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**"Numeracy, Inequality, Age Heaping, and Economic Growth: New Estimation
Strategies for Western Europe and the U.S. (17th - 19th centuries)"**

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Abstract

This article uses a combination of the age heaping method and anthropometric measures to explore the pre- and early industrial inequality of numeracy. For France and the U.S., the differential numeracy between the upper and lower segments of a sample population of 27 and 22 regions, respectively, is measured and the subsequent impact of inequality on welfare growth examined. For Ireland and England, 18th and 19th century evidence indicates that Ireland was a much more unequal society than England, whereas the northern U.S. had a relatively egalitarian distribution of numeracy before industrialisation took off on a large scale.

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Recent studies on the Industrial Revolution have argued that a relatively modest initial inequality in England might have been an influential factor in creating a modern market for consumer goods (and, perhaps, the motivation for an 'Industrious Revolution').¹ This article tests the hypothesis that an unequal distribution of human capital considerably reduces welfare growth, notwithstanding the fact measuring inequality before and during the Industrial Revolution period is very difficult. The second contribution of this article is therefore to develop a new technique for measuring human capital inequality. This technique incorporates a set of methods which were mainly developed to investigate the phenomenon of "age heaping" - the tendency of poorly educated people to round their age erroneously, or because of missing number discipline.² For example, more often than better educated people, individuals from a lower social background might indicate their age as "40" when in fact they are 39 or 41.³

In a related study, we have found that the relationship between illiteracy and age heaping for Less Developed Countries (LDCs) is rather close after 1950.⁴ Age heaping and illiteracy figures for no less than 270,000 individuals, classed by 416 regions extending from Latin America to Oceania, produce a correlation coefficient as high as 0.63, even if only the age bracket of 23-42 year-olds is taken into account. When we compared them to the PISA results for numerical skills, these data yield a correlation coefficient of even 0.85.⁵

¹ Murphy, Shleifer, and Vishny, 'Industrialization.'

² Mokyr, 'Ireland.'

³ Even if the precise birthday is known to the individual, it might well be she does not know the exact number of years since birth. The number of years means less to an individual than the birthday, as the latter is often celebrated.

⁴ Crayen, 'Age Heaping;' A'Hearn, Baten, Crayen, 'Microfoundations of Age Heaping.'

⁵ see also the working paper on U.S. census manuscripts and other sources by A'Hearn, Baten, Crayen, 'Microfoundations of Age Heaping,' Brazil excluded. See this working paper on the estimation details and data quality issues.

The crucial advantage of age heaping methods is that data are widely available for the early modern period, since people were asked for their age in a more or less standardized way when entering the military, getting married, etc. Even women who were accused of witchcraft in court were asked for their age, so a forthcoming project of us will be to analyze the human capital of “witches.” In addition, age accuracy reflects numerical skills even more than literacy skills, and numeracy could be particularly important for technical, commercial and craftsman’s occupations. In this study, age heaping methods are applied to a sample of countries for which data are available. The quality of the data was carefully assessed by scrutinizing the relevant institutional frameworks and selection processes, as far as those could be reconstructed.

The first sample used is based on a data set of the French army, originally collected by John Komlos and his French collaborators. This data set is large enough to reconstruct numeracy even for relatively small regions of France since the late 17th century. Maps of French numeracy for several periods are presented below, which allow conclusions as to the regional inequality of human capital formation. From the degree of heaping and some anecdotal evidence, we can be sure that soldiers were in effect asked for their age directly (no birth certificates were demanded, and no comparisons with other sources were made by the registrars). One advantage of this data set is the inclusion of anthropometric variables, which allows the assessment of the relationship between net nutritional status and numeracy. Other interesting sources come from the registration of convicts in the United Kingdom, and the Civil War armies of the United States.

Moreover, different criteria are used here to assess inequality: inequality between taller and shorter individuals (reflecting their nutritional status and social stratification) is measured, along with differences between occupations which are generally associated with middle/upper versus lower social status. A particularly interesting side-result here is that height serves as a good predictor of numeracy for all four countries under study: the taller half of the height

distribution shows a much lower tendency towards age heaping, hence higher numeracy. In addition, the extent of the difference varies by country and region.

This article begins with a review of the literature on the inequality - growth relationship, both for income inequality in general, and the inequality of human capital in particular. In the third section of the article, a new measure is presented which can be applied to numeracy inequality for the period before and during the Industrial Revolution. In section 4, this measure is then applied to 27 French provinces, yielding for the first time estimates of the inequality of human capital in the 17th and 18th centuries. The change is furthermore mapped over time. Lastly, a modified version of the measure is applied to 22 U.S. states in the early and later 19th century. Section 5 examines whether a negative impact of human capital inequality on welfare growth can be observed in French regions. As a proxy for welfare growth, height growth between the 17th century (1650-1709) and the late 19th century is used. Finally, we test whether numeracy inequality in the United States, measured for birth cohorts before 1840, had a significant impact on economic growth between 1860 and 1880.

Section 2: Views of the literature on inequality and growth

Inequality and Growth

The new growth theory, pioneered by Romer, Lucas, Barro, and Barro and Sala-i-Martin has aimed at explaining long-term growth *within* the framework of its own models, rather than by exogenous variables like unexplained technological progress.⁶ Moreover, new growth economics has strongly emphasized the role of human capital formation and its persistence in nations over time. During the last decade, many scholars have extended this endogenous growth theory to incorporate distributional aspects of income as well.

⁶ Romer, 'Long-Run Growth;' Lucas, 'Economic Development;' Barro, 'Inequality and Growth;' Barro and Sala-i-Martin, 'Economic Growth.'

This approach differs somewhat from earlier studies on the inequality phenomenon, which rather tended to view inequality as the variable to be explained. Most prominently, Simon Kuznets, in analyzing the effect of economic growth on income inequality, postulated the famous hypothesis of an ‘inverted U’ relationship between income and inequality, according to which the degree of inequality first increases and then decreases with economic growth.⁷

During the 1990s, a fairly large body of literature has sought to test Kuznets’ hypothesis of an inverted U relationship, although the results have been ambiguous.⁸ Deininger and Squire have pointed out that most empirical work on this topic used cross-country instead of longitudinal data to test an intertemporal relationship.⁹ According to them, the inverted U shape tends to vanish if regional dummies are included. Oshima has argued that the transformation of technology over the centuries has had an impact on the time-variant relationship between inequality and economic growth.¹⁰ According to this view, technology in the late 19th century, such as the steam engine, was characterized by large indivisibilities in production: large factories were necessary to achieve sufficient economies of scale. In effect, all but the richest segments of society were thus prevented from accumulating capital, while a large contingent of unskilled workers was required. Industrialisation therefore came at the cost of growing inequality over time. By contrast, it can be argued that the link between growth and inequality may not turn out equally significant for recent times, since current technology is much more divisible and improved capital markets enable a much larger share of the population to make profitable investments. Barro has pointed out that recent empirical work has potentially failed to confirm the Kuznets curve as, according to these more recent

⁷ Kuznets, ‘Income Inequality.’

⁸ see, for example, Bourguignon and Morrison, ‘Income Distribution;’ Bourguignon, ‘Growth and Distribution;’ Milanovic, ‘Transition Economies;’ Polak and Williamson, ‘Poverty and Industrialization.’

⁹ Deininger and Squire, ‘New Ways.’

¹⁰ Oshima, ‘Technological Transformation.’

approaches, inequality would depend on the time past since a new technological innovation was introduced into an economy, and not on per capita GDP.¹¹

Beside this literature on the determinants of inequality, a new body of research has studied the effects of the distribution of income, i.e. the opposite direction of causality. This was triggered by the contrast between relatively low levels of inequality on the one hand, and high growth rates on the other hand in Asian countries, at a time when many Latin American economies displayed higher inequality and much lower growth rates. Research in this regard can be roughly grouped according to the specific channels through which inequality is assumed to affect growth. The next section presents the main strands of this literature, highlighting only a small portion of the vast literature existing.

1. Credit Market Imperfections

Deininger and Squire have demonstrated that an unequal initial distribution of land is significantly associated with lower subsequent growth, arguing that credit rationing in the presence of indivisible investment (like formal education) prevents asset-poor people from making economically profitable investments in physical and human capital.¹² Combining credit market constraints and the indivisibility of investments in human capital with intergenerational mobility, Galor and Zeira have shown that growth is negatively affected by an unequal distribution of wealth, both in the short and in the long run.¹³ However, more recently, Barro has argued that an offsetting force arises through credit market imperfections if investments require setup costs,¹⁴ which implies that investments in human or physical capital may be most useful when carried out beyond some minimal level. If these kinds of setup costs are large in relation to median income, this element might in fact generate a positive effect of inequality on economic growth.

¹¹ Barro, 'Inequality and Growth.'

¹² Deininger and Squire, 'New Ways.'

¹³ Galor and Zeira, 'Macroeconomics.'

¹⁴ Barro, 'Inequality and Growth.'

