Poor, Hungry and Ignorant: Numeracy and the Impact of High Food Prices in Industrializing Britain, 1780-1850

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Abstract: This paper uses the ability to recall one's age correctly as an indicator of numeracy. We show that low levels of nutrition impaired numeracy in industrializing England, 1780-1850. Numeracy declined markedly among those born during the war years, especially where wheat was dear. England's nascent welfare state mitigated the negative effect of high food prices on cognitive skills. Nutrition during early development mattered for labor market outcomes: individuals born in periods or countries with high age heaping were more likely to sort into occupations with limited intellectual requirements.

Keywords: nutrition, cognitive development, age heaping, numeracy, occupational choice, Industrial Revolution, social spending, poverty traps, effects of war.

JEL: O11, O15, N33, I28

I. Introduction

Nutrition in the past was often poor. Average heights were low. Adult males born before 1850 often measured less than 170 cm, below the 10th percentile of the US population today.[1] Stature is a good indicator of cumulative net nutrient intake during the growing years (Steckel 1995). While short-term nutritional deficits can be compensated through so-called catch-up growth, sustained shortfalls affect terminal heights. Because Europeans' genetic composition has changed little in the last two centuries, historic heights must reflect severe chronic malnutrition in the more distant past.[2]

The consequences of wide-spread stunting are less clear. Costa (1993) investigated the predictive power of low stature for the health of Union army recruits. Waaler (1984) demonstrated that heights and weight were good predictors of individual mortality risk. Fogel (1994) argued that low calorie intake drastically curtailed output per capita in the past. What has remained unexplored are the consequences of massive malnutrition in the past for cognitive development and educational attainment. Lack of data has so far stood in the way of such enquiries. Standard measures of numeracy, such as IQ or math test scores are not available for the more distant past. Instead, we focus on age heaping – the number of people who wrongly report their age as a multiple of five in the census. Self-reported age data often show a tendency for people to 'round off' to the nearest multiple of 5 or 10 (Mokyr 1983, Myers 1976). Roman tombstones, for example, show high rates of age heaping (Duncan-Jones 1990). Age heaping can serve as a good proxy of numerical skill.[3] Today, numeracy has high predictive power for wages

[1] This is the average height of 18th century Dutchmen and Norwegians, who today are amongst the tallest populations on earth (Fogel 1994).
[2] Social differences in stature could also be marked: Upper class boys from the Military Academy at Sandhurst towered by up to 23 cm (9 inches) over their contemporaries from the London slums (Floud et al. 1990).
[3] Gradual changes in heaping over longer periods can reflect a number of factors, such as schooling, the importance of administrative procedures relying on age, and evolving cultural norms. These factors are unlikely to explain abrupt changes over short periods. Short, sharp shocks to numeracy are more likely to reflect environmental factors.

and employment.[4] Because numeracy is correlated with stature in many historical samples, it reflects the cognitive effects of malnutrition.

We construct a new dataset on misreported ages in England, 1780-1850, derived from 19th century censuses. We exploit evidence from a large, exogenous shock that drastically curtailed food availability in Britain – the nutritional crisis during the Napoleonic wars. As a result of a blockade and poor harvests, grain prices increased drastically. Amongst Englishmen born after 1790, numerate ability declined sharply. As grain prices rose by up to 100% after 1790, wrongly reported ages doubled. The decline also differed by region. England had an early and generous form of poor relief (Mokyr 1993). Some parishes were more generous than others in helping the poor. This cross-sectional variation can be explained by the level of income support for the poor – those with the most generous payments saw the smallest declines in numeracy.

To substantiate the link with nutrition, we then turn to the stature of military recruits. Numeracy fell the most in those counties that witnessed the biggest declines in height. We conclude that numeracy in the past can be captured by age heaping, and that this measure in part reflects the influence of nutrition. Finally, we show that those affected by the food crisis of the Napoleonic years – and especially those born in counties with limited poor relief – were more likely to end up in professions requiring lower cognitive skill, receiving lower wages as a result. Thus, malnutrition in the past may have led to poor labor market outcomes in part by curtailing cognitive development.

Related literature includes work on nutrition and cognitive development, which suggests that nutrient intake in utero and in childhood affects intelligence directly. Our conclusions are in line with recent research showing that nutritional status is correlated with cognitive ability and labor market success. Persico, Postlewaite and Silverman (2004) showed that heights have

[4] Rivera-Batiz 1992.

considerable explanatory power for wages. Case and Paxson (2006) argue that this largely reflects the superior cognitive scores of the taller and better-nourished.[5] We discuss this literature in more detail in Section II.

More broadly, our findings relate to recent work on health, labor market outcomes, and educational attainment (Currie 2009). In both developing countries and the developed world, there is substantial evidence that poor nutrition in early childhood has a negative effect on physical and mental health later in life, on educational attainment, and on labor market success. The medical research and intervention studies in the Third World, as well as twin studies all suggest that sudden shocks to nutrient availability should have marked effects. Surprisingly, evidence in favor of aggregate shocks having a major effect is surprisingly rare. While disease outbreaks may have strongly adverse consequences (Almond 2006, Almond, Edlund and Palme 2007), economic dislocation has rarely been shown to affect cognitive and health outcomes in a consistent fashion. Cutler, Miller, and Norton (2007) examine the effects of the US ‘dust bowl’ on children who were in utero.[6] They do not find negative effects of hard times for heights, chronic disease, or body mass. Similarly, Banerjee et al. (2007) examine the effect of phyloxera – a disease affecting grapevines. Regions devastated by it in the 19th century saw a dramatic decline in incomes. While heights suffered, infant mortality remained largely unaffected. The same is true of evidence from the Dutch hunger winter in 1944-45. Retreating German forces left part of the population starving for 5-6 months. Those affected in utero or just born showed no systematic reduction cognitive ability later in life, perhaps because the insult could be compensated shortly

[5] Komlos (1989) argued that nutrition mattered at the opposite end of the skill spectrum as well. He observed that many innovators of the Industrial Revolution in the UK were born during the good times of the 1730s, when food prices were low.

[6] The dust bowl of the 1930s was a terrible ecological event in the U.S. prairie lands. It caused large agricultural damage and led to significant income declines.

thereafter.[7] One study that finds strong effects of severe economic and social dislocation is Alderman et al. (2006). Children affected by the Zimbabwean civil war suffered severe malnutrition. Relative to their siblings, those born during the civil war suffer from reduced stature, lower grades in school, as well as lower school attendance.

Compared to these studies, this paper makes a number of contributions. We are the first to document a strong negative effect of an aggregate economic shock on numeracy. While the weight of evidence suggests that the effect is driven by poor nutrition undermining cognitive development, part of it could also reflect negative effects on school attendance. We also show that, in 18th century Britain already, early welfare systems could mitigate the impact of 'hard times'. Finally, we demonstrate that wartime shocks to nutritional status in childhood had negative consequences for labor market outcomes many decades later.

Our results build on recent anthropometric research that has sought to measure nutrition in the past, mainly based on heights (Steckel 1995, Komlos 1994 and 2005, Fogel 1994). Other related research includes work on human capital formation in industrializing Britain (Mitch 1998, Schofield 1973). Finally, our findings have an indirect bearing on research into the origins of accelerating growth after 1850. One class of unified growth models (Galor and Weil 2000, Sunde and Cervellati 2005) has aimed to join human-capital based interpretations with models of fertility choice. In this class of models, more investment in the skill of the workforce was crucial for the transition to self-sustaining growth. While we do not examine these arguments directly, we document how nutrition constrained a key dimension of pre-modern human capital – numeracy.

