	3.32	1.73	1.13	3.48	0.55	3.42	2.30	0.93
34	2.91	1.50	1.52	0.82	1.54	2.71	1.98	1.74	4.27	2.93	1.54	4.41	3.71	1.41	1.86	2.26	1.17	2.64	2.55	1.72	3.26	2.53	2.95	1.41	1.56	1.99	2.49	0.51	3.07	3.77	1.11	2.64	0	2.54	3.68	2.80	2.97	3.48	4.21	3.31	3.00	1.87	2.56	3.00	2.66	4.13	1.72	2.16
35	1.31	1.65	3.51	3.08	2.72	0.98	1.37	2.91	4.31	0.60	1.61	4.65	3.65	1.56	1.71	2.24	3.43	0.60	2.82	2.62	1.22	2.39	3.57	1.22	1.82	0.63	3.30	2.07	2.08	4.59	3.35	0.74	2.45	0	5.92	0.77	0.61	1.10	4.08	1.17	3.73	1.22	1.71	3.55	0.33	3.75	1.72	0.50
36	5.87	4.53	2.64	3.05	3.40	5.80	5.05	3.44	5.42	6.32	4.75	5.21	5.35	4.49	4.66	4.60	2.66	5.96	4.19	3.77	6.41	4.66	3.96	4.73	4.31	5.60	3.64	4.11	5.50	4.36	3.00	5.92	3.68	5.92	0	6.07	6.49	6.82	5.65	6.90	3.72	5.55	5.25	4.87	6.04	5.83	5.32	5.74
37	0.66	1.60	3.58	3.29	2.73	0.46	1.13	2.81	3.97	0.40	1.59	4.32	3.44	1.60	1.51	1.89	3.76	0.20	2.53	2.49	0.50	2.00	3.22	1.42	1.78	1.23	3.06	2.53	1.52	4.42	3.54	0.17	2.80	0.77	6.07	0	0.84	0.79	3.73	1.32	3.43	1.84	1.22	3.58	0.52	3.45	2.40	1.03
38	1.49	2.12	4.03	3.60	3.27	1.23	1.74	3.40	4.58	0.47	1.99	4.96	3.94	2.07	2.15	2.63	4.00	0.77	3.28	3.10	1.13	2.78	3.98	1.76	2.34	1.01	3.77	2.60	2.35	4.96	3.83	0.90	3.97	0.61	6.49	0.84	0	0.75	4.31	0.61	4.18	1.49	2.03	3.86	0.61	3.98	2.05	0.83
39	1.23	2.38	4.36	4.03	3.47	1.10	1.92	3.59	4.45	0.56	2.35	4.84	3.90	2.36	2.29	2.64	4.44	0.89	3.23	3.27	0.69	2.70	3.94	2.13	2.54	1.66	3.80	3.15	2.06	5.03	4.28	0.95	3.48	1.10	6.82	0.79	0.75	0	4.18	1.09	4.14	2.21	1.92	4.11	0.85	3.82	2.76	1.46
40	3.38	3.37	3.92	4.13	3.42	3.52	3.33	3.28	0.42	4.00	3.53	0.90	0.88	3.43	3.18	2.96	4.56	3.77	2.96	3.19	3.71	2.89	3.00	3.64	3.29	4.19	3.08	4.29	3.03	1.64	4.26	3.68	4.21	4.08	5.65	3.73	4.31	4.18	0	4.64	3.10	4.56	3.07	2.17	3.97	0.75	4.88	4.13
41	1.96	2.53	4.39	3.93	3.75	1.76	2.14	3.83	4.94	0.99	2.31	5.33	4.29	2.52	2.59	3.05	4.40	1.27	3.77	3.51	1.50	3.24	4.41	2.22	2.82	1.35	4.22	2.95	2.83	5.31	4.12	1.37	3.31	1.17	6.90	1.32	0.61	1.09	4.64	0	4.64	1.64	2.48	4.11	1.21	4.34	2.23	1.18
42	2.93	2.29	2.06	2.61	1.54	3.06	2.52	1.28	2.97	3.80	2.64	2.88	3.16	2.35	2.08	1.61	3.01	3.43	0.97	1.41	3.54	1.45	0.41	2.75	2.01	3.74	0.51	3.25	2.24	2.90	2.76	3.32	3.00	3.73	3.72	3.43	4.18	4.14	3.10	4.64	0	4.09	2.24	3.59	3.66	3.29	4.32	3.73
43	2.34	1.83	3.22	2.59	2.83	2.04	1.82	2.98	4.77	1.71	1.59	5.07	4.05	1.75	2.12	2.70	2.96	1.64	3.33	2.75	2.31	2.98	3.93	1.39	2.12	0.62	3.60	1.47	3.00	4.71	2.79	1.73	1.87	1.22	5.55	1.84	1.49	2.21	4.56	1.64	4.09	0	2.48	3.45	1.54	4.32	0.67	0.81
44	0.72	1.09	2.82	2.77	1.88	0.88	0.76	1.86	3.23	1.61	1.34	3.48	2.93	1.16	0.73	0.78	3.31	1.26	1.38	1.55	1.30	0.80	2.03	1.33	1.08	1.93	1.92	2.48	0.61	3.63	3.02	1.13	2.56	1.71	5.25	1.22	2.03	1.92	3.07	2.48	2.24	2.48	0	3.28	1.55	2.94	2.94	1.82
45	3.56	2.88	3.13	3.02	3.02	3.50	3.04	2.99	2.29	3.74	2.91	2.52	1.57	2.90	2.97	3.08	3.38	3.51	3.31	2.93	3.83	3.23	3.50	2.98	2.93	3.37	3.30	3.08	3.58	1.81	3.11	3.48	3.00	3.55	4.87	3.58	3.86	4.11	2.17	4.11	3.59	3.45	3.28	0	3.62	2.17	3.57	3.41
46	1.05	1.70	3.62	3.25	2.76	0.73	1.35	2.93	4.20	0.38	1.70	4.55	3.58	1.62	1.69	2.17	3.61	0.41	2.73	2.64	0.93	2.27	3.49	1.34	1.84	0.94	3.25	2.31	1.85	4.57	3.52	0.55	2.66	0.33	6.04	0.52	0.61	0.85	3.97	1.21	3.66	1.54	1.55	3.62	0	3.63	2.04	0.78
47	3.13	3.28	4.06	4.18	3.39	3.23	3.21	3.37	0.96	3.68	3.48	1.42	0.65	3.31	3.10	2.97	4.50	3.49	2.95	3.26	3.43	2.87	3.22	3.45	3.17	3.93	3.22	4.13	2.86	2.06	4.36	3.42	4.13	3.75	5.83	3.45	3.98	3.82	0.75	4.34	3.29	4.32	2.94	2.17	3.63	0	4.62	3.86
48	2.86	2.17	3.21	2.51	2.91	2.54	2.29	3.15	5.06	2.28	2.01	5.34	4.29	2.04	2.50	3.08	2.69	2.21	3.59	2.97	2.89	3.34	4.21	1.69	2.38	1.18	3.81	1.28	3.44	4.86	2.72	2.30	1.72	1.72	5.32	2.40	2.05	2.76	4.88	2.23	4.32	0.67	2.94	3.57	2.04	4.62	0	1.40
49	1.57	1.50	3.29	2.80	2.65	1.27	1.28	2.79	4.36	0.93	1.33	4.68	3.70	1.44	1.66	2.22	3.23	0.84	2.88	2.50	1.50	2.45	3.54	1.09	1.78	0.23	3.27	1.81	2.30	4.51	3.03	0.93	2.16	0.50	5.74	1.03	0.83	1.46	4.13	1.18	3.73	0.81	1.82	3.41	0.78	3.86	1.40	0

Notes: Variables included in the analysis are wheat prices 1856-65, wheat prices 1866-75, a dummy variable for provinces with a port, and the distance to the most important trade centers.

Table 5.8: Results of a cluster analysis using the standardized Euclidean distance, specification 5