2. Political Channels

Other scholars have focused on the effect of income or wealth inequality through political channels, the idea being that by lowering the income of the median voter relative to the national average, the ensuing greater inequality would increase the pressure for redistribution and thus imply a higher tax rate. This, in turn, is supposed to reduce incentives for productive investment by inducing economic distortions.¹⁵ Persson and Tabellini have provided empirical evidence that equity is positively correlated not only with the level of income, but also with the rate of economic growth.¹⁶ In their simplified generation-overlapping two-period model, taxation has a negative influence on investment in human capital.

Barro has argued that even if no redistribution takes place, higher inequality implies higher costs for the rich to prevent redistribution,¹⁷ since lobbying activities consume resources and promote official corruption while tending to hamper economic performance. Therefore, inequality can have a negative effect on growth through the channel of politics, even if no income redistribution takes place in equilibrium.

3. Social Unrest

This branch of theory is based on the idea that sociopolitical conflict reduces the security of property rights, thereby discouraging the accumulation of capital. Perotti has found that sociopolitical instability is enhanced by higher inequality, which then hampers economic development.¹⁸ In particular, when the gap between rich and poor widens, the latter are presumably more tempted to engage in rent-seeking or predatory activities at the expense of

¹⁵ Alesina and Rodrik, 'Distributive Politics.'

¹⁶ Persson and Tabellini, 'Growth.'

¹⁷ Barro, 'Inequality and Growth.'

¹⁸ Perotti, 'Democracy.'

the former, which negatively affects growth.¹⁹ Moreover, as Barro has argued, crime and riots deter investment and reduce the productivity of an economy.²⁰

4. *Saving Rates and Demand*

Keynes was the first to stress the effect of income distribution on aggregate demand and saving rates.²¹ According to his *General Theory*, individual saving rates rise with the level of income. If this were so, a redistribution of resources from the rich to the poor would tend to lower the aggregate rate of saving in an economy.²² Via this channel, rising inequality would then tend to raise investment. However, this effect arises only if an economy is partly closed, so that domestic investment depends, to some extent, on national saving.

Another level-dependent effect of income distribution arises in the theory formalized by Murphy, Shleifer and Vishny.²³ The authors condition industrialisation on the existence of a 'leading sector' such as the main export sector or the agricultural sector which creates a sufficiently large demand for manufacturing goods, as well as on a sufficiently equal distribution of income. They argue that the inequality of income between the upper class and the rest adversely affects the home demand of the middle class, whose members are considered the 'natural consumers of manufactured goods.' Hence, inequality would reduce the potential for industrialisation, assuming that industrialisation requires a sufficiently large domestic market to make sophisticated technologies profitable. However, this argument only applies to small economies, since very populous economies might have a large enough middle class to fuel demand for manufactured goods, in spite of high inequality.

5. *Human Capital Inequality*

¹⁹ Benabou, 'Inequality.'

²⁰ Barro, 'Inequality and Growth.'

²¹ Keynes, 'General Theory.'

²² see also prominently Gerschenkron, 'Economic Backwardness.'

²³ Murphy, Shleifer and Vishny, 'Industrialization.'

Only very recently, research has begun to focus not only on the inequality of wealth or income, but also explicitly on the inequality of human capital. Loury has developed an overlapping two-generations model: individuals have varying abilities, which are also not perfectly correlated with parental investment capabilities into children's human capital.²⁴ Hence, in this model, income inequality affects the inequality of human capital through decreasing returns to human capital investment at the individual level – after all, richer people are not able to increase their human capital as much with higher income. Redistribution would therefore lead to higher human capital investment among poor people and increased aggregate human capital investment. Benabou's model implies that economic segregation leads to a persistent inequality of income and education, which again leads to lower growth rates.²⁵ Checci has analyzed the relationship between educational achievements and income inequality, using education Gini coefficients.²⁶ She considered a situation in which the initial level of education is low and the average educational attainment rises rapidly.

Thomas, Wang, and Fan have focused on the effect of development on the inequality of education.²⁷ Providing a unique data base of educational Gini indices covering 85 countries for the second half of the 20th century, they find strong evidence for the existence of an education Kuznets curve between countries over time. Lopez, Wang and Thomas have provided a theoretical background to the detrimental effects of the inequality of human capital on economic growth.²⁸ Since education and talents are bound to individuals and not tradable like most other goods, they assume that the marginal product of human capital across individuals is not generally equalized. Hence, aggregate production depends not only on the total level of human capital, but also on its distribution. The authors furthermore found empirical evidence that more unequal education tends to have a negative impact on per capita

²⁴ Loury, 'Distribution of Earnings.'

²⁵ Benabou, 'Equity and Efficiency.'

²⁶ Checci, 'Education Gini Coefficient.'

²⁷ Thomas, Wang, and Fan, 'Education Inequality.'

²⁸ Lopez, Wang and Thomas, 'Education Puzzle.'

income in most countries. These results also indicate that an equal distribution of human capital does not enhance growth by itself, but needs to be embedded in an adequate policy environment. Economic policies which suppress market forces tend to dramatically reduce the impact of human capital on economic growth. Below, we assess one political environment of liberal character (the U.S. in the 19th century), and the French interventionist policy environment of the 17th and 18th centuries.

As this literature review has shown, (a) there are recent theoretical approaches which focus directly on human capital inequality as a negative determinant of growth, but (b) there are many different channels through which income inequality could have a similar impact on growth. Given that inequality of income and inequality of human capital might be closely correlated, we must take such alternative interpretations into account when assessing their relationship in the subsequent parts of this analysis.

Empirical Doubts of the Inequality – Growth Relationship

The large majority of studies cited above has found more or less strong empirical evidence that inequality affects economic growth negatively. However, some recent empirical work has again challenged that belief. For instance, Barro has argued that inequality retards growth in poor countries, but fosters growth in richer areas.²⁹ One possible interpretation of his results involves the idea that credit-market constraints more seriously affect poorer countries. However, his data from a broad panel of countries reveal little overall relation between income inequality and rates of growth and investment.

Forbes has argued that most earlier studies on the inequality – growth relationship were prone to a bias induced not only by omitted variables like corruption and labour market characteristics, but also systematic measurement error.³⁰ Moreover, most negative coefficients turned insignificant after regional dummies were added to the regressions. In her study,

²⁹ Barro, 'Inequality and Growth.'

³⁰ Forbes, 'Reassessment.'

Forbes addresses all of the abovementioned issues, at least for the short and medium term. In a panel estimation, she finds a significant positive relationship between inequality and growth which proves highly robust. However, her data are not broad enough to assess the effects of inequality on long term growth. Furthermore, Forbes has pointed out that the positive impact of inequality on growth might be weakened or even reversed over time.

In summary, once advanced panel estimation techniques and high quality data are employed, the strong empirical evidence for a negative relationship between inequality and growth cannot be confirmed for modern economies. Therefore, new evidence is clearly of advantage, and the 17th to 19th century histories can potentially shed light on this important debate, provided that measures are found for the inequality of human capital (and income). For these early centuries, we would hypothesize that the negative effect of inequality on growth dominated, as the credit market was generally less developed than today. In consequence, individual investment depended more on individual savings, making it even harder for poor individuals to borrow money and make efficient investments.

Section 3: A new method to measure human capital inequality

The age heaping method is now arguably a well-established indicator of the numeracy of groups.³¹ Yet one problem remains: how can upper and lower group members of historical populations be distinguished from each other for which we possess no individual income data? Occupations have often been used to classify upper versus lower income group individuals since occupations such as “day-labourer” or “agricultural worker” typically yielded a low income, whereas professionals, noblemen, factory owners, and skilled craftsmen had higher incomes. However, in some occupational systems, there could be large variation of income even within a given occupation. The presumably most notable case in point is the “farmer,” whose income might have ranged from that of a large land-owner to a small peasant

³¹ Mokyr, ‘Ireland;’ Long, ‘Victorian Britain;’ A’Hearn, Baten, and Crayen, ‘Microfoundations of Age Heaping.’

(especially if occupation was self-reported, even the smallest cottager could at times go through as “farmer”). Moreover, much structural change occurred after the late 19th century when workers in large textile firms, for example, advanced to relatively high incomes, whereas farmers generally lost in relative terms.

This study proposes an alternative, but similarly rough proxy to distinguish social groups: human stature. More precisely, individuals above and below mean height are first contrasted, then human capital characteristics are aggregated by those two groups. Almost all anthropometric studies which considered occupational or income groupings have found that the well-off strata of society are taller as long as regional differences are held constant (such as proximity to protein production).³² A second very interesting aspect of this approach is that tall individuals are much less likely than short individuals to have suffered from infant protein deficiency syndrome (IPDS), which reduces learning abilities to some degree and could thus affect complex numerical abilities. One caveat to this method is clearly that height variation can have genetic reasons as well, which must be averaged out with sufficiently large samples. Secondly, as in all inequality studies, it needs to be taken into account which social strata are in fact covered by a given sample, since in many types of sources, the lower classes are over-represented. Hence, inequality might appear smaller than in samples with broader coverage. Lastly, concentration on the lowest income ranks within the lower class can occur in different intensities. Therefore, it is crucial to discuss the representativeness of each type of sample here.