[7] This is despite reductions in birth weight (Stein and Susser 1976). At the same time, there is evidence that the cohorts affected suffered from greater incidence of heart disease and personality disorders (Neugebauer, Hoek and Susser 1999).

Section II reviews the literature on the link between IQ, malnutrition, and labor market performance. Section III describes our preferred measure of numeracy based on age heaping, and Section IV discusses the datasets we use in more detail. Our results are presented in Section V. We show evidence from difference-in-difference estimation that nutritional availability in industrializing Britain influenced numerical ability. We document that Englishmen born in the hungry decades of the 1790s and 1800s sorted into jobs with lower skill requirements – especially those from areas with limited poor law support. In Section VI, we discuss our results in context, and Section VII concludes.

II. Nutrition, cognitive ability and occupational outcomes

In this section, we briefly review the literature linking nutrition, cognition, educational attainment, and labor market outcomes. There is strong evidence that childhood health and nutrition matter for cognitive ability, education, and success in the labor market later in life. Experimental evidence suggests that nutrition in childhood influences intellectual ability. Studies on mammals show a strong impact of pre- and post-natal nutrition on brain development (Winick and Rosso 1975). Low birth weight in humans predicts lower cognitive scores (Richards et al. 2002).[8] Malnutrition between ages of 1 to 16 months is a strong predictor of poor cognitive outcomes (Lloyd-Still 1976). In one study of preterm infants, the protein content of the diet was varied on a random basis (Lucas 1998). Children receiving less nutrient-rich diets showed markedly lower neurodevelopment (lower mental development scores and psychomotor scores) at the 18 month follow up than the control group. These effects could still be detected as late as at age 7.5, when IQ scores were significantly lower. Other randomized trials of stunted children

[8] Currie and Hyson (1999) demonstrate that low birth weight is associated in British post-WW II data with lower employment probability, lower IQ scores, and lower income. Case, Fertig, and Paxson (2005) show that this effect is still visible for subjects at age 42. However, Almond, Chay, and Lee (2005) use twin comparisons to argue that the true impact of low birth weight may be smaller than estimated elsewhere.

similarly show that nutritional supplements can produce important gains in intellectual development (Grantham and McGregor 2002). Vermeersch and Kremer (2004) show that a protein enriched diet given to pre-school children in Kenya improved both participation in educational activities as well as cognitive scores in schools with experienced teachers. In addition, poor in utero conditions, as reflected by low birth weight, are systematically associated with a greater risk of mental disease (Linnet et al. 2006).

The positive correlation of heights and cognitive scores also suggests that malnutrition can adversely affect intellectual development. The heights of individuals are in part determined by parental genes. The same is probably true for intelligence. In populations, however, the gene pool stays approximately constant over time. Changes in average heights primarily reflect the influence of environmental factors up to young adult ages (Steckel 1995). Intelligence is likely to be affected in the same way. Richards et al. (2002) use data on IQ scores and height at various ages for a large British post-war sample, and find that the variables are strongly and positively correlated. In particular, maximum height gain during early childhood and the timing of the adolescent growth spurt predict cognitive ability. There is also some evidence that rising IQ scores in developed countries may partly reflect improving nutrition, and not better education (Hiscock 2007; Lynn and Vanhanen 2002). A randomized experiment in Guatemala suggests that protein supplements can produce marked improvements in cognitive ability (Pollitt et al. 1993; Brown and Pollitt 1996). Genetic factors play a role, but do not dominate. While results vary, studies of Scandinavian twins reason that genetic influences cannot explain the correlation between heights and cognitive ability (Magnusson, Rasmussen, and Gyllensten 2006).[9] Earlier studies of malnourished children and their (better fed) siblings also suggested that nutrition, in

[9] Sundet et al. (2005) argue that height and intelligence may be jointly determined by parental genes, and argue that this accounts for approximately 30% of the observed comovement.

addition to parental IQ scores, is a prime determinant of cognitive performance (Craviato and deLicardie 1975).

While sensitivity is great in utero and in early childhood (Heckman 2007), nutrition during the second decade of life also appears to have substantial effects. Recent studies found a clear cumulative effect of persistent exposure to malnutrition and poverty. The longer a child's nutritional, emotional and educational needs are not satisfied, the greater his or her cognitive deficits (CHP 1998, Paxson and Schady 2005). There also appears to be little ‘catch-up’ in cognitive scores, except in the case of very brief shocks. Different studies have tracked the effects of a disadvantageous early environment into late middle age and beyond retirement. Abbott et al. (1998) conclude that men in their 70s show lower cognitive ability if they were shorter. Richards et al. (2002) and Richards and Wadsworth (2004) conclude that the negative effects of a deprived childhood can be found in IQ scores measured at all ages up to 53. Paxson and Schady (2005) find that, in a large sample from Ecuador, test scores for shorter children are significantly lower than for taller ones.

Cognitive ability also has a clear effect on labor market outcomes. Zax and Rees (2002) show that intelligent members of the workforce earn substantially more. Heckman (1995) also finds IQ to be one important predictor of wages. Based on controlled experiments in today’s Third World, Behrman (2006) argues that the correlation between height and wages reflects nutrition’s impact on cognitive development, and not strength or resilience to disease. Using British post-WWII data, Case and Paxson (2006) show that the correlation between height and earnings disappears when one controls for cognitive scores as well. This suggests that much of the observed association of stature with earnings may simply reflect the effect of nutrition on intellectual development.

Childhood health also affects labor market outcomes because it improves schooling. Miguel and Kremer (2004) show that worm eradication in Kenya increased school attendance markedly (while leaving test scores unaffected).[10] Bleakley (2007) examines the effects of hookworm in the US South, and finds that its eradication improved literacy and schooling. Grossman and Kaestner (1997) investigate the effects of child health on education as a result of absenteeism. However, mental health issues appear more important than absenteeism itself (Currie and Stable 2003).

III. Numeracy

Using age heaping as an indicator of numeracy is not new. Bachi (1951) and Myers (1976) showed that across countries and within them, richer, more educated populations were less prone to show age heaping. Historical applications include the work of Herlihy and Klapisch-Zuber (1978) on fourteenth century Florence, Mokyr (1983) on selectivity bias among Irish emigrants, and Duncan-Jones (1990) on the Roman Empire. Over the very long run, numeracy as proxied by age heaping varies strongly with income, and is highly correlated with literacy (Clark 2007, A'Hearn, Baten and Crayen 2009).

The most commonly used indicator of age heaping is the Whipple index.[11] It calculates the number of self-reported ages that are multiples of 5, relative to the number expected with a uniform distribution of ages:

$$W = 100 \frac{\sum (n_{25} + n_{30} + n_{35} \ldots n_{60})}{\frac{1}{5} \sum_{i=23}^{62} n_i} \qquad (1)$$

[10] Bobonis, Miquel, and Sharma (2006) show that anemia and worm infection reduces school attendance in India.
[11] For an overview of different indicators, cf. A'Hearn, Baten, and Crayen (2009).