	1	2	3	4	5	6	7	8	9	10	11	12	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49
1	0	1.45	3.01	3.02	1.78	0.36	1.05	2.07	1.78	0.84	1.66	2.12	1.00	1.41	1.15	1.31	3.13	0.69	1.26	1.89	0.31	1.12	2.20	1.45	1.28	1.69	1.94	2.59	0.60	2.46	3.34	0.57	2.74	1.28	4.38	0.52	1.23	0.93	1.62	1.33	2.12	2.29	0.61	2.08	1.02	0.92	2.68	1.50
2	1.45	0	1.60	1.57	0.39	1.36	0.40	0.88	1.88	1.54	0.21	2.08	1.01	0.22	0.39	0.90	1.76	1.24	1.10	0.75	1.67	1.13	1.77	0.60	0.17	1.24	1.26	1.45	1.65	1.59	1.89	1.18	1.42	1.46	2.95	1.34	1.66	2.01	1.80	1.65	1.68	1.56	1.09	0.64	1.53	1.61	2.08	1.17
3	3.01	1.60	0	0.66	1.24	2.96	1.97	1.05	2.63	3.12	1.42	2.61	2.25	1.73	1.86	1.94	1.31	2.83	2.15	1.21	3.26	2.28	2.07	1.97	1.77	2.48	1.67	1.80	3.05	1.42	0.61	2.78	1.35	2.93	1.37	2.94	3.17	3.61	2.65	3.13	2.03	2.41	2.52	0.99	3.08	2.88	2.67	2.52
4	3.02	1.57	0.66	0	1.31	2.89	1.97	1.39	3.02	2.95	1.36	3.07	2.45	1.62	1.92	2.19	0.65	2.69	2.41	1.49	3.22	2.51	2.56	1.75	1.74	2.12	2.09	1.24	3.19	1.97	0.37	2.67	0.76	2.66	1.52	2.84	2.92	3.46	3.01	2.85	2.50	1.92	2.63	0.96	2.86	3.09	2.09	2.21
5	1.78	0.39	1.24	1.31	0	1.73	0.73	0.53	1.84	1.94	0.29	1.98	1.14	0.58	0.63	0.91	1.63	1.63	1.13	0.44	2.02	1.22	1.59	0.93	0.54	1.56	1.07	1.51	1.88	1.28	1.59	1.56	1.35	1.84	2.60	1.72	2.05	2.40	1.80	2.03	1.51	1.78	1.33	0.36	1.92	1.78	2.25	1.52
6	0.36	1.36	2.96	2.89	1.73	0	1.00	2.10	2.06	0.50	1.56	2.40	1.19	1.27	1.14	1.45	2.93	0.35	1.45	1.93	0.35	1.33	2.41	1.22	1.19	1.37	2.08	2.33	2.96	2.59	3.23	0.26	2.54	0.92	4.31	0.17	0.88	0.73	1.91	0.98	2.33	1.98	0.81	1.99	0.66	1.24	2.54	1.17
7	1.05	0.40	1.97	1.97	0.73	1.00	0	1.12	1.68	1.26	0.61	1.93	0.73	0.43	0.19	0.75	2.15	0.95	0.89	0.95	1.29	0.87	1.73	0.69	0.23	1.27	1.28	1.75	1.26	1.71	2.29	0.85	1.79	1.30	3.33	1.01	1.46	1.69	1.58	1.48	1.64	1.72	0.71	1.03	1.29	1.27	2.28	1.15
8	2.07	0.88	1.05	1.39	0.53	2.10	1.12	0	1.63	2.38	0.82	1.69	1.22	1.09	0.96	0.90	1.87	2.06	1.10	0.18	2.35	1.23	1.21	1.45	1.00	2.09	0.71	1.94	2.03	0.78	1.56	1.97	1.68	2.34	2.40	2.12	2.53	2.81	1.63	2.53	1.14	2.29	1.53	0.68	2.39	1.83	2.73	2.04
9	1.78	1.88	2.63	3.02	1.84	2.06	1.68	1.63	0	2.55	2.01	0.35	0.99	2.04	1.54	0.98	3.45	2.28	0.79	1.53	2.07	0.82	0.72	2.37	1.82	2.95	0.96	3.31	1.28	1.35	3.19	2.14	3.19	2.83	3.88	2.20	2.89	2.71	0.17	2.96	0.70	3.40	1.27	2.18	2.68	0.91	3.94	2.80
10	0.84	1.54	3.12	2.95	1.94	0.50	1.26	2.38	2.55	0	1.71	2.87	1.63	1.39	1.44	1.86	2.88	0.32	1.89	2.22	0.69	1.78	2.84	1.21	1.40	1.11	2.48	2.19	1.45	2.95	3.31	0.44	2.48	0.52	4.43	0.35	0.40	0.52	2.39	0.51	2.76	1.71	1.28	2.14	0.20	1.74	2.23	0.92
11	1.66	0.21	1.42	1.36	0.29	1.56	0.61	0.82	2.01	1.71	0	2.18	1.19	0.32	0.59	1.03	1.56	1.41	1.25	0.72	1.87	1.30	1.83	0.64	0.38	1.27	1.31	1.31	1.85	1.57	1.68	1.36	1.23	1.57	2.75	1.53	1.79	2.19	1.94	1.77	1.75	1.51	1.29	0.44	1.67	1.81	2.00	1.24
12	2.12	2.08	2.61	3.07	1.98	2.40	1.93	1.69	0.35	2.87	2.18	0	1.28	2.26	1.77	1.20	3.55	2.60	1.05	1.62	2.42	1.12	0.56	2.61	2.04	3.21	0.98	3.48	1.63	1.24	3.20	2.46	3.32	3.13	3.79	2.52	3.20	3.06	0.52	3.27	0.59	3.62	1.60	2.30	3.00	1.26	4.16	3.07
14	1.00	1.01	2.25	2.45	1.14	1.19	0.73	1.22	0.99	1.63	1.19	1.28	0	1.13	0.62	0.34	2.74	1.34	0.27	1.05	1.31	0.16	1.22	1.42	0.90	1.96	0.94	2.45	0.81	1.47	2.70	1.20	2.42	1.86	3.62	1.29	1.94	1.90	0.86	2.00	1.14	2.44	0.40	1.50	1.73	0.64	3.00	1.82
15	1.41	0.22	1.73	1.62	0.58	1.27	0.43	1.09	2.04	1.39	0.32	2.26	1.13	0	0.51	1.07	1.73	1.10	1.26	0.97	1.60	1.27	1.98	0.38	0.23	1.02	1.48	1.32	1.68	1.81	1.96	1.06	1.37	1.26	3.05	1.22	1.47	1.88	1.95	1.46	1.89	1.36	1.14	0.74	1.36	1.70	1.90	0.96
16	1.15	0.39	1.86	1.92	0.63	1.14	0.19	0.96	1.54	1.44	0.59	1.77	0.62	0.51	0	0.58	2.15	1.12	0.75	0.78	1.41	0.75	1.55	0.84	0.28	1.44	1.09	1.83	1.27	1.52	2.22	1.02	1.81	1.50	3.23	1.17	1.65	1.85	1.44	1.67	1.46	1.86	0.71	0.97	1.48	1.22	2.40	1.33
17	1.31	0.90	1.94	2.19	0.91	1.45	0.75	0.90	0.98	1.86	1.03	1.20	0.34	1.07	0.58	0	2.54	1.55	0.22	0.74	1.62	0.33	1.00	1.41	0.84	2.02	0.63	2.34	1.14	1.15	2.42	1.42	2.25	2.01	3.30	1.53	2.13	2.18	0.91	2.17	0.92	2.43	0.71	1.27	1.94	0.93	2.97	1.89
18	3.13	1.76	1.31	0.65	1.63	2.93	2.15	1.87	3.45	2.88	1.56	3.55	2.74	1.73	2.15	2.54	0	2.67	2.76	1.93	3.28	2.84	3.07	1.71	1.91	1.89	2.58	0.81	3.40	2.54	0.89	2.69	0.40	2.50	1.92	2.84	2.76	3.40	3.42	2.67	3.01	1.52	2.85	1.28	2.76	3.37	1.55	2.03
19	0.69	1.24	2.83	2.69	1.63	0.35	0.95	2.06	2.28	0.32	1.41	2.60	1.34	1.10	1.12	1.55	2.67	0	1.60	1.90	0.67	1.49	2.54	0.97	1.09	1.03	2.16	2.03	1.27	2.63	3.05	0.15	2.28	0.59	4.15	0.19	0.61	0.78	2.13	0.68	2.46	1.64	1.01	1.84	0.40	1.52	2.19	0.83
20	1.26	1.10	2.15	2.41	1.13	1.45	0.89	1.10	0.79	1.89	1.25	1.05	0.27	1.26	0.75	0.22	2.76	1.60	0	0.94	1.57	0.16	0.96	1.58	1.03	2.16	0.70	2.55	1.00	1.24	2.64	1.46	2.47	2.10	3.49	1.55	2.19	2.16	0.70	2.25	0.87	2.60	0.66	1.49	1.99	0.74	3.15	2.03
21	1.89	0.75	1.21	1.49	0.44	1.93	0.95	0.18	1.53	2.22	0.72	1.62	1.05	0.97	0.78	0.74	1.93	1.90	0.94	0	2.17	1.07	1.18	1.34	0.85	1.98	0.66	1.92	1.85	0.85	1.70	1.80	1.71	2.20	2.56	1.95	2.38	2.64	1.52	2.38	1.10	2.22	1.35	0.69	2.23	1.67	2.69	1.92
22	0.31	1.67	3.26	3.22	2.02	0.35	1.29	2.35	2.07	0.69	1.87	2.42	1.31	1.60	1.41	1.62	3.28	0.67	1.57	2.17	0	1.43	2.51	1.57	1.50	1.70	2.24	2.68	0.84	2.77	3.56	0.61	2.89	1.19	4.62	0.48	1.09	0.65	1.91	1.20	2.43	2.31	0.91	2.31	0.89	1.19	2.86	1.50
23	1.12	1.13	2.28	2.51	1.22	1.33	0.87	1.23	0.82	1.78	1.30	1.12	0.16	1.27	0.75	0.33	2.84	1.49	0.16	1.07	1.43	0	1.09	1.57	1.04	2.12	0.86	2.58	0.84	1.40	2.75	1.35	2.53	2.02	3.63	1.44	2.10	2.03	0.71	2.15	1.01	2.59	0.52	1.58	1.89	0.60	3.15	1.98
24	2.20	1.77	2.07	2.56	1.59	2.41	1.73	1.21	0.72	2.84	1.83	0.56	1.22	1.98	1.55	1.00	3.07	2.54	0.96	1.18	2.51	1.09	0	2.35	1.78	2.98	0.52	3.09	1.82	0.68	2.66	2.41	2.88	3.02	3.23	2.51	3.13	3.12	0.83	3.17	0.09	3.33	1.61	1.86	2.94	1.47	3.83	2.87
25	1.45	0.60	1.97	1.75	0.93	1.22	0.69	1.45	2.37	1.21	0.64	2.61	1.42	0.38	0.84	1.41	1.71	0.97	1.58	1.34	1.57	1.57	2.35	0	0.58	0.64	1.58	1.14	1.84	2.18	2.11	0.98	1.32	0.96	3.24	1.13	1.20	1.72	2.27	1.16	2.26	1.02	1.33	1.00	1.12	1.92	1.58	0.59
26	1.28	0.17	1.77	1.74	0.54	1.19	0.23	1.00	1.82	1.40	0.38	2.04	0.90	0.23	0.28	0.84	1.91	1.09	1.03	0.85	1.50	1.04	1.78	0.58	0	1.21	1.29	1.55	1.49	1.66	2.06	1.02	1.56	1.35	3.12	1.18	1.54	1.86	1.72	1.54	1.69	1.59	0.94	0.81	1.39	1.48	2.13	1.11
27	1.69	1.24	2.48	2.12	1.56	1.37	1.27	2.09	2.95	1.11	1.27	3.21	1.96	1.02	1.44	2.02	1.89	1.03	2.16	1.98	1.70	2.12	2.98	0.64	1.21	0	2.49	1.13	2.21	2.83	2.49	1.12	1.50	0.63	3.64	1.22	0.89	1.60	2.83	0.79	2.89	0.61	1.79	1.57	0.94	2.38	1.16	0.20
28	1.94	1.26	1.67	2.09	1.07	2.08	1.28	0.71	0.96	2.48	1.31	0.98	0.94	1.48	1.09	0.63	2.58	2.16	0.70	0.66	2.24	0.86	0.52	1.85	1.29	2.49	0	2.57	1.69	0.54	2.24	2.04	2.36	2.58	2.94	2.16	2.72	2.81	0.99	2.75	0.45	2.81	1.33	1.34	2.54	1.40	3.31	2.40
29	2.59	1.45	1.80	1.24	1.51	2.33	1.75	1.94	3.31	2.19	1.31	3.48	2.45	1.32	1.83	2.34	0.81	2.03	2.55	1.92	2.68	2.58	3.09	1.14	1.55	1.13	2.57	0	2.97	2.70	1.58	2.08	0.49	1.76	2.69	2.22	2.01	2.70	3.24	1.92	3.02	0.72	2.45	1.26	2.04	3.02	0.87	1.29
30	2.60	1.65	3.05	3.19	1.88	0.96	1.26	2.03	1.28	1.45	1.85	1.63	0.81	1.68	1.27	1.14	3.40	1.27	1.00	1.85	0.84	0.84	1.82	1.84	1.49	2.21	1.69	2.97	0	2.23	3.47	1.14	3.05	1.86	4.42	1.12	1.83	1.48	1.11	1.93	1.76	2.78	0.56	2.23	1.62	0.37	3.36	2.02
31	2.46	1.59	1.42	1.97	1.28	2.59	1.71	0.78	1.35	2.95	1.57	1.24	1.47	1.81	1.52	1.15	2.54	2.63	1.24	0.85	2.77	1.40	0.68	2.18	1.66	2.83	0.54	2.70	2.23	0	2.02	2.52	2.40	3.01	2.55	2.65	3.17	3.31	1.43	3.18	0.67	3.06	1.86	1.45	3.00	1.93	3.50	2.76
32	3.34	1.89	0.61	0.37	1.59	3.23	2.29	1.56	3.19	3.31	1.68	3.20	2.70	1.96	2.22	2.42	0.89	3.05	2.64	1.70	3.56	2.75	2.66	2.11	2.06	2.49	2.24	1.58	3.47	2.02	0	3.02	1.10	3.03	1.15	3.18	3.28	3.82	3.20	3.22	2.61	2.28	2.92	1.26	3.23	3.34	2.41	2.58
33	0.57	1.18	2.78	2.67	1.56	0.26	0.85	1.97	2.14	0.44	1.36	2.46	1.20	1.06	1.02	1.42	2.69	0.15	1.46	1.80	0.61	1.35	2.41	0.98	1.02	1.12	2.04	2.08	1.14	2.52	3.02	0	2.29	0.73	4.11	0.16	0.75	0.84	1.99	0.83	2.32	1.73	0.86	1.80	0.54	1.38	2.29	0.93
34	2.74	1.42	1.35	0.76	1.35	2.54	1.79	1.68	3.19	2.48	1.23	3.32	2.42	1.37	1.81	2.25	0.40	2.28	2.47	1.71	2.89	2.53	2.88	1.32	1.56	1.50	2.36	0.49	3.05	2.40	1.10	2.29	0	2.10	2.21	2.45	2.36	3.00	3.14	2.28	2.80	1.19	2.50	1.02	2.36	3.04	1.33	1.63
35	1.28	1.46	2.93	2.66	1.84	0.92	1.30	2.34	2.83	0.52	1.57	3.13	1.86	1.26	1.50	2.01	2.50	0.59	2.10	2.20	1.19	2.02	3.02	0.96	1.35	0.63	2.58	1.76	1.86	3.01	3.03	0.73	2.10	0	4.17	0.76	0.26	0.98	2.69	0.20	2.93	1.21	1.57	1.96	0.33	2.11	1.71	0.47
36	4.38	2.95	1.37	1.52	2.60	4.31	3.33	2.40	3.88	4.43	2.75	3.79	3.62	3.05	3.23	3.30	1.92	4.15	3.49	2.56	4.62	3.63	3.23	3.24	3.12	3.64	2.94	2.69	4.42	2.55	1.15	4.11	2.21	4.17	0	4.28	4.42	4.93	3.93	4.36	3.21	3.40	3.89	2.32	4.36	4.23	3.47	3.72
37	0.52	1.34	2.94	2.84	1.72	0.17	1.01	2.12	2.20	0.35	1.53	2.52	1.29	1.22	1.17	1.53	2.84	0.19	1.55	1.95	0.48	1.44	2.51	1.13	1.18	1.22	2.16	2.22	1.12	2.65	3.18	0.16	2.45	0.76	4.28	0	0.72	0.68	2.04	0.81	2.42	1.83	0.93	1.96	0.50	1.40	2.39	1.02
38	1.23	1.66	3.17	2.92	2.05	0.88	1.46	2.53	2.89	0.40	1.79	3.20	1.94	1.47	1.65	2.13	2.76	0.61	2.19	2.38	1.09	2.10	3.13	1.20	1.54	0.89	2.72	2.01	1.83	3.17	3.28	0.75	2.36	0.26	4.42	0.72	0	0.75	2.74	0.13	3.04	1.44	1.62	2.19	0.22	2.11	1.92	0.73
39	0.93	2.01	3.61	3.46	2.40	0.73	1.69	2.81	2.71	0.52	2.19	3.06	1.90	1.88	1.85	2.18	3.40	0.78	2.16	2.64	0.65	2.03	3.12	1.72	1.86	1.60	2.81	2.70	1.48	3.31	3.82	0.84	3.00	0.98	4.93	0.68	0.75	0	2.55	0.88	3.04	2.18	1.51	2.63	0.66	1.83	2.68	1.42
40	1.62	1.80	2.65	3.01	1.80	1.91	1.58	1.63	0.17	2.39	1.94	0.52	0.86	1.95	1.44	0.91	3.42	2.13	0.70	1.52	1.91	0.71	0.83	2.27	1.72	2.83	0.99	3.24	1.11	1.43	3.20	1.99	3.14	2.69	3.93	2.04	2.74	2.55	0	2.81	0.80	3.29	1.13	2.15	2.53	0.74	3.85	2.68
41	1.33	1.65	3.13	2.85	2.03	0.98	1.48	2.53	2.96	0.51	1.77	3.27	2.00	1.46	1.67	2.17	2.67	0.68	2.25	2.38	1.20	2.15	3.17	1.16	1.54	0.79	2.75	1.92	1.93	3.18	3.22	0.83	2.28	0.20	4.36	0.81	0.13	0.88	2.81	0	3.08	1.33	1.69	2.15	0.32	2.20	1.80	0.65
42	2.12	1.68	2.03	2.50	1.51	2.33	1.64	1.14	0.70	2.79	1.75	0.59	1.14	1.89	1.46	0.92	3.01	2.46	0.87	1.10	2.43	1.01	0.09	2.26	1.69	2.89	0.45	3.02	1.76	0.67	2.61	2.32	2.80	2.93	3.21	2.42	3.04	3.04	0.80	3.08	0	3.24	1.53	1.79	2.85	1.41	3.75	2.78
43	2.29	1.56	2.41	1.92	1.78	1.98	1.72	2.29	3.40	1.71	1.51	3.62	2.44	1.36	1.86	2.43	1.52	1.64	2.60	2.22	2.31	2.59	3.33	1.02	1.59	0.61	2.81	0.72	2.78	3.06	2.28	1.73	1.19	1.21	3.40	1.83	1.44	2.18	3.29	1.33	3.24	0	2.32	1.65	1.53	2.92	0.57	0.81
44	0.61	1.09	2.52	2.63	1.33	0.81	0.71	1.53	1.27	1.28	1.29	1.60	0.40	1.14	0.71	0.71	2.85	1.01	0.66	1.35	0.91	0.52	1.61	1.33	0.94	1.79	1.33	2.45	0.56	1.86	2.92	0.86	2.50	1.57	3.89	0.93	1.62	1.51	1.13	1.69	1.53	2.32	0	1.67	1.40	0.60	2.89	1.61
45	2.08	0.64	0.99	0.96	0.36	1.99	1.03	0.68	2.18	2.14	0.44	2.30	1.50	0.74	0.97	1.27	1.28	1.84	1.49	0.69	2.31	1.58	1.86	1.00	0.81	1.57	1.34	1.26	2.23	1.45	1.26	1.80	1.02	1.96	2.32	1.96	2.19	2.63	2.15	2.15	1.79	1.65	1.67	0	2.09	2.14	2.06	1.57
46	1.02	1.53	3.08	2.86	1.92	0.66	1.29	2.39	2.68	0.20	1.67	3.00	1.73	1.36	1.48	1.94	2.76	0.40	1.99	2.23	0.89	1.89	2.94	1.12	1.39	0.94	2.54	2.04	1.62	3.00	3.23	0.54	2.36	0.33	4.36	0.50	0.22	0.66	2.53	0.32	2.85	1.53	1.40	2.09	0	1.90	2.04	0.75
47	0.92	1.61	2.88	3.09	1.78	1.24	1.27	1.83	0.91	1.74	1.81	1.26	0.64	1.70	1.22	0.93	3.37	1.52	0.74	1.67	1.19	0.60	1.47	1.92	1.48	2.38	1.40	3.02	0.37	1.93	3.34	1.38	3.04	2.11	4.23	1.40	2.11	1.83	0.74	2.20	1.41	2.92	0.60	2.14	1.90	0	3.49	2.20
48	2.86	2.08	2.67	2.09	2.25	2.54	2.28	2.73	3.94	2.23	2.00	4.16	3.00	1.90	2.40	2.97	1.55	2.19	3.15	2.69	2.86	3.15	3.83	1.58	2.13	1.16	3.31	0.87	3.36	3.50	2.41	2.29	1.33	1.71	3.47	2.39	1.92	2.68	3.85	1.80	3.75	0.57	2.89	2.06	2.04	3.49	0	1.36
49	1.50	1.17	2.52	2.21	1.52	1.17	1.15	2.04	2.80	0.92	1.24	3.07	1.82	0.96	1.33	1.89	2.03	0.83	2.03	1.92	1.50	1.98	2.87	0.59	1.11	0.20	2.40	1.29	2.02	2.76	2.58	0.93	1.63	0.47	3.72	1.02	0.73	1.42	2.68	0.65	2.78	0.81	1.61	1.57	0.75	2.20	1.36	0

Notes: Variables included in the analysis are wheat prices 1856-65 and the distance to the most important trade centers.