In sum, we apply the age heaping method (our non-numeracy indicator) to the taller half and the shorter half of our sample populations. For an initial test, we intentionally use very different height and age heaping samples:

- (1) The *Wandsworth prison sample* collected by Deborah Oxley comprises more than 2,700 English criminals who were incarcerated in the Wandsworth prison in London. For our

³² Baten and Murray, ‘Bavaria.’

analysis, we considered individuals of 23 years or older, i.e. born between the 1800s and 1840s and representing about half of the sample. Clearly, middle and upper class individuals are underrepresented, as in most prison samples. While this is true for all four samples used in this section, one could imagine that the Wandsworth sample has a particularly strong concentration on a certain subset of British society. However, as Oxley has demonstrated, British prison samples of this kind represent the lower classes in a relatively complex way.³³ Note also that the working class accounted for a large share of British society anyways, whereas the middle class was much smaller than today and the upper class was diminutive.

(2) A closely related sample, the *New South Wales (NSW) convict data*, allows us to gain some insight into inequality within the Irish lower class as well. The British strategy to deport convicts to Australia produced a comprehensive and large source of height and age statements. Fortunately, this data set reports inmates' country of birth, listing more than 2,000 convicts aged 23 and older from Ireland. We find that the taller half of the Irish population reported their age with much higher accuracy than the shorter half, which is indicative of higher numerical human capital (Table 1). Interestingly, short and tall English convicts in Wandsworth and tall Irishmen sent to Australia had similar values of age heaping, although short Irish convicts displayed clearly a much stronger age heaping pattern. Social selectivity in this sample of transported criminals might have been similar to that in the Wandsworth prison sample, although perhaps with a slightly lower concentration on the lower classes.

(3) For the U.S., we compare nearly 15,000 soldiers from the *Union army data* set collected by Fogel and collaborators. Immigrants are excluded, as their height and numeracy might have been determined in their countries of origin before they migrated. In general, age heaping is quite low among the northern United States population born between the 1800s and 1840s. Social selectivity was probably much lower than in the samples discussed above,

³³ Oxley, 'Smallpox.'

hence the finding that inequality was lower in the northern U.S. than in Ireland seems credible.

(4) Finally, we analyze a very large sample of *French army soldiers* created by Komlos and cooperators.³⁴ Judging from his description of recruitment practices, this sample has a medium bias towards the lower classes, ranging between that of the U.S. army and the prison samples. Analysing more than 20,000 recruits,³⁵ we find that short soldiers from the Southwest showed very strong heaping (low numeracy) patterns, whereas little heaping is reported for tall Frenchmen from the North. In addition, inequality was higher in the province of Ile de France (Paris) than in any other sample.

The key result from all samples is that the taller halves of the survey populations had always lower or equal heaping values, whereas numeracy tended to be lowest among the shorter population halves. The variety of institutional backgrounds underlying our samples further indicates that our method might yield interesting results for an even larger number of comparable samples as well. Moreover, it is interesting to note that great inequality of numerical human capital can be observed for Ireland, which developed poorly in the later 19th century industrialisation waves. Southern and western France had also high inequality of numeracy (and poor industrial development later on). In contrast, the more protein-rich northeastern France was characterised by only modest inequality. In England and the northern United States, age heaping and the inequality of numeracy were much lower than in France and Ireland. If the low inequality – growth relationship postulated by recent theoretical models held true, it would have to be deduced from our data that the earliest industrial development occurred in England, the northern U.S. and the Northeast of France – which is precisely where it took place in reality as well. Paris is somewhat of an outlier to this relationship, yet maybe its positive development in spite of high inequality was stimulated by proximity to the central government. We take a much more disaggregated view at France and

³⁴ described in detail in Komlos, 'Earlymodern France.'

³⁵ Individuals younger than 23 years or of unknown province are excluded.

the United States below. There might also be measurement error due to the different institutional backgrounds of the samples: while the U.S. soldier sample can be regarded as quite comprehensive, the low inequality within the British Wandsworth sample might be partially caused by the relatively small spectrum of society incarcerated in this London prison.

Section 4: Regional patterns of inequality in France and the U.S.

Is a numeracy differential between the taller and shorter halves of the population even observable on a low regional level? This issue is now examined on the basis of French provinces in the late 17th and early 18th centuries, and for the 19th century U.S. States.

Especially French regional numeracy in the early modern period has been a white area on the map so far, hence this data will be reported in somewhat greater detail.

France

We continue to use the French sample created by Komlos and his collaborators, now focusing on a regional level and making sure that our regional units contain sufficient observations to calculate differential numeracy values for the lower and upper halves. Some French provinces of the *ancien régime* were rather small and provided only small numbers of soldiers, hence they are aggregated with neighbouring provinces for this analysis. The number of French regions is thus reduced from 36 to 27 in order to obtain more similar unit sizes. Since the merged provinces are either conglomerates of very small provinces adjacent to a large neighbouring province, or two small provinces next to each other, we consider the loss of information small. Aggregation is necessary not only spatially but also over time, i.e. birth decades. The resulting 50-year birth cohorts comprise about 200-1300 soldiers each, which leads to reasonably good estimation results with the age heaping method.

From Figure 1, it can be inferred how human capital, measured in terms of numeracy, was distributed across French Provinces in the 17th century. The darker shaded an area, the

lower its level of numeracy (i.e. a higher Whipple index of “non-numeracy”). The highest level of numeracy is found for a belt stretching from Normandy southeastward to Burgundy, as well as for the southern provinces of Languedoc and Guyenne. The latter’s high level of numeracy stands in sharp contrast to the low numeracy level of their neighbouring provinces between Poitou/Aunis and Auvergne. In order to check whether our levels of non-numeracy are in concurrence with existing literacy estimates, we use Furet and Ozouf (1977) data on the level of literacy by department, 1686-1690, finding a significant negative correlation (corr. coeff. -0.28, $p=0.02$), as expected.

In order to assess not only the level of numeracy but also its inequality, we apply the technique described in section 3. Thus, birth cohorts are grouped into tall and short soldiers, measuring their relative height on the provincial level. A recruit is considered tall if his body height is above the mean height of the province where he registered. We then divide the resulting “non-numeracy” of the shorter half by that of the upper half, so that a value of 1.5 signifies a 50% stronger heaping behaviour among the shorter vis-à-vis the taller half, whereas a value of 1.0 or lower indicates little difference (=low numeracy inequality). A value below 1.0 might be expected for regions that required little skills for cattle farming, for instance, and hence had non-market access to protein (in Franche-Comté or the Basque mountains, for example). Estimates of the inequality of numeracy in 17th and 18th century France are presented in Table 2. In general, most provinces display the expected numeracy advantage of the taller over the shorter half (i.e., inequality values above 1). Only four provinces in the early period and three in the later period have values below 1 (i.e. a numeracy advantage of the shorter segment).

Comparing levels of inequality between periods, we find that a larger number of provinces experienced high inequality in the late 17th century, compared with the early 18th century. In 14 out of 27 provinces, inequality declined, while it rose in 6 and remained about equal in 7 provinces (less than 0.1 point change). The highest levels of inequality in the late

17th century were prevalent in North-Central France between Hainaut, Saintonge and Bourbonnais, i.e. the large regions around Paris encompassing much of the grain belt which produced surpluses for the urban development of Paris and the northern cities (Figure 2). Alsace had also high inequality, although this result could be somewhat exaggerated by the small sample size. In contrast, low inequality was prevalent around Franche-Comté in eastern France down to the French Alps, and in the southwestern area of Gascony/Bearn/Foix. It is quite interesting to note that these are all peripheral mountain regions, where income and education might not have been as strongly correlated as in the rest of France. Low inequality is also detected for Limousin and Marche, where both tall and short soldiers had exceptionally low levels of numeracy. In fact, both regions belong to the poorest regions of France today. Moreover, this area was characterized by a particularly adverse environment (swamps etc.), so that the height-education relationship might have been distorted by a heterogeneous disease environment.

Over the next fifty years, the inequality of human capital decreased in North-Central France (Figure 3). Please note that the scale of the map's legend was changed. Besides, inequality in central France, i.e. Auvergne, Limousin and Marche, increased somewhat in relative terms.

What factors determine the degree of numeracy inequality? Are more dynamic regions more equal? It seems that in late 17th century France, higher inequality of numeracy was more often apparent in urbanized, more densely populated regions which tended to industrialize more strongly in the subsequent period. This would not support the hypothesis of Lopez et al., who predicted that inequality hampers economic development.³⁶ Those regions were also relatively market-integrated and concentrated on wheat growing. We should also note that the relationship between the inequality of numeracy and industrialisation might depend to a certain extent on the overall level of numeracy, although we find only a low and negative

³⁶ Lopez, Thomas and Wang, 'Education Puzzle.'

correlation (correlation coefficient of -0.2) when taking both France and the U.S. into account. Rather high inequality within a region might signal only that it had a better educated elite than other provinces, which could in turn imply that inequality can affect economic development either positively or adversely. In summary, on the basis of the underlying data, it does appear as if the economically more dynamic regions of France were initially characterized by higher inequality. Since industrial development was strongest in the North and the Northeast, we cannot confirm Lopez et al.'s hypothesis for early industrial France that a high inequality of human capital adversely affects economic growth.³⁷ These are, however, only preliminary results from a descriptive analysis of numeracy inequality, without controlling for additional variables like the policy environment. The interaction of inequality and additional variables is therefore examined more comprehensively below.