The range of ages has to be chosen so as to include the same number of ages for each terminal digit (in this case, 23 to 62). There is substantial evidence that the Whipple index dominates competing estimators like the Bachi measure, in particular in terms of accuracy at low levels of heaping (A'Hearn, Baten and Crayen 2006). The index ranges from 0 to 500. Accordingly, a Whipple Index of 0 (500) implies no (only) ages ending in multiples of 5. At 100, it would imply that exactly 20% of the population report ages ending in multiples of 5 .

Age heaping can vary considerably. Figure 1 illustrates the phenomenon by plotting the age distribution in two English counties, Somerset in the census year 1851 (upper panel), and Sussex in 1881 (lower panel). In Somerset, heaping was strong – the Whipple score is 125. In Sussex, age heaping was also still present, but the ratio between the number of persons reporting a multiple of five and the expected number is considerably lower (Whipple of 109).

It could be argued that the ability to recall one's age correctly is indicative of schooling, the bureaucratization of life, and changing cultural norms rather than of cognitive development. However, where it varies considerably over short periods, it is less likely to reflect cultural norms and administrative procedures. Since the use of age and birthdays to identify individuals and the prevalence of schooling have generally been on the rise of the last three centuries, there is an asymmetry in how we should interpret short-term fluctuations. Increases could be driven by, say, the introduction of compulsory schooling (in the later 19th century in most European countries). Where numeracy falls sharply, on the other hand other factors are probably at work.

IV. Historical Background and Data

Britain's population started to grow rapidly after 1750, increasing from 5.9 million to 16.7 million in 1850. From being a food exporter, Britain turned into a food importer after 1760. Mancur Olson (1963) described 'food…as the weakest link in Britain's chain of defense'. In years of poor harvests in particular, the country imported grain from the Baltic and from France (Atkin 1992). The French Revolutionary and Napoleonic wars made the flow of grain much more difficult. Insurance rates for shipping to the Baltic were high in wartime (possibly three times their post-war level). Both sides used privateering to destroy the merchant fleet of their adversary (Jacks 2007; Mokyr and Savin 1976). In a bid to hurt the British trade, the Berlin decree of 1806 instituted the Continental System. It prohibited all trade with Britain from French-controlled Europe (Davis and Engerman 2006), denying European ports to British ships. Neutral shipping was also severely curtailed. The system was at its peak in the years 1807-12. While the French supplied Britain with grain in 1810, they did so while charging export licensing fees that more than quadrupled the price of grain at source (Jacks 2007).[12]

The difficulty of importing food could not have come at a worse time for Britain. As a result of poor harvests, average wheat prices rose sharply in 1795/96, 1800/1801 and in the late 1810s. At their peak, they were more than twice as high as they had been in the 1780s. In some years, when price differences were greatest, imports continued to flow into Britain, even from direct military adversaries. However, transaction costs inevitably rose, limiting the extent to which domestic weather shocks could be arbitraged away. Figure 2 shows the price of the main staple, wheat. In the following, we will use prices as food crisis indicator. Clearly, rising prices could have been compensated by rising earnings. Clark (2005) shows only modest declines of real wages in the 1790s and 1800s. His decade-average obscure the magnitude of shocks that hit

[12] According to some estimates, the UK imported around 15% of its total food in 1810 (Jacks 2007).
[13]

at annual frequency. Moreover, the most vulnerable parts of society often did not earn wages, because they depended on the informal sector, or even charity. The misery that motivated the collection of the first household surveys by Sir Frederick Morton Eden (1797) and Reverend David Davies (1795) was real enough. Bread riots in 1795, 1800, and 1812 reflect how precarious Britain's food situation had become.

The grain price data was collected by Liam Brunt and Edmund Cannon from historical prize gazettes.[14] Acts of Parliament ordered the compilation of grain price data during the period 1770 to 1863.[15] In most years, between 140 and 290 towns reported prices. While information on a number of different grains was recorded, we focus on the price of wheat. It was the main staple of eighteenth and nineteenth century British diets. As Figure 3 illustrates, wheat flour alone accounted for 27% of working class expenditure on food.[16] Bread – largely baked from wheat as well – took up another 20% to the food budget. Together with oatmeal, grain-based food accounted for 60% of the food budget, or 40% of the consumer basket overall. To gauge the importance of wheat in particular, and grain more generally, we also have to add part of the 10% spent on drink. The largest share of this would have been consumed in the form of beer, derived in large part from wheat and barley.

Our age heaping data is derived from self-reported data on ages in the 1851 and 1881 censuses. The collection methodology in each case was similar. The aim was to collect information on all individuals who spent the night of 30 March 1851 or the night of 4 April 1881 in a particular home. Information on the age of household members was self-reported. We use the national two per cent sample of the 1851 British census, created by Professor Michael Anderson

[14] The authors kindly made their data available to us as county-year averages. The source is described in more detail in Brunt and Cannon (2005).
[15] 10 George III, 31 George III, 1 and 2 George IV, 9 George IV, and 5 Victoria
[16] The figure is from Voth 2003, and is based on data from Feinstein 1998.

(1987). [17] Kevin Schurer and Matthew Woollard (2002) produced the five per cent national sample of the 1881 British Census. In addition to the reported age, we use information on gender, the county of birth, and occupational information.

That age reporting was not fully accurate in the censuses has been known for some time.[19] The General Report for the 1891 census argued that 'a very large proportion of persons, not improbably the greater number of adults, do not know their precise ages and only report it approximately'.[20] Thomson (1980) traced individuals' self-reported ages across the 1861, 1871, and 1881 censuses. He found that for both men and women, the correct age (found by adding 10 or 20 to the earlier reported age) was only given by 38 to 64 percent of respondents aged 60 and over. Up to 30 percent gave answers that were wrong by more than two years.[21] Various other studies have examined age recording between two or several 19th century British censuses. They found that 2 to 11 percent were 'off' by more than two years (Anderson 1972, Higgs 1989, Robin 1995, Tillot 1972). Adjustments, on the whole, were as likely to be up as down, suggesting that genuine mistakes – and not a desire to appear older or younger – were to blame.[22]

We use the snapshot data from the 1851 and 1881 censuses to compile information on age heaping by birth decade. Our earliest birth decade is the 1780s; the latest, 1850. For technical reasons, we use the period 1779-1788 for the 1780s, 1789-1798 for the 1790s, etc. Whipple indices range from 97.76 (indicating underreporting of ages ending in a multiple of five) to 150.74, with an average of 116.92. These scores indicate that the Englishmen in our sample are

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17 The data are available at http://www.data-archive.ac.uk/, and more recently, and in standardized form, from North Atlantic Population Project and Minnesota Population Center. NAPP: Complete Count Microdata. NAPP Version 2.0 [computer files]. Minneapolis, MN: Minnesota Population Center [distributor], 2008. [http://www.nappdata.org]
18 The creation of the 1881 British Census sample received additional support by the Leverhulme Trust, and the University of Essex Research Promotion fund.
[19] Apart from the heading of the appropriate column in the household schedule which said 'Age [last birthday]', no general instruction was given to households how to report their age.
[20] 1891 Census, p. 27.
[21] We find markedly lower rates of age heaping.
[22] As late as 1951, only 94 percent of men and 64 percent of women reported their ages correctly (Census 1958, p. 36).

not from a population with particularly low literacy, by historical standards. On average, about 4-8 percent of respondents misreported their age.