Table 5.9: Summary results of cluster analyses using the standardized Euclidean distance

	1	2	3	4	5	6	7	8	9	10	11	12	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49
1	0	7.8	17.3	17.0	11.3	4.8	7.7	13.0	16.2	5.4	9.6	18.9	13.1	9.5	7.7	9.4	18.0	5.2	9.1	11.1	3.1	8.4	13.1	8.6	7.7	9.5	11.9	7.9	7.4	18.3	19.5	4.6	8.4	7.1	14.6	3.1	8.1	6.5	16.1	4.6	13.0	12.5	3.3	16.6	5.5	12.8	15.5	8.4
2	7.8	0	11.1	10.7	5.4	9.5	5.5	8.3	16.5	8.7	4.3	18.4	13.6	5.3	3.9	7.6	12.1	7.6	8.9	5.5	9.5	9.0	11.6	5.2	2.4	7.5	9.5	4.4	10.6	15.4	12.9	7.8	4.3	8.1	10.4	7.7	10.1	11.3	16.5	5.8	11.3	8.9	6.0	12.8	8.0	15.2	11.8	7.5
3	17.3	11.1	0	4.1	11.8	16.3	10.8	5.4	17.3	19.1	9.9	18.2	16.0	9.2	12.0	11.5	7.7	18.1	11.6	8.7	19.5	12.5	11.1	11.9	11.1	16.4	9.8	5.6	18.0	12.4	4.8	15.7	4.2	17.9	5.4	16.9	18.8	21.9	18.6	10.6	10.7	16.3	14.7	11.1	18.0	18.5	15.8	14.5
4	17.0	10.7	4.1	0	11.6	15.4	10.9	7.6	19.4	17.8	8.7	20.9	16.4	8.6	12.6	13.2	4.0	16.9	12.6	9.7	18.7	13.1	13.3	10.1	11.1	14.1	11.2	3.8	19.2	14.8	5.1	14.7	2.3	16.0	6.1	16.0	17.1	20.7	20.7	9.6	13.1	13.6	14.9	11.4	16.7	19.1	12.4	12.7
5	11.3	5.4	11.8	11.6	0	13.1	10.3	9.4	18.6	11.3	7.0	20.4	15.5	9.7	8.1	11.1	12.8	9.5	10.5	5.9	12.0	11.3	12.4	8.4	6.8	9.4	9.7	4.8	14.0	16.6	14.3	11.5	4.2	10.8	8.6	11.9	12.8	13.4	19.1	7.8	12.2	10.3	9.6	14.9	11.6	17.3	13.6	12.1
6	4.8	9.5	16.3	15.4	13.1	0	6.8	12.2	16.6	6.8	8.5	19.6	11.8	7.6	9.9	10.9	15.9	6.5	8.2	11.8	5.7	7.2	12.9	7.1	9.4	9.9	11.2	7.1	10.8	18.0	18.7	3.0	7.8	7.7	14.4	3.9	7.2	8.4	17.7	3.7	12.9	12.8	6.4	15.5	6.7	12.0	13.9	7.7
7	7.7	5.5	10.8	10.9	10.3	6.8	0	6.5	13.8	10.0	5.5	16.0	11.4	3.0	4.7	6.0	12.6	9.3	6.6	7.1	10.0	6.4	10.0	5.8	4.7	10.3	8.8	5.4	9.5	13.8	12.6	6.0	5.6	9.8	11.7	7.3	10.0	12.4	14.8	5.1	9.6	12.2	6.0	11.2	9.0	12.7	13.1	7.4
8	13.0	8.3	5.4	7.6	9.4	12.2	6.5	0	13.4	15.8	7.6	14.7	12.5	5.9	8.2	6.7	10.5	14.9	6.7	4.9	15.5	7.6	7.0	9.6	7.7	14.7	5.8	5.9	13.3	10.3	8.8	11.9	5.1	15.2	8.2	13.1	15.9	18.3	14.9	8.9	6.4	15.7	10.1	10.1	14.8	14.4	16.0	12.2
9	16.2	16.5	17.3	19.4	18.6	16.6	13.8	13.4	0	20.1	16.8	3.8	7.4	15.2	14.8	12.2	21.7	19.6	12.1	14.8	18.4	12.4	11.7	17.9	15.5	21.8	13.2	12.0	14.3	7.2	19.6	16.9	11.7	20.9	14.1	17.5	20.9	21.3	3.9	12.0	11.3	23.6	14.3	11.6	19.6	6.9	24.7	19.3
10	5.4	8.7	19.1	17.8	11.3	6.8	10.0	15.8	20.1	0	10.3	22.8	16.1	11.1	9.9	13.3	18.0	2.0	13.2	12.9	3.9	12.6	17.3	8.3	9.3	5.9	15.4	7.0	11.5	21.4	20.6	5.0	7.9	3.0	15.2	4.0	3.8	3.0	20.0	2.0	17.2	8.9	7.8	18.0	2.3	16.4	12.5	7.2
11	9.6	4.3	9.9	8.7	7.0	8.5	5.5	7.6	16.8	10.3	0	19.2	12.6	4.7	7.3	9.6	10.0	9.1	8.0	5.7	10.8	8.0	10.7	3.4	6.0	8.2	8.1	4.1	13.6	14.9	12.2	7.1	4.0	9.3	10.3	9.0	9.8	12.9	18.2	5.8	10.8	9.5	8.0	11.7	9.9	14.6	10.4	8.1
12	18.9	18.4	18.2	20.9	20.4	19.6	16.0	14.7	3.8	22.8	19.2	0	11.0	17.3	16.1	13.3	23.4	22.3	14.7	16.4	21.3	15.2	13.4	20.4	17.2	24.3	15.3	12.5	15.2	8.3	19.8	19.7	12.1	23.5	13.7	20.1	23.5	24.0	4.7	12.9	12.9	25.8	16.8	13.3	22.1	10.6	26.9	21.7
14	13.1	13.6	16.0	16.4	15.5	11.8	11.4	12.5	7.4	16.1	12.6	11.0	0	11.8	13.5	12.5	17.8	15.4	9.0	13.1	14.7	8.7	11.7	13.2	13.4	17.0	10.9	9.9	15.1	8.8	19.0	12.6	9.8	16.3	13.5	13.7	16.3	17.5	9.2	9.7	11.7	18.9	11.6	8.9	15.7	3.4	19.7	15.1
15	9.5	5.3	9.2	8.6	9.7	7.6	3.0	5.9	15.2	11.1	4.7	17.3	11.8	0	6.4	7.6	9.9	10.4	7.3	7.5	11.6	7.2	10.5	4.6	5.0	9.8	8.8	4.0	12.0	14.0	11.1	7.2	4.1	10.1	10.6	8.5	10.7	13.8	16.3	5.4	10.2	11.3	7.9	10.3	9.8	13.6	11.6	6.8
16	7.7	3.9	12.0	12.6	8.1	9.9	4.7	8.2	14.8	9.9	7.3	16.1	13.5	6.4	0	4.9	14.5	9.2	8.5	6.5	10.2	8.5	11.2	7.8	2.4	10.4	10.1	5.5	7.1	14.9	13.3	8.5	5.5	10.1	11.1	8.2	11.4	12.1	14.0	5.9	10.8	11.9	5.6	13.2	8.9	14.7	14.5	8.9
17	9.4	7.6	11.5	13.2	11.1	10.9	6.0	6.7	12.2	13.3	9.6	13.3	12.5	7.6	4.9	0	15.6	12.6	6.4	7.9	12.3	6.4	8.5	10.8	6.1	14.3	8.4	7.0	7.6	12.9	13.3	10.7	6.8	13.6	11.2	10.2	14.8	15.3	11.0	7.4	8.1	16.0	6.5	13.2	12.3	13.4	17.9	11.2
18	18.0	12.1	7.7	4.0	12.8	15.9	12.6	10.5	21.7	18.0	10.0	23.4	17.8	9.9	14.5	15.6	0	17.3	14.4	12.1	19.4	14.9	16.0	10.4	12.6	13.7	13.5	3.1	21.0	17.3	8.2	15.4	2.0	15.8	6.5	16.6	17.0	20.9	23.0	9.7	15.7	12.7	16.3	13.1	16.8	20.5	10.7	12.7
19	5.2	7.6	18.1	16.9	9.5	6.5	9.3	14.9	19.6	2.0	9.1	22.3	15.4	10.4	9.2	12.6	17.3	0	12.2	11.7	3.9	11.7	16.2	7.4	8.5	5.4	14.2	6.4	11.3	20.5	19.8	4.3	7.2	3.4	14.3	3.9	4.9	4.2	19.6	2.6	16.2	8.5	7.1	17.5	3.5	16.0	12.4	7.4
20	9.1	8.9	11.6	12.6	10.5	8.2	6.6	6.7	12.1	13.2	8.0	14.7	9.0	7.3	8.5	6.4	14.4	12.2	0	7.4	11.4	1.5	4.9	9.2	8.4	14.2	3.8	7.8	10.7	12.6	15.4	9.0	7.5	13.5	11.2	10.2	13.8	15.0	14.0	8.3	4.8	16.4	6.4	13.5	12.8	10.2	17.4	12.2
21	11.1	5.5	8.7	9.7	5.9	11.8	7.1	4.9	14.8	12.9	5.7	16.4	13.1	7.5	6.5	7.9	12.1	11.7	7.4	0	12.9	8.2	8.3	7.8	6.0	12.0	6.4	5.8	12.0	12.7	11.4	10.2	5.1	12.7	8.9	11.8	13.1	15.2	16.2	8.3	8.1	13.1	8.6	12.3	12.5	14.9	14.4	12.1
22	3.1	9.5	19.5	18.7	12.0	5.7	10.0	15.5	18.4	3.9	10.8	21.3	14.7	11.6	10.2	12.3	19.4	3.9	11.4	12.9	0	10.6	15.4	9.6	9.9	8.9	14.0	8.4	9.8	20.5	21.7	5.3	9.0	6.2	15.6	4.0	6.9	4.2	18.4	3.9	15.5	12.1	6.1	18.5	5.3	14.4	15.5	9.3
23	8.4	9.0	12.5	13.1	11.3	7.2	6.4	7.6	12.4	12.6	8.0	15.2	8.7	7.2	8.5	6.4	14.9	11.7	1.5	8.2	10.6	0	5.8	9.1	8.6	13.9	4.9	7.7	10.2	13.3	16.0	8.4	7.6	13.0	11.9	9.5	13.2	14.3	14.2	7.6	5.9	16.2	5.8	13.8	12.3	9.8	17.4	11.7
24	13.1	11.6	11.1	13.3	12.4	12.9	10.0	7.0	11.7	17.3	10.7	13.4	11.7	10.5	11.2	8.5	16.0	16.2	4.9	8.3	15.4	5.8	0	12.9	11.3	17.8	3.3	9.4	13.5	10.9	15.3	13.4	8.7	17.6	10.4	14.4	18.0	19.1	14.0	10.8	1.3	19.7	10.1	14.6	17.0	12.5	20.7	16.0
25	8.6	5.2	11.9	10.1	8.4	7.1	5.8	9.6	17.9	8.3	3.4	20.4	13.2	4.6	7.8	10.8	10.4	7.4	9.2	7.8	9.6	9.1	12.9	0	6.1	5.9	10.3	3.5	13.3	16.7	13.7	5.4	4.0	6.7	11.2	7.4	7.2	11.0	19.0	4.5	12.8	7.7	8.1	12.8	7.5	15.0	8.4	5.9
26	7.7	2.4	11.1	11.1	6.8	9.4	4.7	7.7	15.5	9.3	6.0	17.2	13.4	5.0	2.4	6.1	12.6	8.5	8.4	6.0	9.9	8.6	11.3	6.1	0	8.8	9.7	4.7	9.0	14.9	12.6	7.9	4.7	8.9	10.5	7.6	10.6	11.8	15.2	5.9	10.9	10.3	5.8	12.6	8.1	14.8	12.8	7.5
27	9.5	7.5	16.4	14.1	9.4	9.9	10.3	14.7	21.8	5.9	8.2	24.3	17.0	9.8	10.4	14.3	13.7	5.4	14.2	12.0	8.9	13.9	17.8	5.9	8.8	0	15.3	3.9	15.1	21.0	17.3	7.8	5.0	3.4	12.9	7.7	6.1	8.5	21.9	2.9	17.8	3.3	10.3	16.4	5.6	18.5	7.4	4.8
28	11.9	9.5	9.8	11.2	9.7	11.2	8.8	5.8	13.2	15.4	8.1	15.3	10.9	8.8	10.1	8.4	13.5	14.2	3.8	6.4	14.0	4.9	3.3	10.3	9.7	15.3	0	7.9	13.6	11.4	14.1	11.6	7.2	15.4	9.5	12.9	16.0	17.5	15.3	9.7	3.5	17.1	9.0	13.6	15.2	12.5	18.0	14.1
29	7.9	4.4	5.6	3.8	4.8	7.1	5.4	5.9	12.0	7.0	4.1	12.5	9.9	4.0	5.5	7.0	3.1	6.4	7.8	5.8	8.4	7.7	9.4	3.5	4.7	3.9	7.9	0	8.9	10.6	4.8	6.5	1.5	5.6	9.5	7.0	6.6	8.6	11.8	6.8	9.3	2.9	7.4	7.4	6.4	11.3	3.0	4.4
30	7.4	10.6	18.0	19.2	14.0	10.8	9.5	13.3	14.3	11.5	13.6	15.2	15.1	12.0	7.1	7.6	21.0	11.3	10.7	12.0	9.8	10.2	13.5	13.3	9.0	15.1	13.6	8.9	0	17.7	19.3	10.4	9.2	13.2	14.3	9.6	13.6	12.1	12.8	6.7	13.0	17.3	6.8	17.6	11.0	14.1	20.0	13.1
31	18.3	15.4	12.4	14.8	16.6	18.0	13.8	10.3	7.2	21.4	14.9	8.3	8.8	14.0	14.9	12.9	17.3	20.5	12.6	12.7	20.5	13.3	10.9	16.7	14.9	21.0	11.4	10.6	17.7	0	15.0	18.0	9.9	21.2	10.7	18.9	21.7	23.3	9.5	12.7	10.5	22.0	15.8	7.8	20.6	10.7	22.5	18.9
32	19.5	12.9	4.8	5.1	14.3	18.7	12.6	8.8	19.6	20.6	12.2	19.8	19.0	11.1	13.3	13.3	8.2	19.8	15.4	11.4	21.7	16.0	15.3	13.7	12.6	17.3	14.1	4.8	19.3	15.0	0	17.7	3.3	19.1	5.3	18.7	20.0	23.4	20.2	10.6	14.8	16.5	17.2	12.3	19.2	21.4	15.5	15.4
33	4.6	7.8	15.7	14.7	11.5	3.0	6.0	11.9	16.9	5.0	7.1	19.7	12.6	7.2	8.5	10.7	15.4	4.3	9.0	10.2	5.3	8.4	13.4	5.4	7.9	7.8	11.6	6.5	10.4	18.0	17.7	0	7.2	5.8	14.1	2.8	5.0	7.2	17.9	3.0	13.3	10.6	6.0	15.0	4.8	13.1	12.0	6.5
34	8.4	4.3	4.2	2.3	4.2	7.8	5.6	5.1	11.7	7.9	4.0	12.1	9.8	4.1	5.5	6.8	2.0	7.2	7.5	5.1	9.0	7.6	8.7	4.0	4.7	5.0	7.2	1.5	9.2	9.9	3.3	7.2	0	6.7	8.1	7.7	7.7	9.5	11.6	7.9	8.6	4.2	7.6	7.0	7.4	11.3	4.4	5.4
35	7.1	8.1	17.9	16.0	10.8	7.7	9.8	15.2	20.9	3.0	9.3	23.5	16.3	10.1	10.1	13.6	15.8	3.4	13.5	12.7	6.2	13.0	17.6	6.7	8.9	3.4	15.4	5.6	13.2	21.2	19.1	5.8	6.7	0	14.3	5.1	3.5	5.6	20.8	1.6	17.5	6.4	8.8	17.1	2.5	17.1	9.8	5.1
36	14.6	10.4	5.4	6.1	8.6	14.4	11.7	8.2	14.1	15.2	10.3	13.7	13.5	10.6	11.1	11.2	6.5	14.3	11.2	8.9	15.6	11.9	10.4	11.2	10.5	12.9	9.5	9.5	14.3	10.7	5.3	14.1	8.1	14.3	0	14.6	15.3	16.7	14.4	15.6	10.1	12.4	13.0	10.8	14.8	15.1	12.3	13.2
37	3.1	7.7	16.9	16.0	11.9	3.9	7.3	13.1	17.5	4.0	9.0	20.1	13.7	8.5	8.2	10.2	16.6	3.9	10.2	11.8	4.0	9.5	14.4	7.4	7.6	7.7	12.9	7.0	9.6	18.9	18.7	2.8	7.7	5.1	14.6	0	6.2	6.0	17.3	2.9	14.3	10.6	5.1	16.0	3.6	13.9	13.3	5.6
38	8.1	10.1	18.8	17.1	12.8	7.2	10.0	15.9	20.9	3.8	9.8	23.5	16.3	10.7	11.4	14.8	17.0	4.9	13.8	13.1	6.9	13.2	18.0	7.2	10.6	6.1	16.0	6.6	13.6	21.7	20.0	5.0	7.7	3.5	15.3	6.2	0	5.5	21.5	0.9	18.0	8.6	10.1	17.6	3.8	16.9	10.2	7.1
39	6.5	11.3	21.9	20.7	13.4	8.4	12.4	18.3	21.3	3.0	12.9	24.0	17.5	13.8	12.1	15.3	20.9	4.2	15.0	15.2	4.2	14.3	19.1	11.0	11.8	8.5	17.5	8.6	12.1	23.3	23.4	7.2	9.5	5.6	16.7	6.0	5.5	0	21.1	2.8	19.0	11.4	9.5	20.3	4.8	17.3	14.9	10.0
40	16.1	16.5	18.6	20.7	19.1	17.7	14.8	14.9	3.9	20.0	18.2	4.7	9.2	16.3	14.0	11.0	23.0	19.6	14.0	16.2	18.4	14.2	14.0	19.0	15.2	21.9	15.3	11.8	12.8	9.5	20.2	17.9	11.6	20.8	14.4	17.3	21.5	21.1	0	11.4	13.6	23.6	14.3	12.7	19.3	8.5	25.4	19.0
41	4.6	5.8	10.6	9.6	7.8	3.7	5.1	8.9	12.0	2.0	5.8	12.9	9.7	5.4	5.9	7.4	9.7	2.6	8.3	8.3	3.9	7.6	10.8	4.5	5.9	2.9	9.7	6.8	6.7	12.7	10.6	3.0	7.9	1.6	15.6	2.9	0.9	2.8	11.4	0	10.8	4.3	5.9	9.8	1.8	10.1	5.8	2.5
42	13.0	11.3	10.7	13.1	12.2	12.9	9.6	6.4	11.3	17.2	10.8	12.9	11.7	10.2	10.8	8.1	15.7	16.2	4.8	8.1	15.5	5.9	1.3	12.8	10.9	17.8	3.5	9.3	13.0	10.5	14.8	13.3	8.6	17.5	10.1	14.3	18.0	19.0	13.6	10.8	0	19.6	10.0	14.2	16.8	12.5	20.6	15.8
43	12.5	8.9	16.3	13.6	10.3	12.8	12.2	15.7	23.6	8.9	9.5	25.8	18.9	11.3	11.9	16.0	12.7	8.5	16.4	13.1	12.1	16.2	19.7	7.7	10.3	3.3	17.1	2.9	17.3	22.0	16.5	10.6	4.2	6.4	12.4	10.6	8.6	11.4	23.6	4.3	19.6	0	13.0	16.8	8.4	20.7	5.0	7.1
44	3.3	6.0	14.7	14.9	9.6	6.4	6.0	10.1	14.3	7.8	8.0	16.8	11.6	7.9	5.6	6.5	16.3	7.1	6.4	8.6	6.1	5.8	10.1	8.1	5.8	10.3	9.0	7.4	6.8	15.8	17.2	6.0	7.6	8.8	13.0	5.1	10.1	9.5	14.3	5.9	10.0	13.0	0	15.0	7.6	11.9	15.8	8.8
45	16.6	12.8	11.1	11.4	14.9	15.5	11.2	10.1	11.6	18.0	11.7	13.3	8.9	10.3	13.2	13.2	13.1	17.5	13.5	12.3	18.5	13.8	14.6	12.8	12.6	16.4	13.6	7.4	17.6	7.8	12.3	15.0	7.0	17.1	10.8	16.0	17.6	20.3	12.7	9.8	14.2	16.8	15.0	0	17.0	11.7	16.5	14.3
46	5.5	8.0	18.0	16.7	11.6	6.7	9.0	14.8	19.6	2.3	9.9	22.1	15.7	9.8	8.9	12.3	16.8	3.5	12.8	12.5	5.3	12.3	17.0	7.5	8.1	5.6	15.2	6.4	11.0	20.6	19.2	4.8	7.4	2.5	14.8	3.6	3.8	4.8	19.3	1.8	16.8	8.4	7.6	17.0	0	16.2	11.5	5.5
47	12.8	15.2	18.5	19.1	17.3	12.0	12.7	14.4	6.9	16.4	14.6	10.6	3.4	13.6	14.7	13.4	20.5	16.0	10.2	14.9	14.4	9.8	12.5	15.0	14.8	18.5	12.5	11.3	14.1	10.7	21.4	13.1	11.3	17.1	15.1	13.9	16.9	17.3	8.5	10.1	12.5	20.7	11.9	11.7	16.2	0	21.8	16.4
48	15.5	11.8	15.8	12.4	13.6	13.9	13.1	16.0	24.7	12.5	10.4	26.9	19.7	11.6	14.5	17.9	10.7	12.4	17.4	14.4	15.5	17.4	20.7	8.4	12.8	7.4	18.0	3.0	20.0	22.5	15.5	12.0	4.4	9.8	12.3	13.3	10.2	14.9	25.4	5.8	20.6	5.0	15.8	16.5	11.5	21.8	0	9.1
49	8.4	7.5	14.5	12.7	12.1	7.7	7.4	12.2	19.3	7.20	8.1	21.7	15.1	6.8	8.9	11.2	12.7	7.4	12.2	12.1	9.3	11.7	16.0	5.9	7.5	4.8	14.1	4.4	13.1	18.9	15.4	6.5	5.4	5.1	13.2	5.6	7.1	10.0	19.0	2.5	15.8	7.1	8.8	14.3	5.5	16.4	9.1	0