United States

The following analysis is based on the very large U.S. census database provided by the Integrated Public Use Microdata Series (IPUMS) of the Minnesota Population Centre (MPC). Our data cover the decennial population censuses of 1850 - 1870 and 1900 (the censuses of 1880 and 1910 were discarded, since they were problematic for some states and nationalities, listing only ten-year age intervals.). Heights are not reported in this dataset, but the inequality of numeracy can be distinguished by occupational groups. The IPUMS team classified all occupations according to their income group around 1950, which is certainly not unproblematic for our purposes but can provide a first guideline for analysis. Individuals with occupations classified as zero income are omitted. The zero income group is very heterogeneous, including both individuals of typically high education (such as retired businessmen, gentlemen, and Ladies with inherited wealth) and persons with typically quite low education (e.g. unemployed people, slaves, or Native Americans living in reservations).

³⁷ Lopez, Thomas and Wang, 'Education Puzzle.'

Women are also omitted completely in this first step, since a very large share of them were housewives or at least reported as having no occupation (although they might have been involved in family businesses). We also exclude all immigrants from our analysis, since large shares migrated when they were already young adults. Therefore, migrants can be considered as having received their education by and large in their countries of origin, unless they migrated with their families as children. Family migration was wide-spread until the mid-19th century, when the single (or couple) migrant became a more frequent phenomenon.

In order to classify the population into two groups of different social status, we distinguish the upper half of the occupational hierarchy from the lower half. The upper half is led by physicians and other academics with an occupational score of 80 (income in hundreds of Dollars in 1950). All occupations with an annual income of 21 (hundreds of Dollars) represent roughly the “top 40” percent of the population. The lower segments of those “top 40” typically include skilled workers (carpenters etc.). As a caveat, it must be noted that some groups with a relatively high income around 1950 had a much lower social and economic status in the 19th century (as was the case for workers in textile factories, for example). On the other hand, all farmers were classified by the IPUMS research team as belonging to the “bottom 60%” segment, which may or may not reflect conditions in the 19th century United States. Certainly, we must keep in mind that some farmers may well have been relatively wealthy and skilled. Having excluded all states for which either the upper or lower segment was based on less than 100 observations, we compute the Whipple Index for both social groups and the ratio of both index values (lower to upper class), which we then use to measure inequality. The ratio thus reflects the relationship between the lower and upper halves of the occupational scores, with a higher ratio indicating a larger inequality of numeracy.³⁸

³⁸ The question of endogeneity naturally arises: did they achieve a good position in the upper half of the occupational hierarchy because of their good numerical skills? Or was social mobility still relatively low, and hence most sons took over the occupations of their parents? Probably both patterns existed. However, for our purposes, the question is not as relevant, since we simply intend to measure the numeracy differential between the more and less successful halves of the population within as many States as possible.

We start out with the hypothesis that the highest inequality of numeracy will be found for the southern plantation belt of the U.S., where a relatively small group of farmers benefited strongly from the export-oriented plantation system, whereas the majority of smaller farmers and other occupations had a much lower income and hence less financial means to invest in children's education. This pattern is indeed observable for those cohorts born before 1840 (i.e. before large-scale industrialisation started in the U.S., see Figure 4). States like Alabama, Louisiana, Georgia, and Mississippi clearly had the highest inequality of numeracy, resulting from a particularly low numeracy among individuals belonging to the lower 60 percent segment of the occupational hierarchy. Note that slaves are not included in this statistic, as they were coded in the "zero income" occupational group.

It is interesting that inequality was very low in the Northeast where economic growth was strongest, in contrast, because these differences would support the interpretation of Lopez et al. that lower inequality of human capital stimulates economic growth.³⁹ It is also reassuring that the low inequality among northeastern Americans grouped by occupation confirms the low inequality of the Union Army sample grouped by height, which further underlines the robustness of our results. We can therefore roughly summarize the situation before 1840 as follows: numeracy was low and unequally distributed in the South, while it was higher and rather equal in the North, especially the Northeast.

For the post-1840 birth cohorts, the economic environment of the U.S. changed dramatically. Large parts of the country became heavily industrialized and attracted workers from other parts of the world. Kuznets hypothesized that inequality rises in the first stages of industrial development, an effect which we would have expected to find for the newly emerging centres of industrial expansion. Moreover, the arrival of more and more immigrants at the East coast (who tended to be less skilled than previous pools of immigrants) might have increased inequality in the industrial centres, with lower-skilled Native Americans now

³⁹ Lopez, Thomas and Wang, 'Education Puzzle.'

having to compete with the new arrivals. We observe that the inequality of numeracy of industrial states such as Connecticut and New Jersey moved into the top ten of American inequality in this period (Figure 5). The higher inequality of northeastern states such as Connecticut, New Hampshire and New Jersey can be attributed to the lower numeracy levels of their lower classes. In contrast, inequality of numeracy declined significantly in all southern states except Louisiana after the plantation system ceased to have an inequality effect on the cohorts born after 1840. This is even more remarkable since freed African Americans, whom it would probably have taken some time to acquire numeracy skills, were now largely included in the statistics, hence their presence should have increased inequality. However, we find that the reduction of inequality in the South was not only due to slightly improved numeracy among the lower strata of society, but also to a decline in numeracy amongst the middle and upper classes. Thus, the upper classes of Alabama, Georgia, and South Carolina experienced a reduction of their average numeracy of 26, five, and nine percent, respectively.

In summary, the following conclusions can be drawn for the early period: inequality of numeracy was low in the Northeast, where industrialisation was in fact strongest later on. For the birth cohorts after 1840, industrialisation in the U.S. led to increased inequality in the centres of industrial development, which supports Kuznets' hypothesis. Moreover, it can be observed that the aftermath of the Civil War and the end of the Southern plantation system had egalitarian effects, not least since deskilling processes affected the Southern middle- and upper classes.

Section 5: Does inequality of numeracy influence welfare growth?

In today's world, the inequality of human capital has a strong negative influence on welfare growth, as the studies cited above have demonstrated.⁴⁰ However, compared with the pre-20th century period, present-day growth might be much more driven by human capital intensive

⁴⁰ Lopez, Thomas and Wang, 'Education Puzzle.'

processes that require schooling and numeracy from a large part of society. Gerschenkron has argued that income inequality might in fact have been more conducive to growth in the 19th century than it is now.⁴¹ Growth during the high time of the Industrial Revolution certainly depended strongly on physical capital formation: it mattered much more then whether financial investments could be undertaken, whereas in the late 20th century, the skills of the workforce can be assumed to have become a much stronger determinant. As to whether income inequality is correlated with human capital inequality, opposing views have been put forward for different centuries, but illuminative empirical tests are scarce for the later period and non-existent for the early period. Hence, it remains an open issue which theoretical concept applies best to the real world in the long run.

The French case: inequality of numeracy, or centralité?

We now want to test the effect of human capital inequality, and in particular the inequality of numeracy as measured in the previous section, on welfare change, for 17th and 18th century French regions. As a dependent variable, we use change in height, which proxies the biological standard of living.⁴² While alternative indicators such as industrial value added, real wages, income per capita, or life expectancy are unavailable for 17th century French regions, this proxy indicator has even some conceptual advantages for our purposes. One advantage vis-à-vis income is its being an outcome indicator, taking into account the health effects of public goods. As it has frequently been argued, the centers of economic development were unhealthy places, generating overall a much lower standard of living than unadjusted incomes would have suggested. Height, in contrast, reflects the amount of public goods spent on improving hygienic and health conditions, such as waste removal or the isolation of infectious disease carriers.

⁴¹ Gerschenkron, 'Economic Backwardness.'

⁴² Komlos, 'Earlymodern France.'

The increase of human stature between the 17th and the 19th centuries was quite different across French regions (Figures 7 and 8). In central regions such as Anjou, Ile de France (incl. Paris), and Poitou, heights increased substantially. In contrast, periphery regions did not improve much in comparison with the catastrophic height minimum of the 17th century: Provence/Venaissin, Languedoc/Roussillon, Dauphine, Gascony/Bearn/Foix, and Alsace were clearly losers relative to the average French development of heights, just as the Lyonnais and Lorraine. While this pattern seems quite obvious and reasonable against the background of French *centralité*, we are particularly interested in the potential additional effects of the interaction with numeracy inequality, as measured using our age heaping method. For example, the adverse provinciality effect could have been much more detrimental in unequal Alsace than in more egalitarian Gascony, if Lopez et al.'s view of human capital inequality effects held true.⁴³ A separate effect seems not very likely, as becomes apparent from Figure 9: Anjou, for example, is a clear counter-example in this regard.

Is Gerschenkron's positive or Lopez et al.'s negative view of inequality visible in the history of the regions of France? Or do the two approaches represent opposing forces which leave the empirical picture inconclusive because both are important? Finally, which other factors need to be taken into account? Two further variables assessed here are the initial level of numeracy and the initial level of height. The level of numeracy (or human capital in general) could be seen as an indicator of capability for growth, following Barro.⁴⁴ The level of initial height should control for convergence effects. When thinking of regional development in France, the centralist French political system immediately comes to mind. France has had a reputation for centralizing many important institutions and gathering decision-makers and the most talented people in Paris since at least the Napoleonic period. Only recently, i.e. during the last few decades of the 20th century, has an opposite movement been put in motion, reallocating some institutions back to the periphery. However, during the 19th century, Paris

⁴³ Lopez, Thomas and Wang, 'Education Puzzle.'