In all counties in our sample, multiples of 5 are over-reported. On average, we find scores around 125 (100 corresponds to perfect recall). One important question concerns age-specific changes in the respondents' ability to remember their age correctly.[23] If age alone leads to a deterioration of numeracy, we should find that, say, the 60-year-olds in the 1881 sample have higher Whipple scores than the 30-year-olds in the 1851 sample. If anything, greater age should have made it more difficult for people to recall their ages. Instead, we find that heaping was sometimes more prevalent amongst the same cohort in the earlier census year (i.e., younger persons). There are also no clear-cut effect of age in a set of 165 countries examined over the period 1820-1949 (Crayen and Baten 2009).[24] This suggests that there is no simple mapping from age to age heaping. Note that migration does not represent a confounding influence -- we use the county of birth, as reported in the census, to construct measures of heaping by county and birth decade.

We merge our new dataset on numeracy with information on the generosity of poor relief under the so-called Old Poor Law. Britain was one of the first states to offer income supplements for able-bodied adults in need of support (outside a workhouse). Moreover, the system was comparatively generous. Its cost was high, consuming as much as two percent of GDP (Mokyr 1993). At a time when an agricultural laborer could expect to earn 22-35 shillings a year, relief expenditures per recipient ranged from 7 to 19 shillings (Boyer 1986). Generosity was determined at the parish level, by the overseers of the poor. Funding was also raised locally,

[23] In the main empirical section, we will use a fixed-effects approach to bypass some of the underlying difficulties.
[24] Except perhaps for the youngest age groups. Our results are unaffected if we introduce such an adjustment (results available upon request from the authors).
[25] In the main empirical section, we will use a fixed-effects approach to bypass some of the underlying difficulties.
[26] Except perhaps for the very young ones. If an adjustment for those is applied, our results do not change, see Appendix available from authors.

through property taxes. Economic factors partly explain differences in generosity. Some regions had much greater incentives to retain a large number of able-bodied poor than others (for example, to retain a workforce of sufficient size to cope with the harvest). In the empirical analysis, we will control for these factors separately.

Boyer (1986) compiled information on the generosity of outdoor relief under the Old Poor Law. His data is based on a survey by the Poor Law Commission, conducted in the summer of 1832. Motivated by growing concern about the surging cost of poor law provision, it sent out a questionnaire, called the Rural Queries, to all parishes in England. They received answers from ca. 10% of them. Of these, Boyer used a sample from 21 counties in Southern England.[27] We supplement Boyer's data with additional information from his original source, the Parliamentary Papers (PP), on the North of England. We collected data on relief expenditure for the years 1801, 1811, 1821, and 1831. The returns reproduced in the PP include information on average relief expenditure, summer and winter unemployment, the existence of allotments, the percentage of land used for grain production, and the presence of cottage industry, as well as the annual income of agricultural laborers. From the returns, we calculate relief expenditure per county. Table 1 contains the data descriptives for our key variables. Since our unit of analysis is birth decade, county, and gender, half of our sample by definition is female. Grain prices fluctuated markedly over time (Figure 2). Relief payments varied widely between parishes (Figure 4). Grain-growing areas accounted for 12 percent of our sample.

We also examine interactions between numeracy and height. To do so, we use height data for the British recruits (Floud, Gregory and Wachter 1990). After discarding the cases that could not be matched with the counties and dates in our numeracy sample, this data set contains 7,608

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[27] A total of 735 returns came from Southern parishes. Boyer selected the most complete ones.

cases.[28] The British army consisted of a mixture of volunteers and militia until 1820, the latter being selected by ballot from the general population ("Ballot Militia"). The rich would often pay for replacement soldiers to serve instead of themselves. In contrast, after 1820 the army relied on volunteers only. As in all military organizations, the meaning of 'volunteer' was flexible.[29] Because of a minimum height requirement and other factors, the heights of English soldiers are not representative of the population. To correct for the effect of height standards, we use truncated regression methods.[30] Overall, we derive estimates for 134 county-year units of observation where heights as well as information on age-heaping and grain prices is available. Height estimates range from 165.2 cm (Buckinghamshire in the 1820s) to 178.3 cm (Kent in the 1800s). We estimate average heights 170.9 cm for adult Englishmen. This is quite similar to Cinnirella's (2008) estimates for England.

V. Empirical Results

In this section, we first highlight that across a wide range of samples, from different time periods, countries, and social groups, the well-nourished show greater numeracy. We then document that numeracy fell precipitously in industrializing England as grain prices during the Napoleonic Wars surged. Declines in numeracy were particularly pronounced in counties where (i) grain prices were particularly high (ii) income support for the poor was less generous. The exogenous component of grain price changes, as driven by weather shocks, was an important determinant of numeracy. We show that nutritional status, as proxied by height, correlated with numeracy. The

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[28] We removed (a) counties that were not in our sample (b) birth decades before 1780 and after 1820 (because there were too few cases for the 1830s), (c) extreme heights (below 120 cm, above 200cm) and (d) individuals younger than 19 or older than 55 (controlling for the ages 19, 20 etc with dummy variables), (e) county-birth decade units with less than 20 observations.

[29] Cinnirella (2008) suspected that the latter recruitment system might have implied a lower average height, but analysing those recruited before and after 1820 separately, he could show that the adjacent birth decades were characterised by very similar height levels. It seems that the difference between pure volunteer army and the early mixed system did not play a large role.

[30] We estimate with the highest standard imposed, 65 inches.

part of the variation in heights in our sample driven by grain price shocks predicts age heaping to a significant extent. Did any of these effects matter for labor market outcomes? This is the question we address in the final section, where we demonstrate that those more poorly nourished as a result of the Napoleonic Wars ended up in professions with lower intelligence requirements, where they also earned less than their peers.

To what extent are nutrition, cognitive ability, and numeracy linked? While the influence of nutrition on cognitive ability is well-established in experimental and quasi-experimental settings, the relationship between age-heaping and cognitive facilities requires further analysis. A large number of factors unrelated to cognitive ability – such as schooling, changing cultural norms, and bureaucratization – has the potential to influence of age-awareness. In the appendix, we show that in modern data from the Health and Retirement Survey (HRS), greater heaping is strongly associated with lower cognitive scores. To address the issue in a historical setting, we turn to heights. These capture cumulative nutritional status since childhood (Floud, Gregory, and Wachter 1990). Well-nourished individuals stand a better chance to reach their genetic potential in terms of height. In Table 2, we present data from the US, France, Ireland, and the UK, from the 1660s to the 1840s. The samples are divided into 'tall' and 'short', according to whether individuals' heights are above or below the median. We then calculate Whipple indices for both groups. Throughout, the tall are less likely to misreport their age. In some cases – such as the data from Wandsworth prison– the difference is small. In other cases, such as the Irish prisoners sent to Australia, and French Army recruits from Paris, the differences are marked, with Whipple indices that are 20-40 percent higher for the shorter group than for the taller one. Since the samples are drawn from relatively homogenous backgrounds, this strengthens the *prima facie* case in favor of a link between nutrition and our indicator of cognitive ability, age heaping.[31]

Did years of high prices affect numeracy? Figure 5 plots the median Whipple indices over time. After the outbreak of the Napoleonic wars, Whipple indices rose sharply in both generous and less generous counties. Starting from very low levels in the 1780s, median scores reach their highs for the sample in the 1790s and 1800s – 125 to 130. Counties with limited relief show a greater and more sustained rise. There, Whipple scores stayed elevated in the 1800s, while they were already declining in the more generous counties. While not conclusive proof that the poor in parishes with low income support suffered worse declines in nutritional status, harming their children's cognitive development, the pattern in the cross-section and over time is consistent with such an interpretation.