Notes: Averages of 5 previous specifications.

6 The Seed of Abundance and Misery: Peruvian Living Standards from the Early Republican Period to the End of the Guano Era

Abstract

This paper scrutinizes the development of heights in Peru from the early Republican period to the end of the guano era. Studying heights of prisoners from the Lima penitentiary, we find stagnation for the lower social classes throughout the period. We argue that the presence of such a valuable export good as guano had no positive effects on the standard of living of the middle and lower classes, not even in Lima, where most benefits from guano exports concentrated. Statistically significant regional disparities in living standards did not exist throughout the period after controlling for ethnic and occupational differences. Moreover, we find that racial differences were pronounced during that time and remained on the same level throughout the whole century. In addition to the data on male prisoners, the study is the first to present data on Peruvian women for the 19^{th} century.

The Seed of Abundance and Misery[1]: Peruvian Living Standards from the Early Republican Period to the End of the Guano Era[2]

6.1 Introduction

Nineteenth century Peru was not just a field of nitrate and some guano islands, but can be described as a rich economy in terms of natural resources, e.g., silver mining in the mountains, sugar and cotton plantations on the coast, as well as rubber production in the forest. All of it had been known since Incan times, but extraction was discontinued after the demise of the colonial power and was only rediscovered gradually during the 19th century, for instance, the guano deposits in the 1840s. At the same time most of the literature calls this period a 'lost century' (Hunt 1985, Bonilla 1974, 1985) and even a '*fictitious prosperity*' (Gootenberg 1993), because all that was left was a highly indebted country depending on others' benevolence at the end of the 19th century. Yet in 1822, Simón Bolívar said to José de San Martín[3] that '*neither we nor even the next generations are going to see the splendor of the Republic that we are creating*' (cited in Contreras 2004, p. 13). He might have already had in mind the total absence of popular representation in any of the decisions taken concerning the political and economic organization of independent Peru.

This article studies the development of the biological standard of living approximated by adult height in Peru during the nineteenth century, from independence to the end of the guano era. Data is available from prisoners of the Lima penitentiary, registered between 1866 and 1909, to study birth cohorts from the 1820s to the 1880s. We argue that the presence of such a valuable export good as guano had no positive effects on the standard of living of the middle and lower classes, not even in Lima, where most benefits from guano exports concentrated. Comparing this outcome with other Latin American countries, we find a similar pattern as Salvatore (2004, 2007) detected in Argentina where the export-led growth of the country was accompanied by stagnation in heights at the

[1]Enrique Buster (cited in Romero 1949, p. 410).
[2]This chapter is based on an article submitted to *Economics and Human Biology*: Twrdek and Manzel (2009). The concept for the paper was developed jointly, the analyzes and writing was equally shared.
[3]Both being the liberators of Latin America.

end of the nineteenth century.

Regional disparities and urban-rural disparities in economic wealth and living conditions in Peru did not exist throughout the period considered. Racial disparities, in contrast, were exceptionally evident and remained on the same level throughout the whole century. Social structures formed during the Colonial period still prevailed and determined ordinary life. Most interestingly, Indians and blacks, both on the bottom of the social hierarchy, were the ones with the largest gap in terms of height, followed by Indians and whites. Blacks, although mostly former slaves, may have had higher living standards because the slave owner had spent money to acquire them, whereas the Indians' labor force was coerced and for free, a legacy of colonial times. These results support the hypothesis that inequality between different races slowed improvements in living standards. Inequality contributed to keeping poverty rates exceptionally high, since only a small part of the population, the governing 'white' elite, was profiting from trading surplus.

While the economic part of this story has been studied extensively (Bonilla 1974, Gootenberg 1989, Hunt 1995), living standards, especially those of the lower social strata, were often disregarded. This is the first time that Peruvian welfare trends are connected directly with economic and social issues. We show that the abundance of the valuable export product guano led to no more but stagnation of living standards, although economic theory would have suggested that an expanding export industry should lead, at least to some extent, to an improvement in living standards as a result of rising incomes (North 1955). This paper therefore presents empirical evidence for the notion that the country, despite its wealth, was not able to improve the living standards of a majority of the population.

This paper is divided into seven sections. The following section describes already existing studies on the biological standard of living in Latin America and the intuition of the concept of the biological standard of living. The third section describes the historical background. A presentation of the data set with its possible biases follows. The fifth section deals with Peruvian history focusing on welfare development, which leads us to section six where we study regional and social differences to determine the extent of inequality in the society. The last section summarizes and draws conclusions.

6.2 The Biological Standard of Living in Latin America

Anthropometric techniques are by now a well established method to infer about living conditions in the past. These are especially valuable to study periods and countries for which conventional economic data such as GDP/c or wages are not available for studying living standards (Steckel 1995, Komlos 1998). Moreover, using anthropometric methods, all individuals in an economy are taken into consideration, such as self-employed people like peasants or workers in the informal sector (Baten and Fraunholz 2004). The literature on the biological standard of living assumes that the stature is determined by environmental conditions (nutrition, disease environment, hard body work, and hygienic behavior) as well as genetic factors. These genetic factors can be ruled out if whole populations are under observation, so that the residual contains all the errors we cannot measure. Studies of twins have shown that, above all, the environmental conditions during childhood affect growth (Eveleth and Tanner 1990, p.176; Bogin 1988). Thus, adult body height gives us information about nutritional and environmental conditions around the time of birth, as the body size is mainly influenced in the first years after birth.

Studies on the biological standard of living in Latin America are still scarce, but nonetheless, we can deduce a general pattern of the development of stature in the 19^{th} and 20^{th} century from existing studies. In general, stagnating heights reflect the living conditions in Latin America throughout the (late) 19^{th} century, whereas the 20^{th} century yielded somewhat increasing heights (López-Alonso and Porras Condey 2003; Salvatore 2004, 2007; Carson 2005, 2008; López-Alonso and Carson 2005; Frank 2006; Meisel and Vega 2007; Baten, Belger, and Twrdek 2009).

Meisel and Vega (2007) study Colombian heights on the basis of National Identification Cards and passport records. They find stagnating heights for the elite group of passport holders for the birth cohorts of 1870-1919, but an estimated increase of not less than 9 cm for the average Colombian during the period 1905-1985 using the national citizenship files. However, the elite group was much taller than the average Colombian. In a study about Mexican heights, López-Alonso and Porras Condey (2003) also find that the elite were substantially taller than the working class from the 1870s to 1910s. The lower social classes in Mexico, in contrast, experienced stagnating living conditions until the end of the Porfiriato (1877-1911). During the revolution and its aftermath, stature declined. Only for those born after the 1940s, heights increased again. The authors conclude that the unequal income distribution made it impossible for the lower social classes to benefit from the economic prosperity of the country. These results are supported by Carson (2008) who studies the height development of Mexican-born and U.S.-born Mexican prisoners in the U.S. during the late 19^{th} century. He also finds only stagnating heights for those born in Mexico in spite of considerable social and political turmoil, not the sharp decline that he had expected.

Salvatore (2007) studies the stature of Argentines from registers of prisoners and military recruitment lists starting in the late colonial period to the mid-20^{th} century. He, as well, comes to interesting conclusions about the development of the standard of living. Against conventional wisdom, he finds an improvement in nutrition and health for recruits born in the post-independence period which he associates with institutional reforms and market liberalization. In the following two periods of extensive export growth, however, he observes a situation of nutrition stress in this food rich economy. Living standards stagnated during this time. Neither the expansion of wool and cattle (1850-1880) nor the expansion of wheat exports (1880-1914) led to an improvement in living standards. Moreover, the export boom reinforced existing regional disparities. The author concludes that besides an increase in food prices, the pressure of immigration on the labor market led to decreasing wages. Further, diseases and child labor aggravated the situation and led to the observed stagnation in living standards. Only the interwar period showed a renewed sustained growth in average stature.