⁴⁴ Barro, 'Inequality and Growth.'

was a strong attractor of French elites and of taxes: public goods were centered disproportionately on Paris, financed in part by the provincial tax-payers. In the course of the 19th century, Paris was gradually transformed from an overcrowded and unhealthy Moloch into the cultural capital of the world. It is frequently the case – in other countries as well – that the capital region is favored in terms of spending on public goods. For today’s LDCs, for example, recent studies have argued that the government spends much more on the capital region in order to satisfy its nearby citizens, they posing a much more direct threat to government authority in times of crisis and unrest. In the French case, this could have meant that centralization was strongly reinforced by the French Revolution, which demonstrated what dissatisfied nearby citizens can do to the ruling classes.

In sum, it is clear that *centralité* and its potential interaction with the inequality of numeracy must be controlled for in our analysis. We measure *centralité* by distance to Paris, assigning nine different categories from Ile de France (coded as zero) to the Provence coded as eight (Corse, for which we reserved the tenth category, cannot be measured because of insufficient observations). We interact this distance variable with the inequality measures for the French provinces in the 17th (more precisely: birth cohorts 1650-1709) and 18th (1710-1759) centuries obtained above (Figure 6).

In a regression framework, we can control for the effects of distance/centralism while considering its interaction with the inequality of numeracy. In fact, this interaction term has a significant additional negative effect for the entire period from the 17th to 19th centuries. That is, the negative effect of distance to Paris on regional welfare is amplified once the inequality of numeracy rises. If we control for initial height and numeracy (column 2), the coefficients of the distance variable as well as those of the interaction term of distance and inequality are robust, the latter variable still being at the margin of statistical significance (p-value 0.11). In contrast, when regarded separately, both the level of numeracy and its inequality are insignificant. Moreover, some convergence effects in height are observable.

These results confirm our hypothesis that centralism in France was crucial to regional development. Possible explanations include selective migration to the capital as well as the central allocation of state funds, which left provinces at a far distance from Paris at a much worse provision of public goods than provinces located closer to the capital.

We are also curious whether the impact of centralism was stronger in the earlier period from the 17th and 18th centuries, or between the 18th and 19th centuries. We find that French centralité developed mainly in the later period: Louis XIV – despite his claims to be l'état himself – might have been innocent of this development. It is therefore not surprising that all coefficients for the change between the 17th and 18th centuries are insignificant. Rather, it was in the aftermath of the French Revolution and under another autocrat from the periphery of Corse that this development became visible and significant.

We measure the explanatory variable in column 4 with a separate inequality estimate for each 18th century province (whereas columns 1-3 referred to our 17th century estimates). Hence, we would argue that these results are robust, in spite of the obvious measurement error which should bias significance downwards (see also notes to Table 3). It must be pointed out that in the French case, only the interaction of inequality with distance to the government is significant, whereas inequality of numeracy alone had never any significant influence.

Did inequality of numeracy enhance or hamper growth in the U.S.?

We also want to test the theories put forward by Lopez et al. vs. Gerschenkron for the U.S. in a regression framework,⁴⁵ using our inequality measures for the United States obtained in section 4 of this paper as an explanatory variable. More specifically, the question is whether inequality of numeracy had any statistically significant effect on economic growth in the United States.⁴⁶ To address this issue, we use manufacturing samples from the manuscripts of

⁴⁵ See Lopez, Thomas and Wang, 'Education Puzzle;' Gerschenkron, 'Economic Backwardness.'

⁴⁶ Note that we solely consider inequality before 1840, and economic growth for the period of 1860-1880 only, while autocorrelation is quite low and insignificant. Thus, endogeneity is not a problem.

the decennial federal censuses of 1860 and 1880 collected by Attack, Bateman and Weiss.⁴⁷

The latter drew random samples of each state and territory, incorporating 7.000 and 10.000 firms, respectively, and covering 22 of the 25 states covered by our descriptive analysis above.⁴⁸

As a proxy for economic performance, we calculate the added value of individual firms (total value of output - total value of raw materials) in the manufacturing census samples and aggregate them at the state level. Since input and output values are reported in nominal Dollar amounts, we adjust for price changes using Attack, Bateman and Margo's price deflators.⁴⁹ The change over time (relative to 1860) of the state-specific deflated value added is classified as the dependent variable, in the following referred to as real growth. In general, the South was characterized by rather high inequality and low growth, while the North experienced higher growth rates and lower inequality.⁵⁰

This would suggest a negative causal link between inequality of numeracy and economic development. Certainly, important differences existed between the South and North of the U.S. in the 19th century. Not only did the South suffer severe destruction of its infrastructure and population during the Civil War in the early 1860s, but also was its general economic structure much different from the North. Hence, we control the Civil War and other North-South effects in the regression with a "South"-dummy, assessing furthermore the initial level of numeracy and value-added. Nevertheless, given the limited number of cases, we interpret the results as first evidence which must yet await further scrutiny.

Table 4 reports the coefficients of our empirical analysis. If tested in a univariate regression model, inequality of numeracy (measured for the birth cohorts 1780s-1830s) displays a significant (p-value 0.09) and negative impact on economic growth from 1860-

⁴⁷ see Attack and Bateman, 'U.S. Industrial Development,' for a description of the data set.

⁴⁸ For Rhode Island, all census years are missing, while for Georgia and Louisiana, only 1880 is available.

⁴⁹ Attack, Bateman and Margo, 'U.S. Capital Deepening.'

⁵⁰ We group the data on the basis of the census divisions used by the US Census Bureau. Accordingly, we create the groups of "North" (including the divisions of East North Central, Middle Atlantic, and New England) and "South" (West South Central, East South Central, and South Atlantic).

1880. In a multivariate regression which includes not only the deflated value added in 1860 to catch convergence effects, but also the level of age heaping (non-numeracy) and a “South”-dummy which takes the value 1 for the 11 southern states and 0 otherwise, the inequality variable even gains in significance.⁵¹ As can be seen from Table 4, a highly significant convergence effect exists for manufacturing output, just as a negative growth effect ensues from low levels of numeracy. As in the previous regression, it can be concluded that inequality of numeracy hampers economic development. Rather surprisingly, the “South”-dummy turns out statistically insignificant. All in all, the model can explain nearly 60% of the variance in y , which is a rather high value especially in light of the limited sample size.

In summary, our empirical analysis of the 19th century United States shows mild support for a negative impact of inequality on economic development, as predicted by Lopez, Thomas and Wang.⁵²

Conclusion

Age heaping allows us to measure the numeracy of populations before the Industrial Revolution in an exciting new way, provided that a number of institutional factors can be controlled for. Moreover, if proxies are available for the lower versus middle/upper class origin of individuals in a sample (such as occupational groups or anthropometric percentiles), it becomes even possible to study the inequality of numeracy in pre-industrial economies. One important result from all the samples analyzed in this study is that age heaping is always less or equally prevalent and numeracy higher among the taller half of the population. We have employed this methodology for a number of samples from the 17th through the 19th century. In addition, maps of numeracy inequality for France in the 17th and 18th centuries, and the U.S. in the 19th century were introduced. Next, we have studied whether recent theories which

⁵¹In line with the classification above, we define Alabama, Delaware, Georgia, Kentucky, Louisiana, Maryland, Mississippi, North Carolina, South Carolina, Tennessee and Virginia as southern States.

⁵²Lopez, Thomas and Wang, ‘Education Puzzle.’

suggest a negative influence of human capital inequality on subsequent welfare growth can be confirmed for this period, finding that this was indeed the case for the U.S., as the Northeast experienced very low inequality and strong growth afterwards. Moreover, we ran a regression using the relative change of value added over time as a proxy for economic growth. We found that the inequality of numeracy exerted a significant negative influence on the subsequent economic development of the United States. For France, the relationship was less clear, which is why political factors (such as centralism) had to be taken into account as well. For example, the proximity of a region to the central government in Paris turned out to be an influential variable for 19th century France. Interestingly, in interaction with numeracy inequality, this factor has some explanatory power in addition to mere distance to the government: peripheral regions with high inequality experienced substantially lower welfare growth.

It is also important to note that an equal distribution of human capital does not enhance growth automatically, but only when embedded in an adequate policy environment. Economic policies which suppress market forces tend to dramatically reduce the impact of human capital on economic growth. We assessed one policy environment of liberal character (the U.S. in the 19th century) and contrasted it to the interventionist French policy environment of the 17th and 18th centuries, to which our explanatory variables related.

The U.S. case allowed us the tracing of the path of inequality into the industrial period. We found that the industrial (and immigration) centers of the Northeast experienced strong surges of inequality in the spirit of Kuznet's inverse U hypothesis, whereas the opposite development took place in the post-bellum South where the numeracy of some members of the middle and upper classes even declined.