Next, we examine these patterns more systematically. Table 3 shows OLS and quantile regressions, with the Whipple index as the dependent variable. Wheat prices and relief generosity serve as explanatory variables. Higher grain prices are consistently and strongly associated with greater age heaping in our sample. On average, a one standard deviation increase in county wheat prices pushed up the Whipple index by 2 – 2.5 points (regressions 1 - 3). Counties with generous relief (above the median of payments per capita) lowered their Whipple scores by 2.6 points (reg. 2). Instead of the simple dichotomous variable that codes counties as generous or not, in regressions 3-5, we use a continuous transformation of the poor relief variable. This allows us to test if numeracy declined consistently in those parishes where relief payments were smaller. We define relieflack as $[R_{max}-R_i]$, where R_{max} is the highest relief payment per capita recorded in any county, and R_i is the relief payment in county i. It expresses the difference in relief payments in any one county relative to the most generous one (Sussex in 1810) in our sample. We find that lack of poor relief consistently and strongly predicts higher Whipple scores. The continuous

[31] In his analysis of nineteenth century Bavaria conscripts, Schuster (2005) finds that individuals with exceptionally low intelligence were heavily concentrated amongst the shortest recruits.

measure of poor relief generosity does not undermine the size and significance of the grain price variable. The effect was big. According to our results, the average county in our sample – with a relieflack measure of 1.34 – had Whipple scores that were 6-7 points higher than the most generous ones. In reg. (4), we also use the national grain price index instead of the county one, which yields very similar results.[32]

Regression (5) uses a quantile regression (for the median), which minimizes the mean absolute deviations instead of the square of deviations. The influence of outliers is thus reduced. We still find similar effects for county grain prices and relieflack, evaluated at the median. We also explore responses across the range of the dependent variable. Figure 6 plots the coefficients for relieflack and county grain price, for different points in the distribution of the dependent variable (Whipple score). In both cases, as we examine higher and higher conditional percentiles, the effects of the explanatory variables rises. At the 80th percentile, for example, a one standard deviation increase in relieflack raises the Whipple by 3 points (vs. 1 at the median). Similarly, at the 80th percentile, a one standard deviation rise in the grain prices pushes up the Whipple by 3.5; at the median, the effect is merely 2.4.

The evidence in Table 3 suffers from one important drawback – possible bias from unobserved heterogeneity. Panel estimation at the county level can help to overcome the biggest pitfalls of cross-sectional analysis.[33] We use the following fixed effects setup:

$$W_{i,t} = a_i + \beta G_{i,t} + \gamma X'_{i,t} + \varepsilon \qquad (2)$$

[32] The question of endogeneity will be addressed below. One strategy already applied here is to use the national grain price, as the national price is less likely to be endogenously influenced by county-specific developments. All standard errors are clustered at the county level.

[33] For a discussion of estimation techniques in health studies, see Todd and Wolpin (2003).

where $W_{i,t}$ is the Whipple index for county i at time t, a is a county-specific intercept, $G_{i,t}$ is the grain price in county i at time t, and X' is a vector of controls. Since most of these do not vary over time, we cannot use them at the same time as we use fixed effects. The results are presented in Table 4. The $\hat{\beta}$'s in the fixed effects regressions are broadly similar to the OLS results. They suggest a rise of one to two Whipple points for every standard deviation increase of national grain prices (eq. 1 - 3), and of 2 to 7.5 Whipple points for county grain prices (reg. 5-7). These results are unaffected if we use county-specific controls (eq. 4 and 8), such as population density, whether an area is grain-growing, and the presence of cottage shop manufacturing. These additional control variables are only available for the Southern counties in our dataset. Therefore, the number of observations declines sharply when we include them. The presence of additional labor market opportunities in home manufacturing, as proxied by the cottage shop industry dummy, had no clear-cut effect on numeracy. Living in a grain-growing area, on the other hand, was good for numeracy on average.[34] "Wealth" is here the average value of real estate per capita in the county and proxies gentry and farmer's wealth rather than lower class standard of living (Boyer 1990).

Table 5 estimates panel regressions, using poor relief as an explanatory variable. If we use either year dummies or county dummies, we find results either greater than or similar to the effects estimated in Table 3. If we use both country and decade dummies, we obtain a wrongly signed and insignificant result for relieflack. In estimating the effect of relieflack, all the important identifying variation is captured by the time and county dummies. In regression (4), we use additional controls for county characteristics. In this specification, the coefficient on

[34] This may be because being grain-growing was highly correlated with high relief payments. We discuss this point below.

relieflack is large and positive, but not significant at conventional levels. We attribute this to collinearity with the dummy variable for grain growing areas.[35]

Endogeneity

In this subsection, we consider the possibility of endogeneity. High grain prices in a particular county could cause the workforce to be less well-fed, and less energetic. This, in turn, would then depress a county's grain output, keeping prices high. To sidestep potential endogeneity issues such as this one, we use an instrumental variable approach. In Table 6, we instrument the main explanatory variable – wheat prices – with the ratio of annual spring rain to its long term average.[36] More rain in the spring was bad for crops, raising prices. Since the concerns about endogeneity are principally to do with the cross-section, we also investigate if the component of county grain prices predicted by the national grain price index predicts numeracy. Reg. (1) performs such a test. We find that the county grain price index, instrumented with national grain prices, gives a near-identical result to the panel estimates reported earlier. We also implement the conditional likelihood ratio test for weak instruments introduced by Moreira (2003) and refined by Mikusheva (2005).[37] The test decisively rejects the possibility of a weak instrument.

In regressions (2)-(7), we use spring rain to instrument grain prices. We initially estimate without fixed effects, and then add county and time dummies. The first stage is strong for both grain price series (adj. R^2 of 0.32 and 0.33; F-statistic 71.9 and 79.3). There is no evidence of a weak instrument.[38] Overall, we find significant coefficients in all cases, except when we use county grain prices and county plus year dummies (when the significance is marginally below

[35] The correlation coefficient is 0.51, significant at the 1% level.
[36] The weather data consists of rain volume (in mm) is taken from Hulme and Barrow (1997). Rain volume is reported for each of the four seasons. Spring rain is particularly important for the harvest.
[37] We use the condiv command in Stata, as implemented by Mikusheva and Poi (2006).
[38] Where we use county and/or year dummies, we cannot test for weak instruments – the condivreg routine in Stata does not converge due to multicollinearity. We use ivreg instead, and report the results.

conventional levels). Coefficients are similar to those in the standard panel estimation. This suggests that the component of grain prices driven by weather shocks has a marked effect on numeracy. Price changes originating from other factors such as local demand shocks play less of a role in determining age heaping. This is in line with our reasoning that the main determinant of poor nutrition during the Napoleonic period – the harvest failures that coincided with trade restrictions – left a particularly strong mark on numeracy.

Heights

The previous sections demonstrates that individuals born in periods of high prices were, on average, less likely to remember their age correctly. The same is true if they were born in parishes where poor relief payments were limited. Using weather as an instrument, we have also shown that the exogenous component in grain prices predicts changes in numeracy. One crucial element in our analysis is missing so far – the link with nutrition. Height is known to be a good indicator of net nutritional status between conception and age 25. In this subsection, we show that (i) the grain price shocks of the Napoleonic wars also led to stunting (ii) that numeracy was systematically lower in parishes where heights declined during the period 1790-1815.