To infer about living conditions among the Brazilian poor, Frank (2006) analyzes records of the Rio de Janeiro city jail. While the stature of the free population stagnated from the 1820s to 1850s, slaves born before 1840 were even taller than poor free

Brazilians. However, their heights declined until the 1860s, probably due to higher food prices and a changing disease environment especially in urban areas.

Stagnating heights reflect the living conditions in Latin America throughout the (late) 19^{th} century. Especially the lower social classes lost ground. Each of the studies cited above finds extensive regional and social disparities in stature. In sum, various scholars consider the development of heights in Latin America. Mexico, Argentina, Brazil and Colombia are well-documented. Peru, however, has hardly been studied so far. The only exception is a study by Baten, Pelger, and Twrdek (2009) that compares the height development in Argentina, Brazil, and Peru (Lima) for the 19^{th} century. We extended their data source for Peru with additional data from prisoners of the Lima penitentiary and the Guadalupe prison (for the year 1909), arriving at 2,735 observations. Moreover, we are able to study regional disparities since prisoners from the whole country were recorded this time, whereas Baten, Pelger, and Twrdek (2009) concentrated on Lima.

6.3 Historical Background: Peru During the Guano Era

The period between 1820 and 1890 can be considered as the one with the most frequent political changes in Peruvian history. After having officially gained independence from Spain in 1824, the governing elites were not prepared yet to share political power among themselves.[4] The early republic was therefore highly instable. Governments changed around 50 times between 1821 and 1845 (8 government changes in 1834 alone) and 5 different constitutions were approved. Civil wars between conservatives and liberals as well as federalists and centralists aggravated the political situation of the country (Blanchard 1996, Vizcarra 2006). Moreover, boundary conflicts with neighboring countries added to this instability. The economy of the country was in a deplorable state. Just as before independence, minerals remained the main export product, but their production had declined considerably since independence. The agricultural sector had suffered from destruction during the wars, from a great reduction of cheap labor force, as an important part of the

[4] San Martín declared Peru independent already in 1821 (Blanchard 1996, p.159).

(black) labor force was lost in the wars of independence, and from a disruption of the internal market (Gootenberg 1990). For nearly two decades, the country continued in this condition.

Then, in the early 1840s, huge guano deposits were found at the Chincha Islands which would soon change Peruvian history. Already the Incas had used guano, the excrements of cormorants, pelicans, and other seabirds, as a soil fertilizer due to its high content of nitrogen and phosphorous. Although minor guano deposits were also found at several smaller Pacific islands, Peru became the world's most important guano exporter and guano the main export staple of the country. The extraction required little capital investment and no transport system by land (Hunt 1985, p. 269). The income helped to stabilize the economic and political situation of the country. Between 1830 and 1878, guano exports rose by 5.7 percent p.a., becoming the most important tax income source. Other sectors of the economy, in contrast, were neglected and received no entrepreneurial input. Agricultural and forest industries fell into decay, partly because of a lack of state activity, but also because of the lack of workers (Hunt 1985, p. 267). Although the cotton and sugar industries experienced an expansion in the 1860s and 1870s, their role in the process of economic development was of minor importance. Nitre became another promising export product in the late 19^{th} century, but after Peru's defeat in the Pacific War with Chile in 1883, the country had to hand over the department of Tarapacá, and this valuable resource was gone (Hunt 1985, p. 258).

Government expenditures increased along with guano revenues. They included not only the building of pompous palaces, an enormous expansion of the military or civilian bureaucracy, but also the payment of indemnifications for the liberation of the black slaves. This spending spree motivated corruption. For instance, slave owners filed claims for indemnification for 25,500 slaves, although there were perhaps only around 17,000 slaves left in the year 1854 (Vazquez 1970).Characteristics of the guano era were disdain and oblivion for the contributions of the people, as well as the lack of interest in creating a tax system which could have served as a regular source for stabilizing the revenues of the state (Romero 1949, p.367). In the end, the internal debt had risen to an incredible amount; inflation prevailed and made the cost of living difficult and nearly impossible.

6.4 Data and Representativeness

In an earlier study, Baten, Pelger, and Twrdek (2009) used data from inmates of the Lima penitentiary and Guadalupe prison collected in the National Archive to study living standards in Lima. They rely on a sample of 1,139 cases which includes a modest number of immigrants. They estimate a height trend which shows a stagnation of heights in Lima during the periods of the 1820s to 1850s as well as the 1860s to the 1880s. They claim a modest upward trend from the 1850s to 1860s, since several decades were considered together, but when separating into decades it seems that especially the 1840s were a harsh time for *Limeños* (inhabitants of Lima). This loss in heights is regained thereafter. Using the extended data set of 2,735 observations, we find further support for the stagnation of heights in the whole country.

The samples are drawn from the inmate books of available years from 1866 to 1909 and thus give insights in the development of mean adult heights for prisoners born between 1820 and 1880. The data set contains height information for 2,735 male Peruvians, 386 female Peruvians, and further 1,141 foreigners. The *'fichas'*[5] comprise information on the place of birth, religion, age, profession, ethnic group, level of instruction (if the person knows how to read and write or not), and their stature. The sample consists of prisoners from all over the country; although most observations are *Limeños* and inhabitants of the coastal zones (81 percent). Table 6.1 describes the summary statistics of the data set.

In a detailed study about the criminals of Lima, Aguirre (2005) ascertains the statistical profile of the inmate population in Lima's penal institutions. It describes well-known patterns in prison populations around the world. Most prisoners belonged to the poor and working segments of the population, were relatively young, and belonged to non-white ethnic groups. The data does not contain information on the type of crime committed, but from Aguirre's descriptions we know that felons at the Lima Penitentiary were mostly

[5] Individual anthropometric records.

sentenced because of having committed homicide or economic crimes such as theft, cattle rustling, or fraud. The sample is skewed towards the lower and middle social strata of the Peruvian society and thus under-represents the economic elite. However, especially the heights of the middle and lower economic strata of the society are more prone to changes in crises than heights of the higher economic classes (Komlos and Baten 2004). We find a higher share of the black population in our sample than the two percent of the Peruvian population given in the census of 1876 Díaz 1974). Farmers are under-represented in the prison sample if we consider the data of Pinto and Goicochea (1977) who report that about 50 percent of the population were farmers. Nonetheless, this should not be considered a major problem since we adjusted our estimates with population weights.

We restricted our analysis below to Peruvian males aged 20 to 50 because younger individuals still had some growth potential and wanted to rule out any distortions.[6] This leaves us with 2,330 cases being considered in the following analysis. If not mentioned otherwise, we report only estimations which are based on at least 30 cases; the sample increases to 240 at most for any birth decade.

6.5 Peruvian Welfare Development

By means of an OLS regression we estimate two height trends, one for males and another one for females (Table 6.2). The results are adjusted with population weights for the racial composition of Peru calculated from the census of Peru in 1876 (Figure 6.1). Heights of male prisoners declined over the 19th century from around 162.4 to 161.4 cm. Although this decrease seems not to be very strong, it is nevertheless astonishing that Peruvian heights stagnated (or declined slightly) in a period of economic prosperity. However, lower class Argentines in the late 19th and early 20th century, similarly, did not benefit from the Argentinean '*Golden Age*', experiencing stagnating living standards instead (Salvatore 2004, 2007). Peruvian heights decreased strongly in the 1840s, improved only slightly afterwards, but remained below the level of the 1820s and 1830s. Frank (2006) detects a

[6] The same restrictions are applied to women and migrants.

similar sharp decline in the stature of Brazilian prisoners for the 1840s, but fails to deliver any specific explanations. Thus, the guano boom in Peru seems to have had no positive effects on the standard of living of the middle and lower social classes.

Female heights, in contrast, showed more variation between the different birth decades which might also be driven by the lower number of cases for females. Over the period 1830 to 1860, an increase in height of about 1 cm can be observed. However, due to the limited number of cases, we must be careful to interpret this development as an improvement in the standard of living of females. Middendorf (1893, p. 212) observed that women in general were quite small, but that their height increased during the years of observation. He explains this with a reference to nutrition and mentions that women started to comsume more meat.

Which might be the reasons for the poor height development of the lower social classes? We argue that the disease environment, a shift in agriculture from foodstuff to export crops, as well as rising prices are responsible for the stagnation in heights. The hygienic situation during the period under study was precarious. During the second half of the nineteenth century, mortality in Lima had been higher than the number of births, which put Lima on the seventh place of cities with the highest mortality at that time (Moreno 1897). Life expectancy at birth in the first half of the 19^{th} century was around 30 years and by 1859 it had risen to 30-32 for men and 32-34 for women only (Huenefeldt 2000, p. 21). Diseases and epidemics like smallpox in 1822 or yellow fever around 1855 could hardly be eradicated. Moreover, tuberculosis and different fevers were widespread. All efforts of different governments to improve the hygienic situation in the city failed. The main reason for this can be seen in the hygienic and health behavior of the inhabitants. Higher income groups were affected as well, since residential quarters of higher and lower social classes adjoined (Moreno 1897) and water-borne diseases affected all classes (Peloso 1985). Food, particularly vegetables or bread, was often contaminated and transmitted dysentery. Until the late 1860s, when yellow fever attacked members of the legislature and the government made sustained efforts to improve the sanitary situation in Lima, the hygienic environment did not improve significantly (Zárate Cárdenas 2006).

In contrast to the disease environment, the provision of foodstuff was quite good. The Creole cuisine relied heavily on meat. Moreno (1897) compares the meat consumption in Peru around 1890 with meat consumption in other countries and concludes that Limeños consumed a lot of meat in international comparison. While cattle was infrequent, sheep and mutton were preferred. Consumption patterns were similar across social groups (Gootenberg 1990, Peloso 1985) and low prices made basic foodstuff like bread and meat affordable for the lower economic strata (Peloso 1985, Gootenberg 1990).

The guano boom benefited primarily a small elite in Lima and some foreigners. But it also transformed the governmental revenue structure. By 1861-1866 guano income accounted for 75 percent of government income. Expenses for education and health also increased, but did probably not trickle down to the lower social classes (Berry 1990). Although real wages increased between 1855 and 1869 in response to a higher demand for domestic products, industrial employment declined around 40 percent (Hunt 1985). The appreciation of the exchange rate led to a flood of foreign imports that threatened the domestic industry. Substantially increasing food prices caused artisans to protest around the end of the 1850s and led to increasing criminality, which compelled the Parliament to discuss the question whether the death penalty should be reintroduced (Bonilla 1974). Thus, despite the guano boom the economic situation of large parts of the Peruvian society did not improve and it is likely that the increasing food prices had additional negative effects. Therefore, stagnating heights during the period of economic prosperity are not surprising.

Over the course of the 19th century food production was increasingly substituted by the production of export crops like sugar or cotton. The latter saw an enormous increase in prices during the U.S. American civil war. Peloso (1985) states that this development affected predominantly the pattern of food allocation. Prices for foodstuff increased as a result of the Dutch disease, i.e., an appreciation of the exchange rate due to the export boom, the replacement of agricultural production by the cultivation of cash crops, and an increasing population in Lima from the second half of the 19th century. Indian communities in Tarma, near the silver mines of Cerro de Pasco, traditionally cultivated potatoes, alfalfa, and corn (to produce chicha - a fermented beverage). But Tarma's landlords seized the opportunity to take these lands in order to cultivate sugar and distil *aguardiente* which was in great demand at the mines (Peloso 1985). This is only one of numerous examples that show the shift in Peruvian agriculture from the production of foodstuff to either export products for European or U.S. markets. Especially Lima and Callao benefited from this development (Smith 1987). Particularly the poor, in contrast, may have suffered from this development.

In sum, enrichment and impoverishment accompanied each other (Bonilla 1974). While the protein consumption in Peru was quite good among all social strata, the unfavorable disease environment, the replacement of agricultural production by export products, and the worsening economic situation for large parts of the population probably led to stagnating heights.

How do Peruvian heights perform in international comparison? Figure 6.2 compares Peruvian heights to heights of immigrants in Peru. [7]Peruvians were shorter than immigrants from Colombia and Chile and had almost the same height as prisoners born in Ecuador. Even if we control additionally for the birth decades, Peruvians remain the shortest (Table 6.3). On average, they were 1.8 cm shorter than prisoners born in Colombia, and 0.8 cm shorter than prisoners born in Chile. However, these differences are not statistically significant. Spanish- and Italian-born prisoners are significantly taller, around 2.8 cm and 3.0 cm, respectively. These differences can be explained by the social composition of Italian and Spanish prisoners. 65 percent of the Italians and 83 percent of the Spanish are classified as skilled or professional according to their occupation. Among the Peruvians, only 46 percent are classified as skilled or professional.[8]

Was the guano boom responsible for stagnating living standards of the lower classes? The relationship between resource abundance and economic growth has been studied extensively by various scholars, for instance, Sachs and Warner (1995, 2001), Isham et al. (2003), and Torvik (2002). A negative association is induced through various mechanisms.

[7]Information on the year of immigration is not available from the prison sources.
[8]See section 6.6.2 for the classification of occupations.

First, the Dutch disease may lead to a downturn in the manufacturing sector which impedes economic development and future growth perspectives. Rent-seeking behavior may also influence the development of a resource boom negatively (the '*resource curse*'). If the appropriation of the rent is the society's principal aim, this causes a distortion of the factor markets and policies. Likewise, oligarchic policies are frequent in resource rich economies and may hamper economic growth (Bulte, Damania, and Deacon 2004). Besides the relationship between resource abundance and economic growth, only Bulte, Damania, and Deacon (2004) scrutinize the effect of natural resources on social indicators like the Human Development Index, the Human Poverty Index, the percentage of undernourished population, the percentage of underweight children, and life expectancy at birth. The authors find a small, but still substantial, negative impact on these social indicators for the late 20^{th} century. If this relationship holds for earlier periods, the guano boom-induced Dutch disease and rent-seeking behavior may also have led to stagnation in living conditions of the lower social classes.

To conclude, despite the wealth of the country, the export boom beginning in the 1840s had no positive impact on the living standards of great parts of the Peruvian population. While prices rose significantly during the guano era, wages did not match this development, at least not in all sectors of the economy (Gootenberg 1990, Hunt 1985). Increasing food prices and unemployment led, together with an unfavorable disease environment, especially in the urban areas of Lima and Callao, to negative impacts on the height development. Peruvian heights remained throughout the period under consideration on a low and stagnating level.

6.6 Guano, the Rentier Economy, and its Impact on Inequality

6.6.1 Regional Inequality

Economic growth in 20^{th} century Peru has been accompanied by growing regional inequalities, and today the country has one of the highest degrees of inequality in regional per capita income in Latin America. Its inequality in income levels outperforms countries like Colombia, Brazil, or Mexico (World Bank 1999). In addition to the regional disparities, large urban-rural disparities exist. Peru has a great variety of different geographical regions and climate zones. The country is divided into three different regions which are separated by deserts and plateaus. The coastal zone is one of the world's driest regions and covers only around 11 percent of the country, but hosts today around 49 percent of the population (Escobal and Torero 2005, pp. 77). In the 19^{th} century, however, the majority of the population lived in the Andean mountain range (*sierra*) on hardly arable lands. The coastal plains are positively and negatively influenced by the Humboldt stream. Agriculture is only possible on irrigated parts on the southern coast, and on the north coast, which receives more rainfalls. The *sierra* hosted the important silver mines. The Amazonas basin (*selva*) consists mainly of dense forests; it has the lowest population density, offers only few transportation routes, and has restricted agricultural potential.