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Table 1: Difference in non-numeracy by tall versus short individuals in various samples

Country/Region	Institution	Birth Decades	Whipple Index		Ratio
			Short	Tall	
England	Wandsworth Prison	1800s-1840s	133	129	1.03
Ireland	NSW Convicts	1790s-1810s	160	131	1.22
US (North)	Union Army	1800s-1840s	103	101	1.03
Paris	French Army	1650s-1760s	141	102	1.38
France (Northeast)	French Army	1650s-1760s	125	117	1.07
France (Southwest)	French Army	1650s-1760s	142	125	1.14
France (Total)	French Army	1650s-1760s	135	123	1.10

Note: a high Whipple index indicates low numeracy, and higher values of the “ratio” indicate higher numeracy advantages of the taller half of the population over the shorter half. The Whipple index is calculated as $(N_{mo5} / N_{total}) / 0.20 * 100$, where N_{mo5} is the number of ages given as multiples of 5 (= those ending with 5 or 0), and is the N_{total} total number of age statements. As one fifth of all age statements should be multiples of five, a Whipple value of 100 equals no age heaping. If it is slightly below or above 100 in small samples, one usually attributes it to random errors.

Table 2: French inequality of numeracy between the taller and shorter half, sorted by low to high inequality in two periods

Province	1660-1709	Province	1710-1759
limous_marche	0.869	limous_marche	0.892
gasc_bearn_foix	0.886	Orleanais	0.905
champagne	0.930	Maine	0.984
franche-comte	0.976	Normandie	1.007
bretagne	1.085	Anjou	1.008
bourgogne	1.104	artois_boul	1.021
lyonnais	1.110	franche-comte	1.040
maine*	1.111	gasc_bearn_foix	1.065
guyenne	1.117	hainaut*	1.078
prov_venais	1.126	poitou_aun	1.091
auvergne	1.162	prov_venais	1.094
dauphine	1.165	Lorraine	1.095
normandie	1.207	Picardie	1.124
lorraine	1.214	Flandre	1.125
orleanais	1.231	Guyenne	1.127
berry_tour	1.235	Lyonnais	1.150
poitou_aun	1.241	Bourgogne	1.172
flandre	1.252	Dauphine	1.203
picardie	1.273	langed_rous	1.281
hainaut*	1.306	bourb_nivernais	1.299
langed_rous	1.319	ile de france	1.306
artois_boul*	1.429	alsace*	1.328
ile de france	1.523	Bretagne	1.349
saintonge	1.524	Auvergne	1.357
anjou*	1.702	champagne	1.365
bourb_nivernais*	1.716	saintonge*	1.383
alsace*	2.062	berry_tour	1.525

* A few provinces have a rather small sample size (<100) of tall and short soldiers for at least one of both birth cohorts and a narrow age range, which leads to odd heaping patterns (sample sizes [tall/short 1660-1709; tall/short 1710-59]: Alsace[32/75;82/107], Anjou[97/126;129/168], Artois and Boulonnais[84/147;173/208], Bourbonnais and Nivernais[99/95;158/188], Hainaut[72/102;88/113], Maine[100/90;141/191], Saintonge [120/135;79/92]).

Table 3: Determinants of height change: Distance, distance interacted with inequality, and other variables

Dependent Var.:	17th-19th C	17th-19th C	17th-18th C	18th-19th C
Distance to government	-0.14 (0.00)	-0.13 (0.00)	0.00 (0.92)	-0.10 (0.07)
Dist * Ineq of numeracy	-0.37 (0.04)	-0.30 (0.11)	0.14 (0.36)	-0.56 (0.09)
Level of Age Heaping 17 th C		0.00 (0.85)		
Inequality of Numeracy 17 th C		0.28 (0.78)		
Level of Height 17 th C		-0.18 (0.00)		
Constant	2.85 (0.00)	314.99 (0.00)	1.19 (0.00)	1.57 (0.00)
R-sq	0.15	0.42	0.02	0.13
N	83	83	83	83

P-values in parentheses. All estimates are robust, adjusted for heteroskedasticity. Notes: We calculate the dependent variable as the height change between adjusted Komlos & Kim estimates (adjusted with the method proposed by Komlos, 'Earlymodern France', p. 64) on the basis of the provinces, and heights in French departments from the *Annuaire statistique* (cited from Baten, 'Cartography'). This means that sometimes two or three department heights are compared with the joint province height estimate, introducing some randomly distributed measurement error.

Table 4: Inequality as Determinant of Economic Growth in the U.S. 1860-80

Dependent Var.: Real Growth 1860-80	(1)	(2)
Value Added 1860		-0.01 (0.00)
Inequality of Numeracy before 1840	-0.94 (0.09)	-1.04 (0.00)
Level of Age Heaping before 1840		-3.92 (0.05)
Dummy for Southern states		-0.17 (0.42)
Constant	1.16 (0.08)	2.83 (0.00)
R-sq	0.10	0.57
N	22	22

P-values in parentheses. All estimates are robust, adjusted for heteroskedasticity.

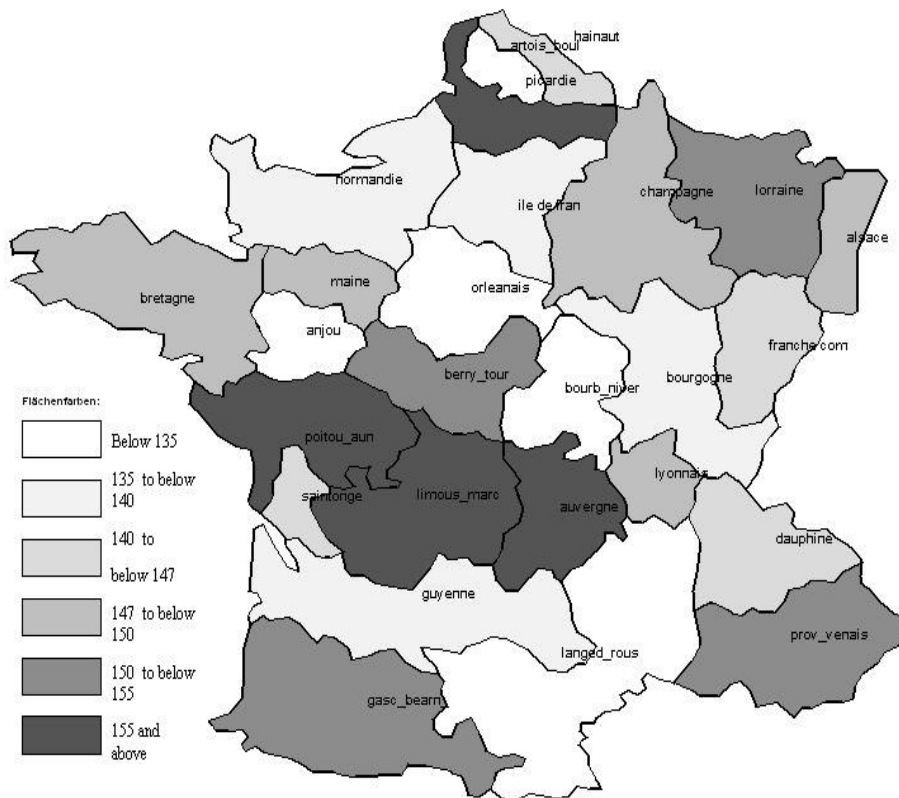


Figure 1: “Non-numeracy” in 17th century France (Whipple Indices of age-heaping)