In regression (1) in Table 7, we show that higher grain prices in the decade of birth are associated with lower terminal heights of recruits. The effect is large. A one standard deviation increase in grain prices reduced heights by 2.2 cm, on average. Figure 7 divides English counties according to the height of recruits those above and below the mean in terms of height. Where soldiers were taller than average, numeracy was also greater, as reflected in lower Whipple scores. Next, we explore how strong the association between height and numeracy is. In regressions (2) – (4), greater height predicts lower Whipple scores. In other words, Englishmen and –women from counties with lower heights on average made more mistakes reporting their ages. The effect can be large – up to two Whipple points for a standard deviation change in heights. The effect remains large and significant when we include year dummies; it falls below conventional significance levels once we include county dummies.

Regressions (5) and (6) use grain prices and relieflack as instruments for heights. Since it is hard to think how the level of grain prices and the lack of poor relief in one's county of birth can influence numeracy a few decades hence in any way other than through nutrition, the exclusion restriction is plausible. In the first stage, grain prices are strong; relieflack is relatively weak. Whether we include relieflack in the set of instruments or not, the final result is the same – the component of heights that we predict based on grain price movements has a large and highly significant effect on numeracy. The fact that both the size and the significance of the coefficient rises should be puzzling. In standard IV-estimation, the opposite would be expected. Measurement errors are unlikely to be a important. Instead, we suggest the following interpretation: Height differences are driven by both nutritional and genetic factors. Since the gene pool will not change quickly over time, most of the important short-term variation derives from shocks to nutritional status. This part of the variation is well-captured by grain price movements. The strength of the link between this component of heights and numeracy reinforces our interpretation: numeracy declined during the Napoleonic period because of adverse shocks to nutrition.

The Skill Requirements of Occupations and Economic Impact

Did the negative nutritional shocks during the Revolutionary and Napoleonic Wars matter for occupational outcomes? We first examine if those born in 'hungry years' sorted into jobs with lower cognitive skill requirements. Second, we examine if there were negative consequences for earnings.

To obtain data on the occupations of individuals, we use information provided in the 1851 and 1881 census returns. These occupations are then classified according to the coding from the Dictionary of Occupational Titles (England and Kilbourne 1988). Their study offers scores for the skills required for a wide range of jobs. Our main interest is in the cognitive skill requirement. In nineteenth century Britain, class and parental income were major determinants of access to higher education. Families that could send children to university were unlikely to suffer much from the dear food prices during the Napoleonic wars. We therefore exclude the professions requiring the highest skills (code 1-199 in the England-Kilbourne scheme –professionals such as architects, medical doctors, etc.). To examine the economic impact of our results, we use census information about occupations to impute average earnings. For each individual in our dataset, we calculate average earnings by occupation, as tabulated by Long (2006) and Williamson (1980, 1982). These are then averaged by county, and analyzed in conjunction with the data on numeracy introduced earlier.

Table 8 shows the results. We examine the impact of numeracy on earnings and the intelligence requirement of jobs into which Englishmen and –women entered. Regression (1) uses intelligence requirements to predict earnings. The positive coefficient on cognitive skill demonstrates that 19th century labor markets were similar to modern-day ones in one respect – better-paying jobs required greater intelligence. In regression (2), we show that the higher the average Whipple score of a county – and thus, the lower numeracy – the lower the intelligence requirement of jobs filled was.[39] In regression (3), we extend the exercise to grain prices and poor relief as explanatory variables. Higher grain prices in the county of birth were associated with, on average, jobs with lower intelligence requirements. The coefficient on the dummy variable for high relief counties is correctly signed, but insignificant. Regression (4) shows that the same

[39] Note that this is not driven by a county-wide effect. By the time of the census, many Englishmen had moved. Yet their county of birth still had a powerful effect on their occupation.

pattern holds true if we use earnings as the dependent variable. Again, we find a strong and significant effect of grain prices in the county and decade of birth on earnings. A one standard deviation increase in grain prices on average reduced earnings by one £, or two percentage points relative to the median. Regression (5) repeats the exercise, predicting average earnings with the county Whipple scores. Again, the effect is significant and large. A one standard deviation rise in the Whipple predicts a decline of earnings by £2.8, a reduction of almost 5.5%. Measurement error and attrition bias due to aggregation probably reduced the estimated coefficients. We therefore think of them as a lower bound on the true effect.

In regression (6), we instrument the intelligence requirements of professions with the Whipple score of the birthplace. The component of intelligence requirements predicted by the Whipple has a strong and significant effect on earnings. Finally, in regression (7), we instrument the intelligence requirements of jobs held by the county grain price, and show that this factor successfully predicts earnings. The significance level is lower than if we use the Whipple. In both regressions (6) and (7), the coefficient is larger than in regression (1), while significance declines somewhat. Overall, there is strong evidence that those born during the nutritional crisis of the 1790s and early 1800s suffered from lower earnings and worse occupational outcomes.

VI. Discussion

Our analysis assumes that wheat prices are a good proxy for the general price of food. Alternative sources of calories were clearly available. Those suffering from high grain prices could have substituted away from relatively dear sources of calories, thus mitigating the impact of dear wheat. A more comprehensive measure of the price of food should also capture that cheaper substitutes such as potatoes. In crisis years, their price also rose dramatically. While wheat prices increased by 73% between 1798 and 1800, rye prices increased by 55%. Potato prices reacted even more sharply, increasing by 78 percent. The magnitude of price changes was similar in 1812. Then, wheat prices increased by 34%, and potato prices shot up by 81 percent (compared to the non-crisis level in 1806). In general, the correlation between wheat and potato prices in the difficult period between 1793 and 1817 was 0.57. In short, while many Englishmen clearly tried to avoid hunger in its most extreme form, by switching from wheat bread to potatoes, this strategy could not work for the hungry masses as a whole. Rapid price increases for all staples caused a deterioration of diets during crisis years. [40] Crucially, little or no money could have been left to purchase food rich in proteins, such as meat, fish, eggs and milk. Since the effect of nutrition on cognitive development probably depends on protein availability (Lucas 1998), this must have sharply reduced infants' chances of developing their full potential.