While it is true that industrialization in the second part of the 20^{th} century deepened regional disparities in Peru (Long and Roberts 1984, p.11), there has always been a dualism between the semi-subsistence sector in the sierra and the export-linked sectors located on the coast. Ever since independence, political and economic power shifted from interior Peru (mainly Cuzco) to Lima. Throughout the 19^{th} century, the export-oriented economy grew substantially (Fisher 1987). Especially the coast benefited from the advantageous position near the harbors to export these agricultural products overseas which assured them higher earnings than the transportation of foodstuff to the interior (Peloso 1985). However, this trade assured more wealth only to Lima's elite and likely meant higher food prices.

Thus, were regional disparities already pronounced during the early Republican period? In the following, we will argue that differences in the biological standard of living between the different Peruvian regions did not exist during the 19^{th} century. While the northern coastal area offered good opportunities for agriculture (cash crops), the Sierra benefited from its silver mines and the export of foodstuff to the coastal areas or the mining centers.

As individuals from the mountain range and the Amazonas basin are underrepresented in this sample, we examine these groups together. Further, we distinguish between prisoners born in the capital and the rest of the coastal areas to check for different living conditions in Lima itself. In this respect, especially the difficult disease environment of Lima could have had adverse effects on the stature of Limeños. Figure 6.3 shows mean adult heights in the three areas considered. Heights for those born in the capital are considerably higher than in the other coastal provinces, the Amazonas basin, or the mountain range. Note that the number of observations is relatively small (for example the 1820s for Lima) and may lead to substantial differences between the birth decades. Those born in other coastal provinces are smaller than those born in Lima and prisoners coming from the Interior (*sierra and selva*) are the shortest. Racial characteristics are especially important in the case of a racially heterogenous country like Peru. Whites lived mainly on the coastal zones around Lima, while a high share of indigenous population lived in the Amazonas basin. After controlling for the different ethnic composition, differences between regions turn out to be insignificant (see table 6.2, column II).

Assuming that the ethnic composition did not change considerably during the 19^{th} century, our data may give valuable hints on the change of living standards within the different regions.[9] Mean adult heights stagnated or deteriorated in all regions. Living conditions in the coastal areas decreased to a greater extent than in the capital. In the interior, in contrast, living conditions stagnated: The decrease of the 1840s is minor in comparison to the development in the other regions. The isolation of these regions from economic and political action may be a reason for this development.

Analyzing only the stature of indigenous people (averaged across all birth decades) in the three regions reveals that those born in the capital were indeed taller than indigenous people living in the rest of the country (Figure 6.4). However, the difference between those born in the interior and those born in the coastal areas is not so clear cut. The same is true for prisoners classified as mestizos. Blacks, in contrast, were about one centimeter taller if they were born in the coastal area rather than in Lima. Blacks on the coast worked mostly on plantations and we would assume better nutrition for them. Blacks

[9] Hunt (1985) shows that migration played only a subordinate role and our data shows no differences over time in the regional ethnical distribution.

in Lima worked mainly as artisans or servants where they were exposed to the rising food prices and the difficult disease environment. The indigenous population, in contrast, worked rarely on plantations, but earned their living from semi-subsistence farming.

Until now, there was little evidence for differences in living standards between urban and rural areas in Peru. No data for mortality or life expectancy for cities and rural areas exists. Therefore, an exploration of the stature in urban and rural places may give us valuable information on the living conditions. Generally, Peru was sparsely urbanized during the 19th century. Besides Lima with its surroundings and Callao, only four cities had more than 10,000 inhabitants in 1876, namely Chiclayo, Arequipa, Cuzco, and Iquique (Smith 1987). These cities benefited from a greater variety of agricultural products on the markets than the rest of the country (Peloso 1985). Moreover, employment possibilities, education, and wealth may have been better in the cities than on the countryside. But on the other hand, the disease environment in the cities may have had adverse effects. Which of these factors dominated is less clear.

Prisoners born in urban areas are, on average, taller than those born in rural areas. From the birth decade of the 1830s onwards, heights decreased until 1870 in urban areas (Figure 6.5). In rural areas, in contrast, heights decreased only until 1840, stagnated afterwards and began to increase again after 1850. Thus, the height advantage in urban areas decreased from the 1830s onwards until the 1870s. However, if we control for a different ethnic composition in urban and rural areas, differences between urban and rural born prisoners are negligible for almost all races. Only the mestizos show a clear urban height advantage of 1.3 cm (Figure 6.6). The results of a dummy variable regression show no significant effect of the urban dummy after controlling for ethnicity (Table 6.2, column III). It seems that urban advantages of a greater variety of foodstuff, better employment opportunities, but also a more difficult disease environment, may have cancelled each other out, leading to equal mean height in urban and rural areas for the lower strata of the Peruvian society.

To conclude, regional differences in living standards certainly existed, but they were mainly a result of the different ethnic composition of the society. Once we control for this composition, differences between regions or urban-rural differences disappear. Social differences seem therefore more important in the case of Peru.

6.6.2 Social Inequality

This section examines the development of social inequality, measured by differences in height between different social groups. We show that Peru's '*lost opportunity*' during the guano era was not only reflected in economic terms, but also in the social conception. Racial and occupational classifications are used to group the prison inmates according to personal wealth, social standing, and education. Skin color in Peru comprises the social and cultural rather than the biological background and seems therefore a good proxy to measure welfare. Middendorf (1893, p.204) mentions that in 19^{th} century Peru there were a great number of people who were classified as whites because of their wealth, political influence, or even their outstanding social status. These people were counted to the white class out of courtesy, even though they might have had more Indian than Spanish blood.

Using a simplified Armstrong (1972) scheme, we classified all occupations in four different categories, namely the unskilled, skilled, professionals, and farmers.[10]Farmers were coded as a separate group because they might have benefited from the proximity to protein rich food (milk, beef) and from their land ownership. This scheme captures the skill level, potential earnings, and the social status of occupations for 19^{th} century censuses well (Armstrong 1972). Around 300 different occupations were listed in the '*fichas*'. Table 6.4 shows the most frequently encountered professions for each category.

The racial classification used here is adopted from the first official census taken in Peru in 1876, where we find the main racial groups being whites, blacks, mestizos, Indians, and Asians (Díaz, 1974, p.29).[11]The zambos, of black and mulatto background, are listed separately in the individual '*fichas*'. To simplify matters, and because their mean height did not differ from the latter, we classified them as blacks.

Figure 6.7 shows mean height trends for all four racial groups. Differences clearly

[10] Armstrong (1972) uses two more categories in his nineteenth century census studies, the semi-skilled and semi-professionals.

[11] In our analysis Asians are excluded because case numbers for Asians born in Peru are too small.

existed throughout the whole period under study and remained important until the end of the guano era. We cannot speak of any convergence process during the 19th century, since racial inequality showed hardly any changes at all. Heights of all races experienced a significant decline from the 1830s to the 1840s, as our regression analysis in section 5 has already shown. We would have expected that the economic boom starting in the 1840s had a positive influence on the development of the standard of living, but our analysis tells a different story. We could already conclude from other historians (Romero 1949, Hunt 1985, Gootenberg 1990) who studied the economic part of the guano era that no major ameliorations were achieved. Empirical evidence from prisoner's heights supports these results as well, with regard to the development of the standard of living of different racial classes.

Blacks were at 167.4 cm in the 1820s as well as the 1880s, the tallest individuals. They had lost nearly 1 cm in height until the abolition of slavery in 1855, but regained this centimeter after it. The difference of 4.9 cm to Indian heights in the 1820s had therefore grown up to 7.1 cm in the 1880s. This supports our hypothesis that blacks were much better off because they were more integrated in the Peruvian society; to name just one example, their unopposed acceptance of the Catholic religion which unified them with the white elite (Tannenbaum, 1946).

Indians and blacks were the two groups on the bottom of the social hierarchy. Still, both groups showed different social patterns despite the fact that the greatest part was categorized as unskilled workers. While Indians became slaves, laborers, and tribute-payers (Gibson 1984, p.381), black people were thought of as an investment. The latter were mainly found to be working as servants in the elite houses of Lima or on haciendas in the coastal regions; Indians who were first living in the highlands from subsistence economy were forced to work in mining industry or on haciendas as bond-slaves with hardly any remuneration, but still enough to be able to pay the contribution. Blacks were always considered to be of more value than Indians because owners had paid a certain amount of money for them (Díaz 1974, p. 27). We argue that blacks had a superior standard of living compared to Indians because they were treated with more care by the white elite of the country. Then, as well, they were culturally assimilated more rapidly. Manumission was a common practice in Peruvian society, and most slaves had already been freed soon after independence and actively took part in the nation, whereas the Indians remained more isolated (Tannenbaum 1946, p. 41).

Racial mixture between whites, blacks, and Indians led to the creation of the mestizo race. These were mainly working in handcraft and classified as skilled workers. They formed the middle class of Peruvian society and tended to be closer to the white elite than any other group.

The indigenous population suffered the most during the 19thcentury. They lost nearly 3 cm from the 1820s to the 1850s, which we can clearly ascribe to the fact that the Indian tax was still at work. The government of Castilla, which had theoretically abolished the Indian tribute in 1824, had it resurrected in 1826 under the name of '*contribución de indígenas*'. The only significant contribution was paid by Indian laborers. Castes which comprised '*non-Indians*' did practically not pay any contributions at all: Their dues were never properly collected. With the guano revenues in mind, the government abolished the contribution of the Indians in 1854 (Kubler 1952). This is when we observe a slight increase in Indian heights, around 0.8 cm, although this meant still a loss of 2.1 cm compared with the level at the beginning of the period. The reason for this might be that Indians could resume making their living from subsistence farming, instead of working on the haciendas or in the mining centers to obtain the money they had needed to pay the contribution (Contreras 2007, p.143).

Whites were gaining in height from the 1840s to the 1850s by 1 cm which might be due to the fact that most were involved in the commerce of the nascent guano boom. Still, already one decade later, they had lost this increase in height and were back at the same level as in the 1830s with 165.3 cm. For the decades of the 1820s, 1870s, and 1880s, few cases are available, indicated by a dotted line in the graph. If we considered them for an overview of the whole century, we would ascertain that whites were gaining in height starting with 163.2 cm in the 1820s and ending up, after an increase of 4.2 cm, at 167.4 cm in the 1880s. We can conclude that a small part of the population, the white elite, actually benefited from the economic boom of the country. Stagnation for most people, coupled with height increases for the elite, would also imply that social inequality between whites and indigenous people, grew over time. However, further data is needed to strengthen this result.

Figure 6.8 is based on professional classifications, which describe the social environment as well as access to education. To facilitate an interpretation, we divided the data into an early post-independence period (1820/30s), the guano era from 1840s to 1860s and a post-guano period (1870/80s). Unskilled people lost 3 cm in height when the apparent economic guano boom took place and regained nearly 2 cm when this boom was over. Still, this meant a loss of 1 cm in height during the overall period. Skilled people as well lost ground, although to a minor extent. The only ones who seem to have benefited from increasing guano revenues are professionals, gaining 0.5 cm in height. Unfortunately, case numbers for the post-guano period are too small to be considered.

The most striking result is the development of Peruvian farmers, who lost 4 cm in height from the beginning of independence to the late 19^{th} century. It seems that governmental concentration on the export product guano and the neglect of all other industries led to a sharp decline in the biological standard of living of farmers. As mentioned above, the reduction of cotton and sugar supply on world markets and fast rising prices of these products in the 1850s caused a displacement of the production of aliments to cash crops.

When analyzing the occupational groups by different races, this time by considering each birth decade, a deterioration of the standard of living for all groups is visible (Figure 6.9). We are missing some subgroups because case numbers were too small, but still, some important conclusions can be drawn from this graph. Indian farmers were taller than Indian unskilled people. The proximity to protein rich food explains why farmers had a slight height advantage to other occupational groups. Skilled black people were also taller than unskilled blacks in the 1840s and 1850s, which confirms the hypothesis that a higher professional standing affects the biological standard of living positively. The same result applies to the unskilled and skilled mestizos.

To conclude, social differences in mean height, measured by racial as well as occupational classification, show strong inequalities in living standards. Differences between the racial groups increased slightly during the 19^{th} century. While blacks and whites exhibited an increase in heights during the second half of the 19^{th} century, Indians and mestizos showed a poorer development. Decreasing Indian heights until the abolition of the '*contribución de indígenas*', and slightly increasing heights afterwards suggest that social inequality was supported by the unequal tax system. However, further data is needed to confirm the positive height trend of the whites, which suggests that the guano boom brought about a few white winners and a lot of indigenous losers. The height trends for occupational groups confirm that mainly the unskilled and farmers lost ground during the guano boom. The prevailing social inequality probably affected the progress of living standards throughout the period.

6.7 Conclusion

The main aim of this research paper was to trace the development of living standards in Peru from the early republican period to the end of the guano era. We explain why the biological standard of living of the lower social strata of the society did not improve during a period of economic prosperity and how social inequality influenced this stagnation of heights. The answer to the first question is quite obvious: The country failed utterly to complement its resource wealth with a solid institutional basis to achieve a steady path of growth. Most resource rich countries suffer this curse of natural resources. Living standards since independence stagnated for the lower social classes in Peru, a development which is similar to living standards of these classes in other Latin American countries like Mexico, Brazil, and Argentina. Despite the enormous export-linked wealth of the country, the lower classes did not benefit at all from the guano prosperity, but suffered even more due to increasing prices and rising unemployment. In addition, agricultural food production was replaced by cash crops which assured the elite high revenues but put in danger the agricultural food production for the whole population. As a result, more and more foodstuff had to be imported at a much higher cost, for instance, cereals and fruits from Chile (Bonilla 1985).

Regional inequalities were less of a concern during the 19th century. Within country inequalities in the biological standard of living turned out to be small, as long as we control for the different social composition within the regions. Neither could we find empirical evidence for urban-rural disparities. Therefore the disparities existing today trace their origin most likely back to the 20th century industrialization process of the country.

Social inequality measured by differences in mean height among racial and occupational groups did not change considerably during the period under study. Independence seems not to have altered much of the colonial structures that had been imposed by the Spanish conquerors. The white elite remained in power and the largest part of the population lived near subsistence level (Contreras 2004). Constant inequality between Indians and blacks as well as the supposed growing inequality between Indians and whites appear to have slowed down improvements in living standards, just as Coatsworth (2005) had suggested. The stagnation of heights that is visible for each subgroup and occupational standing played just a minor role if we controlled for the racial composition. The tall stature of black people is consistent with similar studies of American slaves, which find that free blacks achieved nearly the same heights as their white counterpart and even towered over contemporary Europeans (Bodenhorn 1999).

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6.9 Appendix

6.9.1 Tables

Table 6.1: Characteristics of the data set

Feature	Share in the sample	Observations
Total data set		
Male	88.55	3,889
Female	11.45	503
Literate	49.70	2,183
Peruvian	71.68	3,148
Caste (only Peruvians)		
Black	25.79	601
White	13.69	319
Indian	32.49	757
Mestizo	26.95	628
Region (only Peruvians)		
Coast	49.66	1,157
Capital	31.29	729
Interior	19.05	417
Occupation (only Peruvians)		
No Occupation	0.43	10
Unskilled	38.41	895
Skilled	42.66	994
Professional	4.25	99
Farmer	13.86	323

Notes: Only men between the ages 20 to 50 are included.