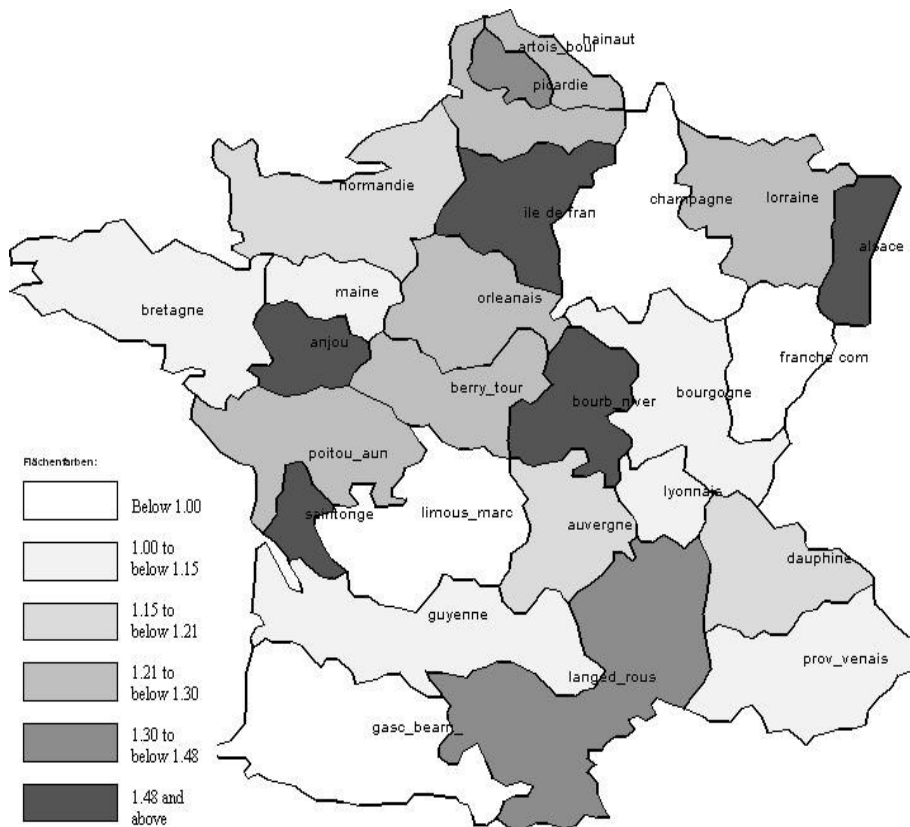


Figure 2: Inequality of Numeracy in 17th Century France

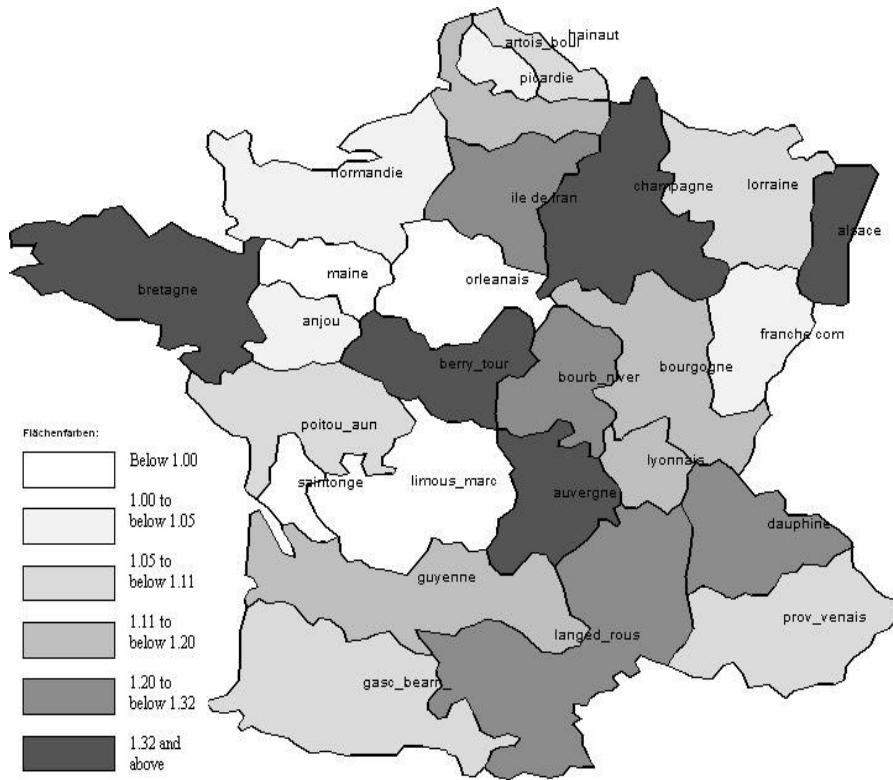


Figure 3: Inequality of Numeracy in 18th Century France

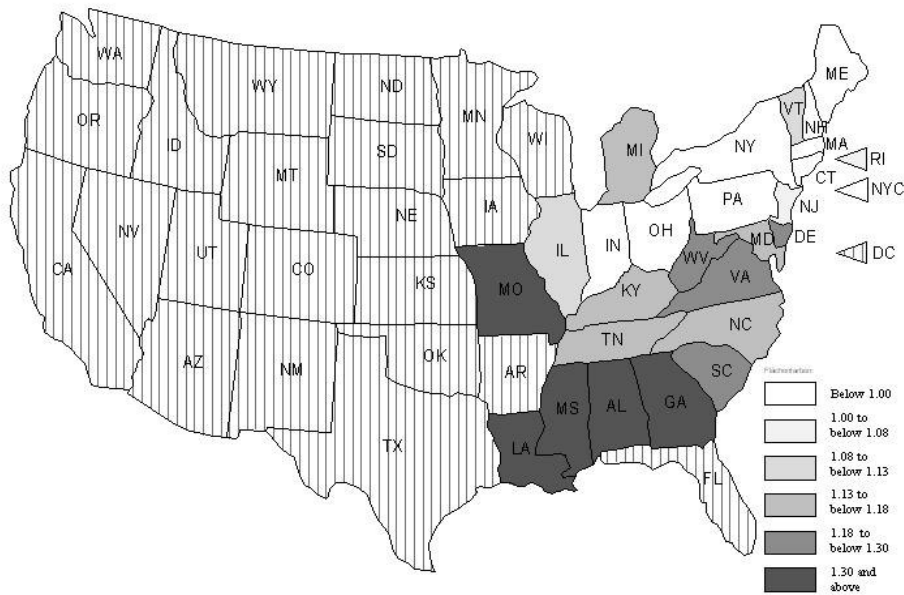


Figure 4: Inequality of Numeracy in the U.S. before 1840

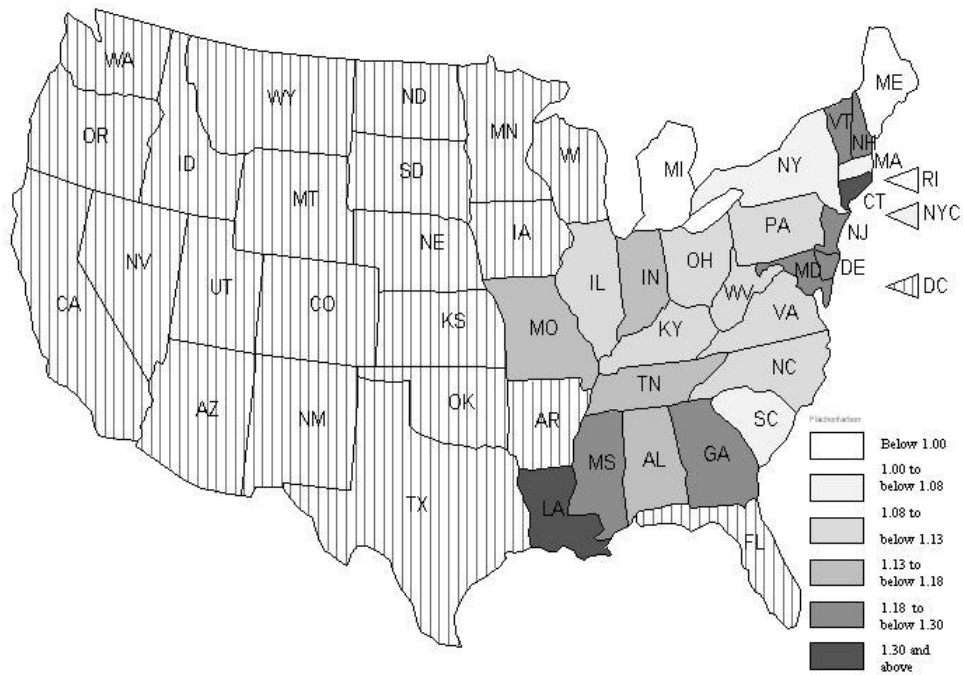


Figure 5: Inequality of Numeracy in the U.S. after 1840

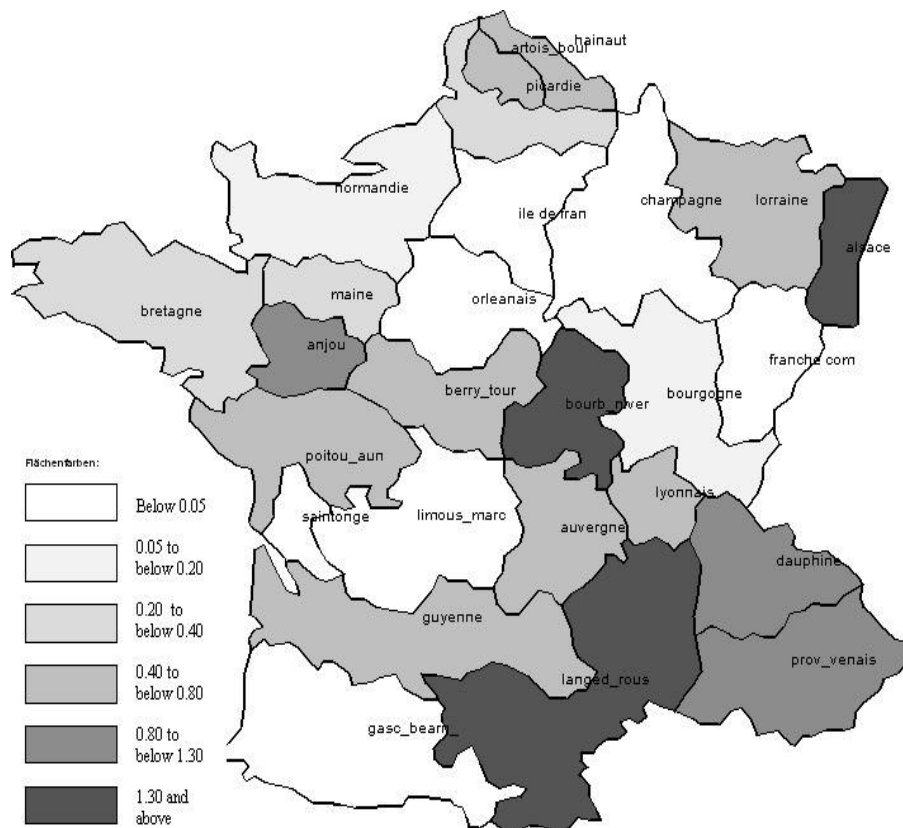


Figure 6: Inequality in 17th Century France, interacted with distance from the governmental center