The decline in numeracy was concentrated during the Revolutionary and Napoleonic wars. Britain fought a war that required unprecedented military, fiscal, and economic mobilization (Brewer 1990). Alternative mechanisms could have caused increased age heaping. For example, wartime dislocation brought about by the absence of fathers may have led to family instability. Passing on information about the age of children could have been disrupted by large-scale mobilization. We think this is unlikely, for a number of reasons. First, since Britain was still fighting the American War of Independence until 1783, and the Fourth Anglo-Dutch War until 1784, establishment size of the armed forces was not that much smaller in the baseline period of the 1780s compared to the 1790s and 1800s. The actual date range for the decade is 1779-1788, comprising five war years (1779-83). Second, the single best indicator for family instability – illegitimacy rates – showed only a small uptick, increasing from 4.6 percent in 1750-74, 5.9 percent in 1775-1799 and to 6.2 percent in 1800-24 (Wrigley et al. 1997). Even if all of the

[40] Horrell (1996) uses data from the Eden-Davies surveys, and finds a negative own-price elasticity of demand for bread, and a positive (but smaller) one for flour. This suggests that price increases led to sharp falls in bread consumption, and that some substitution to home-baked bread took place.

additional 33,000 illegitimate births were caused by the wars, this would pale in comparison with the total rise in misreporting. Third, the army and Royal Navy did not satisfy their demand for manpower by recruiting bachelors who would otherwise have gone on to found stable families. As George Chalmers (1812) put it, in Britain, 'the sword had not been put into *useful* hands.' Press gangs routinely rounded up vagrants and other unproductive elements. Impressment was limited to 'such able-bodied men as had not any lawful calling or employment'.[41] Also, many men in the armed forces – officers and privates alike – joined in their teens. Average age at marriage in England in 1800 was 25 for men (Wrigley et al. 1997). This means that probably less than half of the men in the armed forces were of an age when they ordinarily would have been married. Finally, the numbers for total enlistment include foreigners recruited into the British army. The British army in 1813, for example, consisted of 203,000 British troops and 53,000 foreign ones (Smith 1998; Hall 1992). Since one out of five British soldiers were not from the British isles, any negative effects on family stability that there might have been was probably mitigated.

Our results establish a prior that the availability of adequate nutrition was important for numeracy, and that Poor Law provisions helped the most vulnerable parts of the country fight the effects of high grain prices. Nonetheless, we cannot rule out that other factors – to the extent that they are correlated with the generosity of poor relief – were responsible for our results in the cross section. The validity of our results hence rests on the plausibility of the mechanism we describe, with no direct means of controlling for other variables that might also have provided 'safety cushions' for the poor.

Access to schooling may also have suffered during the Napoleonic wars. Since general economic conditions deteriorated during the war, a decline in schooling – rather than a decline in

[41] Cit. acc. to Brewer 1990, p. 49-50.

nutritional standards – could be responsible for the lower numeracy attained during these decades. Also, parishes with generous poor relief may have invested more in schooling. This would be in line with recent work by Miguel and Kremer (2004), as well as Bobonis, Miguel and Sharma (2006). While possible, the available information on trends in basic literacy – as proxied by the ability to sign one's name – make this interpretation less likely. Schofield (1973) found that illiteracy rates for men and women thus measured were broadly stable or gradually declining between 1750 and 1840. The general view is that the acquisition of basic skills in England took place outside day schools before the 1870s (Mitch 1992). There is no evidence of a sudden fall in signature rates during the Napoleonic wars. Nicholas and Nicholas (1992) examine convict data, and find that literacy by the end of the wars was *higher* than it was at its outbreak.[42] To the extent that the ability to sign one's name is a more basic skill than remembering one's age, our findings suggest that only the performance of more complex tasks suffered. If basic schooling continued unabated, the acquisition of more advanced skills was curtailed. While it cannot be ruled out, there is no evidence to suggest that sharply reduced school attendance was behind lower numeracy.

VII. Conclusions

This paper has argued that low numeracy in the past was often caused by inadequate food intake. We exploit a quasi-natural experiment: When industrializing Britain went to war with France in the 1790s, grain imports from the continent were sharply curtained for many years. When grain did flow in, the cost of imports was unusually high. Prices for wheat and other staples surged, especially in years of harvest failure. Market integration within Britain also declined as privateers preyed on coastal shipping. We examine the impact of these exogenous shocks to food

[42] Subsequently, they document an increase. Their data may suffer from greater problems of representativeness and small sample bias than Schofield's.

availability, and show that they lowered average numeracy throughout the country. Subjects born in the hungry decades of the 1790s and 1800s were much less likely to remember their age correctly, or to perform the calculation necessary to derive it without errors. Our paper is one of the first to demonstrate that large economic shocks in the past had deleterious effects on cognitive ability.[43]

The detrimental effect of high food prices was particularly pronounced in those areas that did little to help the poor. England operated an early and unusually comprehensive system of income support. Generosity was determined at the county level. Individuals from areas hit by particularly high prices, and without much income support, showed particularly low numeracy. We demonstrate that numeracy declined sharply where nutritional intake, as measured by average heights, declined the most. This strengthens the case for a link between nutrient availability and cognitive development, as reflected in age heaping. In addition, the food crisis of the war years also affected the careers of those in their infancy when high grain prices hit. They selected into occupations that were, on average, less demanding in terms of cognitive skills. They also earned less than their peers. Therefore, the 'first welfare state' offered an effective way to improve living conditions for the poorer groups of society. While it is possible that the social disruptions of the Napoleonic Wars played a role through a reduction in schooling, is more likely that lower cognitive ability, driven by poor nutrition, was the main factor behind lower numerical ability.

In his Nobel address, Robert Fogel (1994) discussed the contribution of better nutrition to higher productivity over the last 200 years. Highlighting improved life expectancy, as well as greater resilience and strength of humans today, Fogel concluded that 20-30 percent of total output growth should be attributed to improved food intake. Cognitive ability is a crucial factor not emphasized in his interpretation. If cognitive ability in the past was partly curtailed by poor

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[43] The paper closest in spirit to ours is Alderman et al. (2006), where the effects of war are also apparent in educational outcomes and test scores.

food intake, as our results suggest, then life was not only ‘nasty, brutish, and short’ (in the words of Thomas Hobbes); people were also poor, hungry, and ignorant. More precisely, our research demonstrates suggests that people in the past may have been ignorant because they were often poor and hungry. Yet causation may also have flowed the other way – output may have been low because of low cognitive ability. One potential implication of our research could be that output in the more distant past may have been constrained by low levels of human capital. While we offer no direct proof, the findings presented in this paper suggest that the transition to self-sustaining growth in industrializing Europe may well be related to improved nutrition and higher cognitive ability.[44]

[44] There are also possible implications for the more recent past. Flynn (1984) showed that cognitive scores underlying IQ tests have been rising for several decades in the 20th century. Between 1930 and 1900, average cognitive ability scores rose by the equivalent of 0.6 IQ points per year (Hiscock 2007). The benefits of higher cognitive scores in the labor market today are well-known (Case and Paxson 2006). A strong link between nutrition, cognitive ability, and productivity would arguably offer an alternative explanation for the poverty of the past – one that does not have to put store in the slow rise to dominance of a superior culture, as argued by Clark (2007).