Table 6.2: Regression results of dummy variable estimations

Coefficient	**(I)**	**(II)**	**(III)**	**(IV)**	**(V)**
Constant	162.91***	162.18***	162.76***	153.85***	153.45***
	(400.79)	(305.48)	(332.82)	(112.16)	(108.44)
Birth Decade 1820	0.98	0.82	0.98	-	-
	(-1.22)	(-1.03)	(-1.23)		
Birth Decade 1830	0.87	0.83	0.89	-1.22	-1.21
	(1.51)	(1.44)	(1.54)	(-0.84)	(-0.83)
Birth Decade 1840	-0.31	-0.34	-0.29	-0.43	-0.31
	(-0.58)	(-0.64)	(-0.54)	(-0.35)	(-0.25)
Birth Decade 1850	0.24	0.27	0.23	-2.26*	-2.12
	(0.44)	(0.5)	(0.42)	(-1.82)	(-1.70)
Birth Decade 1860	0.17	0.23	0.14	-	-
	(0.27)	(0.36)	(0.23)		
Birth Decade 1870	-0.16	-0.13	-0.13	-	-
	(-0.21)	(-0.17)	(-0.17)		
Indian	-3.04***	-2.87***	-2.95***	-2.38**	-2.36**
	(8.23)	(-7.50)	(-7.79)	(-2.26)	(-2.16)
Black	3.52***	3.65***	3.46***	3.70***	3.53***
	(9.18)	(9.18)	(8.93)	(3.67)	(3.43)
White	2.30***	2.06	2.20***	3.26	3.08
	(4.97)	(4.28)	(4.67)	(1.64)	(1.55)
Asian	-3.81**	-3.47	-3.87**	-	-
	(-2.05)	(-1.86)	(-2.08)		
Other	-2.21	-1.86	-2.27	-	-
	(-1.15)	(-0.96)	(-1.18)		
Capital	-	-0.12	-	-	0.99
		(-0.30)			(1.14)
Interior	-	2.43	-	-	0.77
		(1.59)			(0.73)
Urban	-	-	0.34	-	-3.59
			(-1.11)		(-0.89)
No Occupation	-	1.82	-	-	-
		(0.86)			
Skilled	-	1.00***	-	-	-
		(3.16)			
Farmer	-	1.16***	-	-	-
		(2.7)			
Professional	-	0.69	-	-	-
		(0.96)			
Observations	2,330	2,330	2,330	386	386
Adj. R^2	0.14	0.14	0.14	0.14	0.13

Notes: ***/**/* implies statistical significance at the 1, 5, and 10 percent levels, respectively. T-values in parentheses. The constant refers to mestizos born in 1880, living in a coastal province and with an occupation classified as unskilled. In (III) the constant refers to mestizos born in 1880, living in a rural area. In (IV) and (V) the constant refers to women born in 1860s. The case number reduces because we included only individuals aged 20 to 50. Other: This category contains individuals which did not belong to one of the other important races in Peru, for example Jewish.

Table 6.3: Regression results of dummy variable estimations: Peruvians vs. migrants

Coefficient	**(1)**	**(2)**
Constant	163.44***	164.71***
	(1091.07)	(558.23)
Colombia	1.74	1.82
	(1.46)	(1.54)
Italy	3.02***	3.13***
	(4.64)	(4.8)
Spain	2.80***	2.84***
	(2.42)	(2.46)
Chile	0.78	0.85
	(1.31)	(1.42)
Ecuador	-0.11	0.07
	(-0.18)	(0.11)
Birth decade 1840	-	-1.99***
		(-5.18)
Birth decade 1850	-	-1.54***
		(-3.92)
Birth decade 1860	-	-1.47***
		(-2.94)
Birth decade 1870	-	-1.13
		(-1.58)
Birth decade 1880	-	-1.25***
		(-2.16)
Observations	2859	2859
Adj. R^2	0.0086	0.016

Notes: ***/**/* implies statistical significance at the 1, 5, and 10 percent levels, respectively. T-values in parentheses. The constant refers to Peruvians born during the 1830s.

Table 6.4: Occupational classification using a simplified Armstrong scheme

Unskilled			
Butcher	Baker	Cook	Day-laborer
Gardener	Launderer	Loader	Mariner
Muleteer	Peasant	Servant	Tailor
Wagoner	Worker		
Farmer			
Agriculturist	Cattle owner	Cultivator	Farmer
Skilled			
Blacksmith	Bookbinder	Cabinet maker	Carpenter
Caretaker	Clerk	Confectioner	Delivery man
Enlistee	Hatter	Mason	Mechanic
Merchant	Painter	Plumber	Printer
Saddler	Silver smith		
Professionals			
Doctor	Engineer	Entrepreneur	Industrial
Journalist	Lawyer	Professor	Proprietor
School teacher	Student	Veterinarian	

6.9.2 Figures

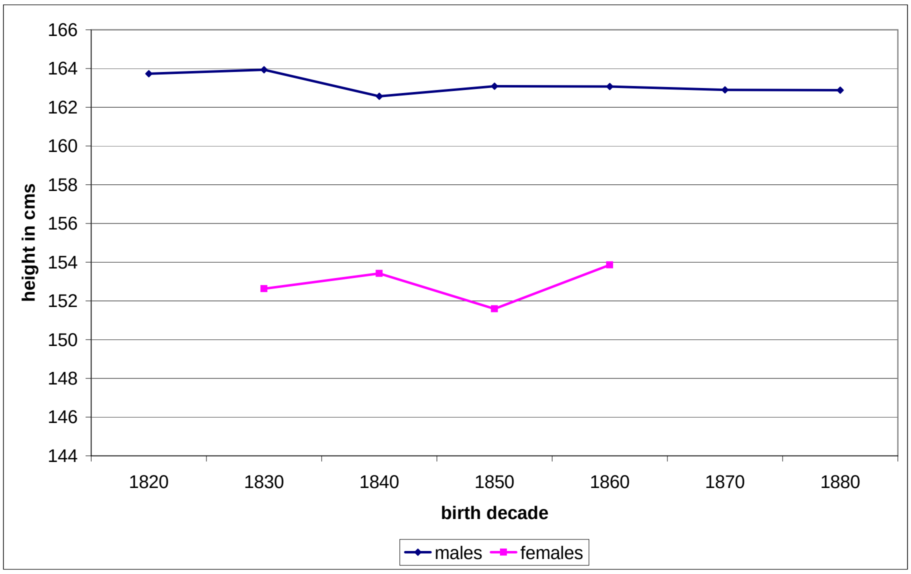

Figure 6.1: Secular height trend in Peru, weighted by share of ethnicity (1820-1880)

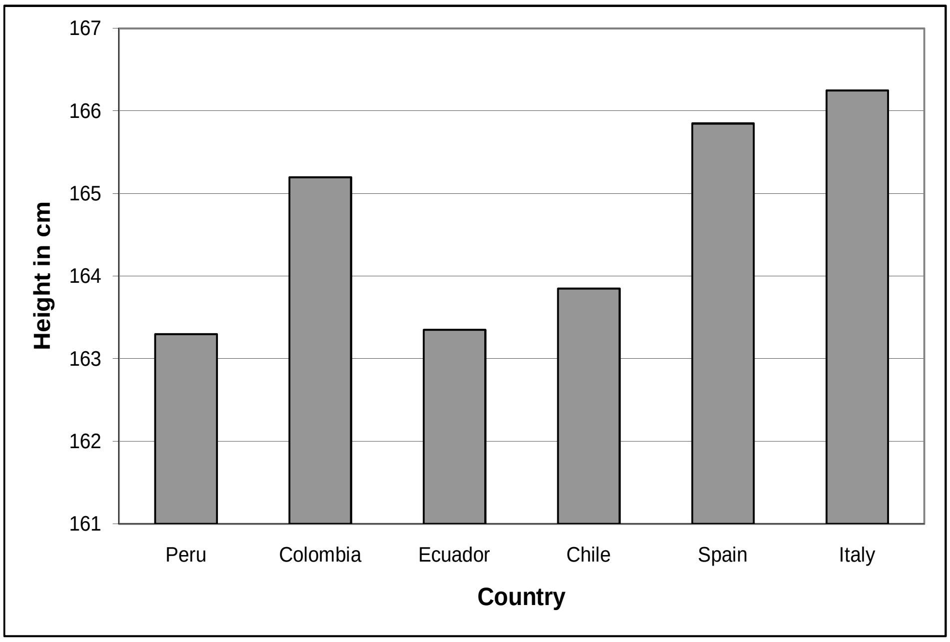

Figure 6.2: Peruvian heights in international comparison, average through all birth decades (1820-1880)

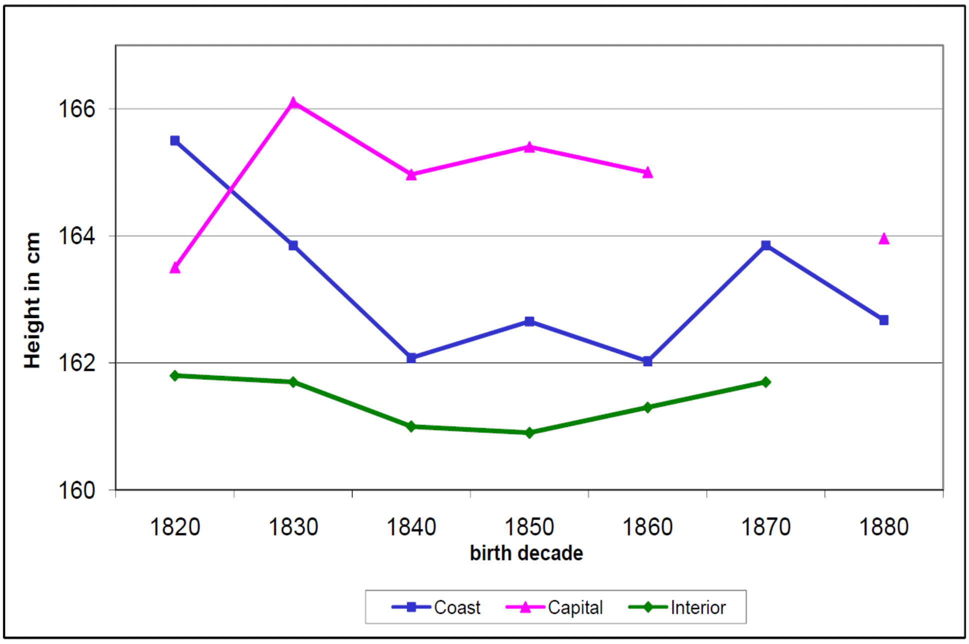

Figure 6.3: Regional development of mean adult height in Peru (1820-1880)

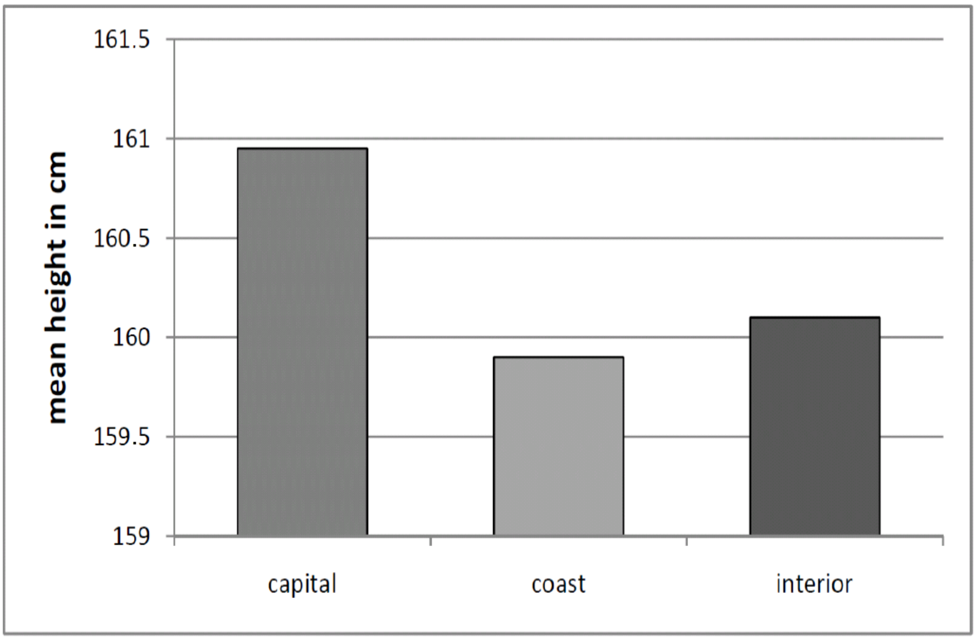

Figure 6.4: Regional mean heights of indios, average through all birth decades (1820-1880)

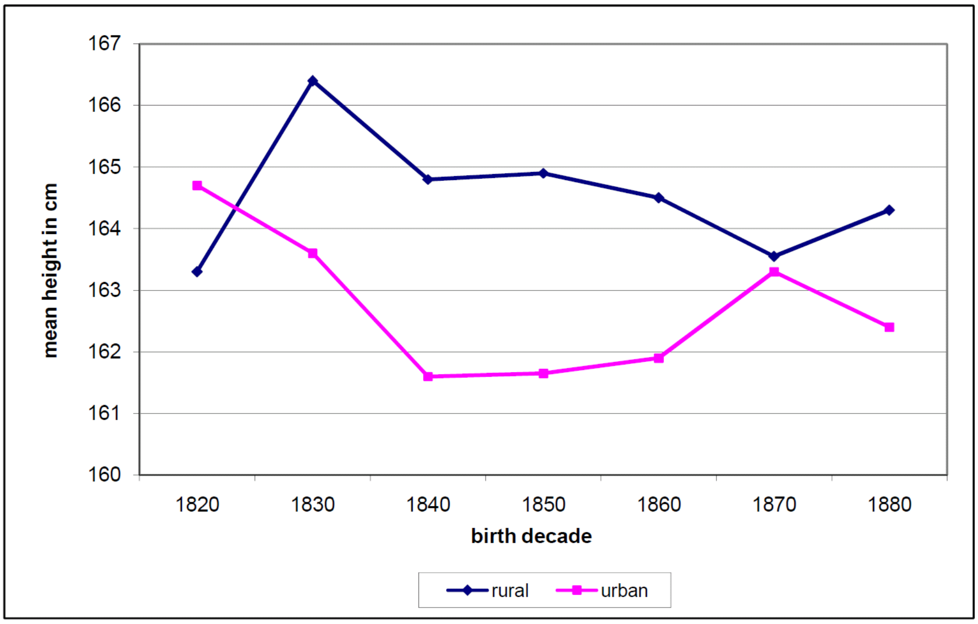

Figure 6.5: Development of mean adult height in urban and rural areas (1820-1880)