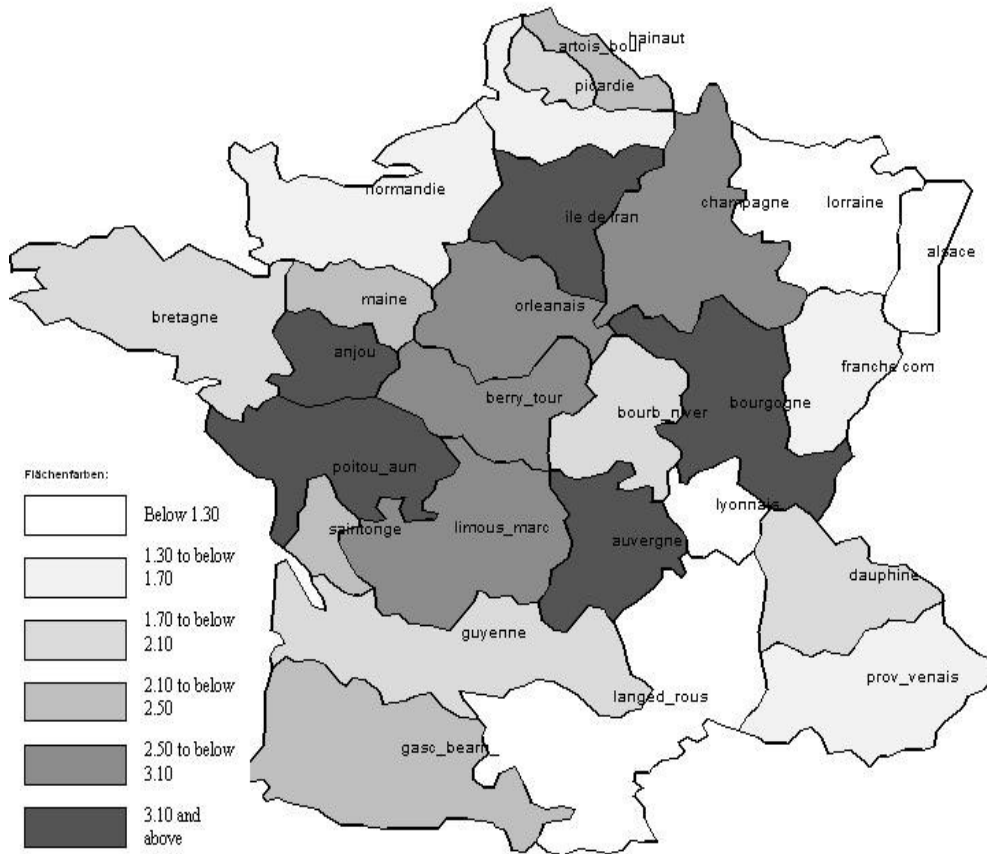


Figure 7: Change in height, 17th to 19th century

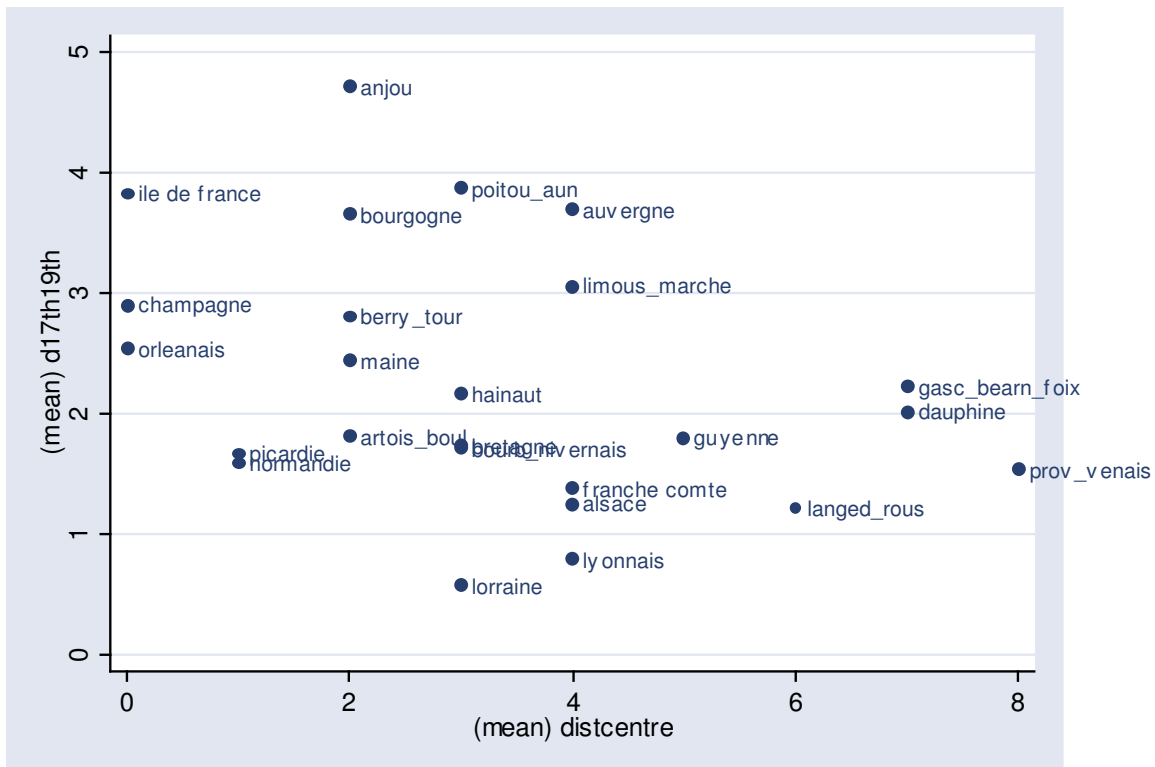


Figure 8: Distance and height change in France, 17th to 19th century, aggregated on province levels.

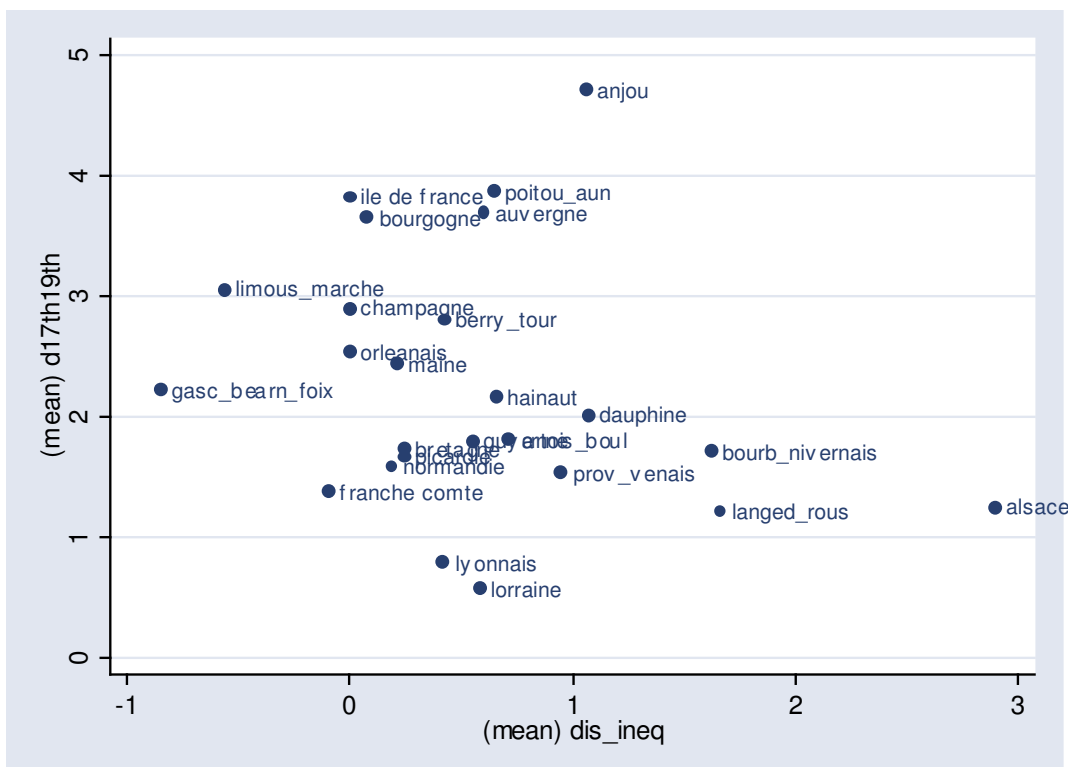


Figure 9: Distance interacted with numeracy inequality and height change in France, 17th to 19th century, aggregated on province levels.