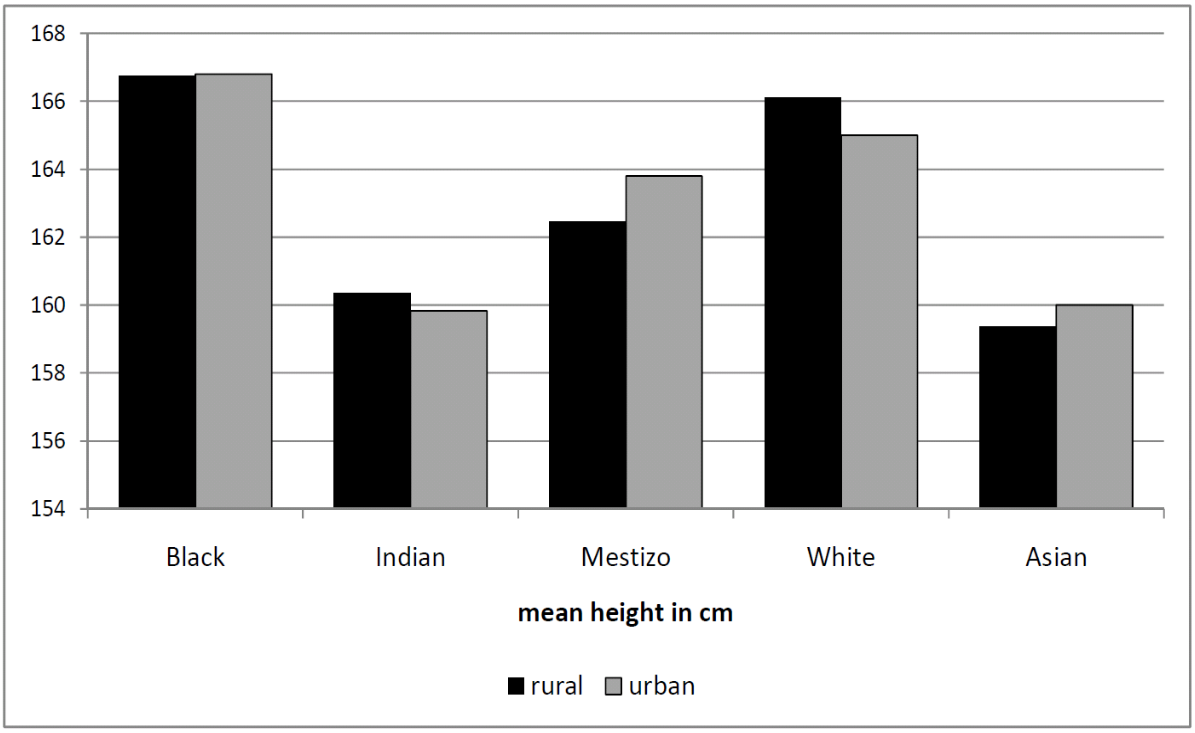

Figure 6.6: Urban and rural mean heights by ethnicity, average through all birth decades (1820-1880)

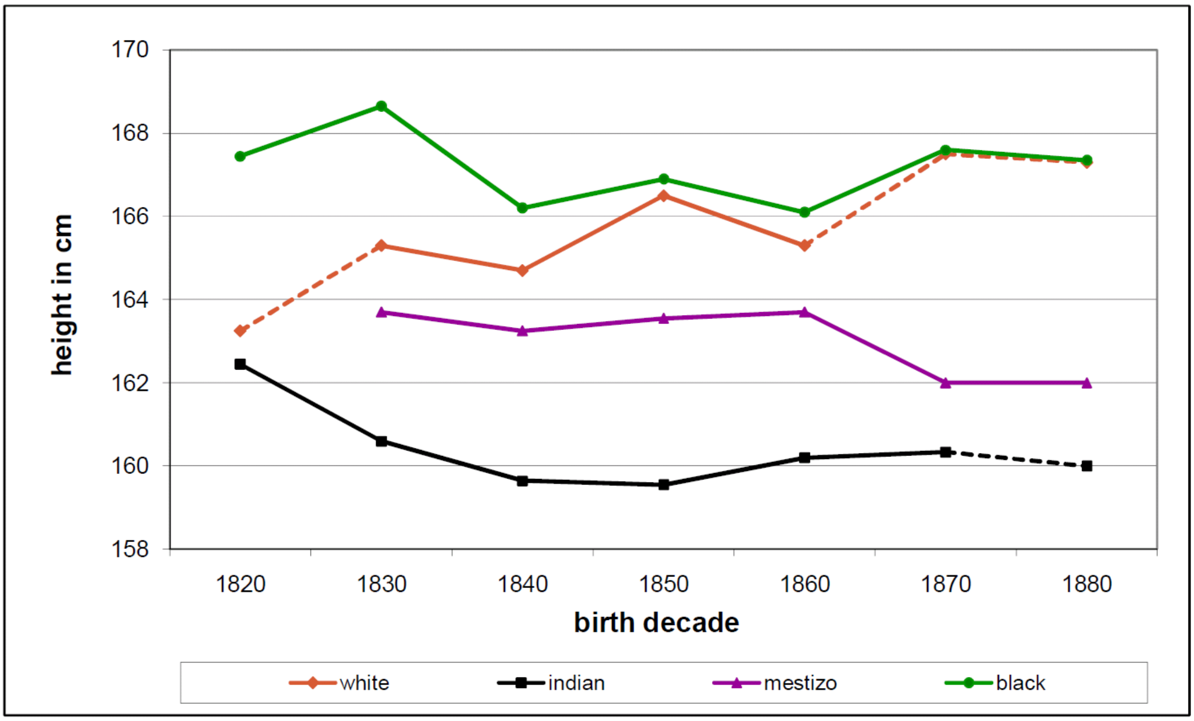

Figure 6.7: Development of mean adult height by ethnicity (1820-1880)

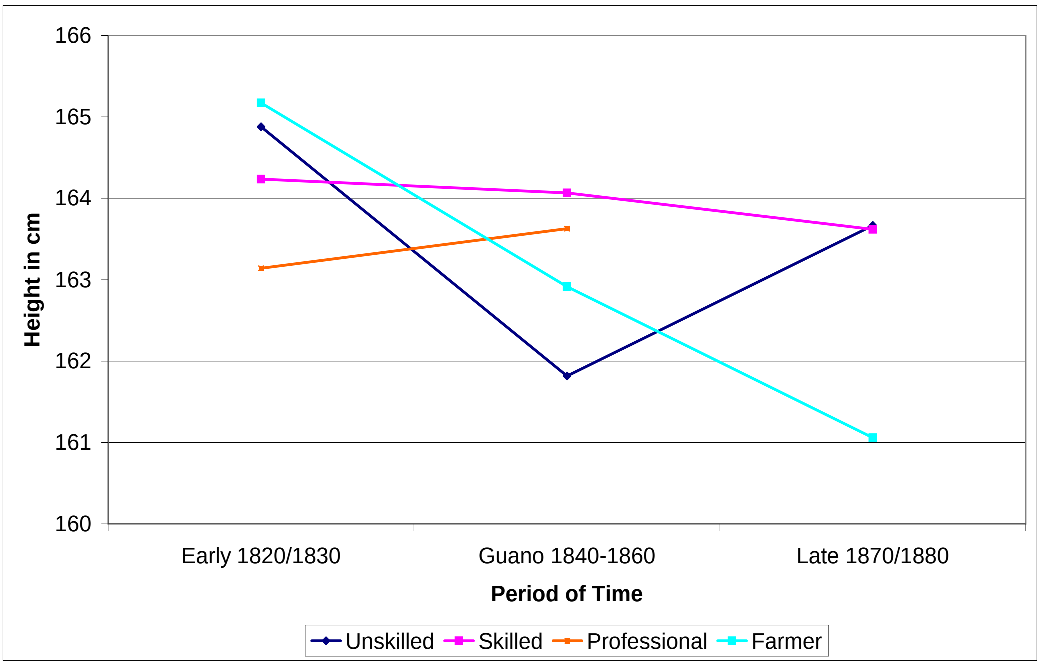

Figure 6.8: Development of mean adult height by occupational group

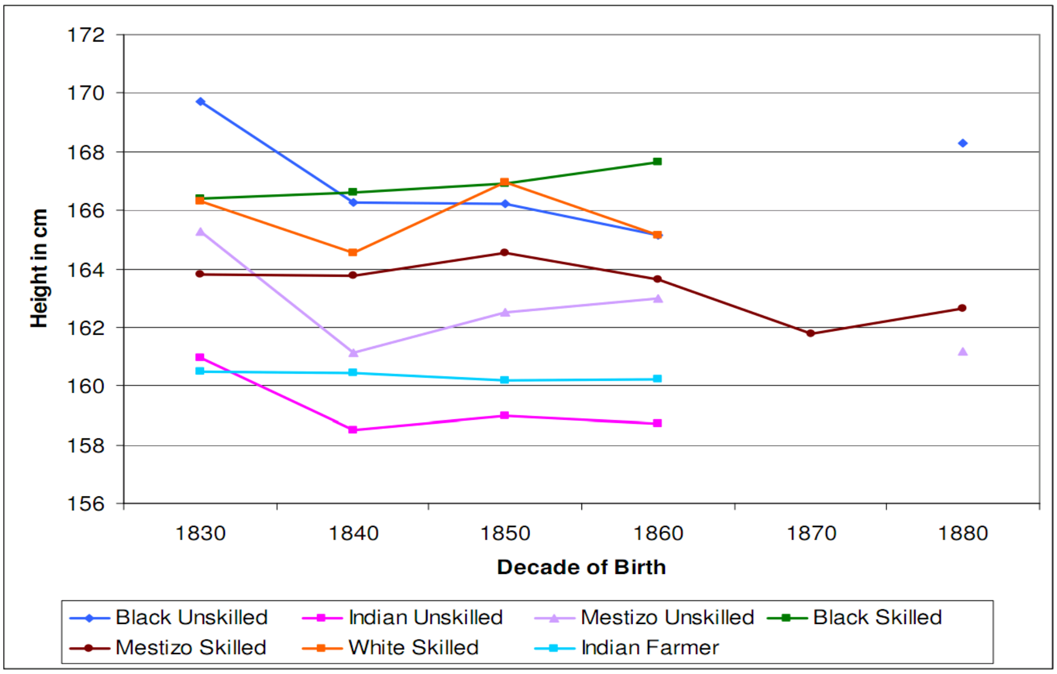

Figure 6.9: Development of mean adult height by ethnicity and occupational group (1830-1880)

7 Summary and Directions for Future Research

Human capital is undoubtedly one of the decisive factors when assessing the socioeconomic development of nations. As early as in 400 B.C. Plato emphasized the importance of education. Since then, many scholars have focused on the development and effects of human capital. Regional disparities in human capital accumulation may be an obstacle to the socioeconomic development of a whole country. Thus, in today's world, politicans are concerned with closing the gap in human capital disparities between regions or countries. Following this strategy, the United Nations millenium development goals aim at a perfect coverage of primary education.

Age heaping as an additional indicator for human capital enables us to study regions and time periods for which conventional data is scarce. New data can help answer questions which have remained unclear until now, like the question whether human capital is a source or a consequence(or both) of economic growth. But even if we do not take into account the possible influence of human capital on economic growth, education has positive externalities and can also be seen as an important aim itself.

The age heaping methodology is a powerful tool to measure basic education. It can be seen as an additional proxy variable to measure education. Age heaping further enables us to study detailed education trends for different population segments or regional units within a country. Conventional human capital proxies often do not allow such a detailed analysis.

To give an overview of the educational development in Latin America since Colonial times, chapter 3 scrutinizes the long-term development of human capital in six important Latin American countries. Data on Brazil, Mexico, Argentina, Uruguay, Colombia, and Peru shows that the Latin American countries had substantially lower numeracy values than the United States, but were on the way to catch up during the 17 th and 18 th century. Around the time of independence, however, progress in numeracy stagnated. The turbulent time of Independence and the following political instability of the new republics probably impeded rapid progress in education. However, more data for the 19 th century would be convenient to investigate the reasons in detail. The first evidence suggests numeracy development stagnated during the time of Independence and that differences between Latin American countries began to emerge in the late 19 th century. European immigration to the Southern Cone countries is likely to be the main factor for the exceptional rapid numeracy progress in Argentina and Uruguay. Mexico and Colombia, in contrast, showed only slow progress. The chapter gives first hints how Latin American education developed during three hundred years. Further studies may extend the database with new country data or with further disaggregated data.

Educational inequality is an important topic in Latin America. In Brazil, for example, free university education is provided at universities with an excellent reputation, but almost exclusively students that finished private secondary education pass the entry exams. Therefore, social inequality in education is seen as an important factor that impedes a reduction in income inequality. Gender inequality in education, addressed in Chapter 4, seems to be of minor concern in the case of Latin America and the Caribbean. Not only today, but already during the 19th and early 20 th century, gender disparities is numeracy have been small. In general, the Hispanic Caribbean had higher levels of gender inequality than the Latin American countries and the non-Hispanic Caribbean. The latter presents exceptionally low levels of gender inequality or even female numeracy advantages. In the non-Hispanic Caribbean, race, color, and class distinctions had always been more important than gender distinctions. In the institutional framework of a society based on slavery, Caribbean women were used to work outside the home and often were the only breadwinner of the family. Even in Haïti, the poorest and least numerate country of the region, there is no evidence for gender inequality in numeracy.

In the Latin American countries, those with low levels of numeracy tend to have lower gender equality, which shows that educational progresses first benefit boys. As the level of education of the whole population increases, females benefit from education expansion. If female labor market prospects increase, parents tend to invest more in girls' education, and if labor market prospects become worse, investment in girls' education is reduced again. We find evidence for such a U-shaped development of gender equality relative to general numeracy. Investment in femal education may have declined in the first phase of development studied, but the decline turned out to be modest empirically. In contrast, an increase in gender equality (i.e., the upward sloping part of the U-shape) during the period under study can be confirmed.

Human capital development in a historical perspective is not only sensitive to educational spending, but also to economic crises. Development economists have already emphasized the importance of declines in educational attainment during economic crises. Chapter 5 deals with the impact of the subsistence crises in the 1840s and 1850s Spain and presents empirical evidence that even a short crisis period of only two years may lead to stagnating numeracy levels. We find that the interior and the coastal provinces followed different paths during the subsistence crises in 1846/47 and 1856/57. While the subsistence crisis in the 1840s hit predominantly the coastal provinces of the peninsula, which were unable to import wheat from overseas during the 'hungry fourties', the crisis in the 1850s affected mainly the major wheat producing interior due to the difficulties of transporting imported wheat from abroad to the interior. This suggest significantly low market integration and high transportation costs. In both cases, these crises are reflected in slightly declining or stagnating numeracy levels.

The last chapter of the thesis analyzes the biological standard of living in 19th century Peru. It shows that living standards for the middle and lower social strata of the society stagnated during a period of economic prosperity. These classes seem not to have benefitted from the resource wealth of their country because the Peruvian state was not able to put the economy on a solid basis. Rather the economic elite of the country was concerned with extracting as much rent from the guano revenue as possible. Comparing this outcome with other Latin American countries, we find a similar pattern that was detected in Argentina where the export-led growth of the country was accompanied by stagnation in heights at the end of the 19th century. Regional disparities in Peru have been surprisingly small as long as we controlled for the different ethnic composition. Ethnic differences that mainly indicate social hierarchies, in contrast, were considerable. Growing inequality between Indians and whites may have slowed down improvements in living standards.