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TABLES

Table 1: Descriptive Statistics

Variable	N	Mean	Std. Dev	Min	Max
Relief	377	0.67	0.3	0.27	2.01
Female	386	0.52	0.5	0	1
Grain price	308	102.61	20.82	61.44	147.97
Whipple	386	116.92	9.05	97.76	150.74
Birth decade	386	1823	19.88	1780	1850
Grain area	200	11.92	4.35	4.48	19.09
Population density	187	0.48	0.34	0.23	1.55
Cottage industry	187	0.28	0.28	0	1
Wealth	187	4.85	1.06	3.82	8.1

Table 2: Stature and Whipple Ratios

Country/Region	Birth Decade	Average		Ratio	Whipple Index		Ratio
		Short	Tall	Height	Short	Tall	Whipple
England	1800-1840	62.66	67.11	0.93	133	129	1.03
Ireland	1790-1810	63.65	67.7	0.94	160	131	1.22
US	1800-1830	65.75	69.81	0.94	124	114	1.09
France - Paris	1660-1760	61.8	63.98	0.97	141	102	1.38
France - North-East	1660-1760	61.64	64.17	0.96	125	117	1.07
France - South-West	1660-1760	61.43	63.98	0.96	142	125	1.14
France - Total	1660-1760	61.52	64.08	0.96	135	123	1.10

Table 3: Regression Analysis: Whipple Scores and Grain Prices (Whipple Index as dependent variable)

regression	(1)	(2)	(3)	(4)	(5)
estimation method	OLS	OLS	OLS	OLS	Quantile
county grain price	0.106***	0.114***	0.126***		0.114***
	(4.93)	(4.84)	(5.58)		(4.68)
female	-1.485*	-1.466*	-1.458*	-1.559*	0.285
	(-1.89)	(-1.85)	(-1.80)	(-1.97)	(0.29)
reliefhigh		-2.637**			
		(-2.28)			
relieflack			5.339***	4.570***	3.839**
			(3.47)	(2.81)	(2.33)
national grain price				0.105***	
				(4.20)	
Constant	108.7***	109.0***	99.65***	102.8***	99.91***
	(52.48)	(48.11)	(32.50)	(29.01)	(26.79)
Observations	308	308	301	311	301
Adjusted R^2	0.060	0.077	0.092	0.062	

t statistics based on standard errors clustered at the county level, in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Relieflack is $[R_{max} - R_i]$, where R_{max} is the maximum relief payment per capita and R_i is the relief payment in county i.

Table 4: Panel Estimates – Grain Prices (dependent variable: Whipple index)

regression	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
national grain price	0.0911***	0.0710**	0.0569*	0.0982***				
	(3.74)	(2.08)	(1.70)	(3.76)				
county grain price					0.0948***	0.370***	0.366**	0.0958***
					(4.05)	(3.88)	(2.49)	(3.42)
female	-1.494*	-1.687**	-1.762**	-1.944	-1.404	-1.592*	-1.647*	1.878
	(-1.79)	(-2.16)	(-2.10)	(-1.61)	(-1.64)	(-1.97)	(-1.91)	(1.59)
grain growing				-0.375**				-0.325*
				(-2.18)				(-1.88)
density				-3.737				-3.699*
				(-1.66)				(-1.79)
cottage ind				3.087				3.033
				(0.89)				(0.92)
wealth				3.277***				3.281***
				(4.12)				(4.41)
Constant	106.0***	111.6***	115.3***	99.72***	105.8***	91.12***	93.92***	98.79***
	(43.97)	(28.59)	(29.51)	(16.00)	(46.01)	(14.17)	(9.12)	(16.33)
Year dummies	N	Y	Y	N	N	Y	Y	N
County dummies	Y	N	Y	N	Y	N	Y	N
Observations	318	318	318	151	308	308	308	151
Adjusted R^2	0.103	0.315	0.402	0.149	0.121	0.361	0.414	0.157

t statistics based on standard errors clustered at the county level, in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 5: Panel Estimates – Poor Relief (dependent variable: Whipple index)

regression	(1)	(2)	(3)	(4)
relieflack	9.032**	3.240**	-1.352	3.959
	(2.07)	(2.10)	(-0.32)	(1.27)
county grain price	0.124***	0.377***	0.334**	
	(4.98)	(3.87)	(2.25)	
grain growing				-0.345**
				(-2.32)
density				-2.124
				(-1.01)
cottage ind				-1.867
				(-0.59)
wealth				2.112**
				(2.78)
Constant	98.74***	85.69***	101.3***	108.8***
	(17.01)	(13.42)	(7.94)	(28.87)
Year dummies	N	Y	Y	N
County dummies	Y	N	Y	N
Observations	301	301	301	187
Adjusted R^2	0.136	0.373	0.416	0.095

t statistics based on standard errors clustered at the county level in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Relieflack is $[R_{max} - R_i]$, where R_{max} is the maximum relief payment per capita and R_i is the relief payment in county i.

Table 6: IV-estimation (dependent variable: Whipple index)

regression	(1)	(2)	(3)	(4)	(5)	(6)	(7)
county grain price	0.0866***	0.176***	0.154***	0.0564			
	(3.44)	(4.04)	(3.89)	(1.63)			
female	-1.508	-1.400	-1.346	-1.685*	-1.471	-1.416*	-1.762**
	(-1.49)	(-1.37)	(-1.56)	(-1.95)	(-1.44)	(-1.70)	(-2.10)
national grain price					0.185***	0.178***	0.0569*
					(4.18)	(4.43)	(1.70)
Constant	110.7***	101.4***	100.0***	115.2***	100.6***	97.47***	115.3***
	(40.98)	(22.29)	(25.84)	(28.30)	(21.85)	(24.61)	(29.51)
Instrument	national grain p	rainfall	rainfall	rainfall	rainfall	rainfall	rainfall
Year dummies	N	N	N	Y	N	N	Y
County dummies	N	N	Y	Y	N	Y	Y
Observations	308	308	308	308	318	318	318
Adjusted R^2	0.058	0.034	0.102	0.403	-0.009	0.063	0.402

t statistics in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 7: Heights and Numeracy

regression	(1)	(2)	(3)	(4)	(5)	(6)
estimation method	OLS	OLS	OLS	OLS	IV	IV
dependent variable	height	whipple	whipple	whipple	whipple	whipple
county grain price	-0.110**					
	(-2.01)					
relieflack	-0.176					
	(-0.12)					
height		-0.845*	-0.628*	-0.493	-3.888***	-3.634***
		(-1.92)	(-1.88)	(-0.61)	(-2.97)	(-2.82)
Constant	180.5***	265.6***	222.9***	193.8	775.7***	732.7***
	(35.17)	(3.52)	(3.99)	(1.39)	(3.50)	(3.35)
Year dummies	Y	N	Y	N	Y	Y
County dummies	Y	N	N	Y	N	N
Instrument	-	-	-	-	county grain price and relieflack	county grain price
Observations	134	134	134	134	134	134
Adjusted R^2	0.429	0.026	0.234	0.023		

t statistics in parentheses; in reg. (1) to (4), derived from standard errors clustered at the county level

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 8: Earnings, Intelligence, and Numeracy (Fixed-Effect Panel Regressions)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
estimator	OLS	OLS	OLS	OLS	OLS	IV	IV
dependent variable	earnings	intelligence requirement	intelligence requirement	earnings	earnings	earnings	earnings
intelligence requirement	15.37***					24.76***	21.95*
	(5.17)					(4.60)	(1.69)
female	-29.71***	-0.0192	-0.0147	-28.82***	-30.04***	-29.57***	-28.49***
	(-35.63)	(-1.37)	(-1.23)	(-28.05)	(-35.75)	(-34.72)	(-27.52)
whipple		-0.0124***			-0.306***		
		(-11.26)			(-4.64)		
county grain price			-0.00217***	-0.0529*			
			(-6.38)	(-1.80)			
reliefhigh			0.0283	1.874			
			(0.85)	(0.66)			
Constant	28.28***	4.719***	3.445***	81.98***	114.1***	-2.681	6.452
	(2.88)	(37.32)	(104.07)	(28.63)	(15.02)	(-0.15)	(0.15)
Instrument						whipple	county grain price
Observations	311	311	233	233	311	311	233
Adjusted R^2	0.806	0.231	0.045	0.765	0.802		

t statistics in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Sample restricted to counties with more more than 1,000 intelligence observations

FIGURES

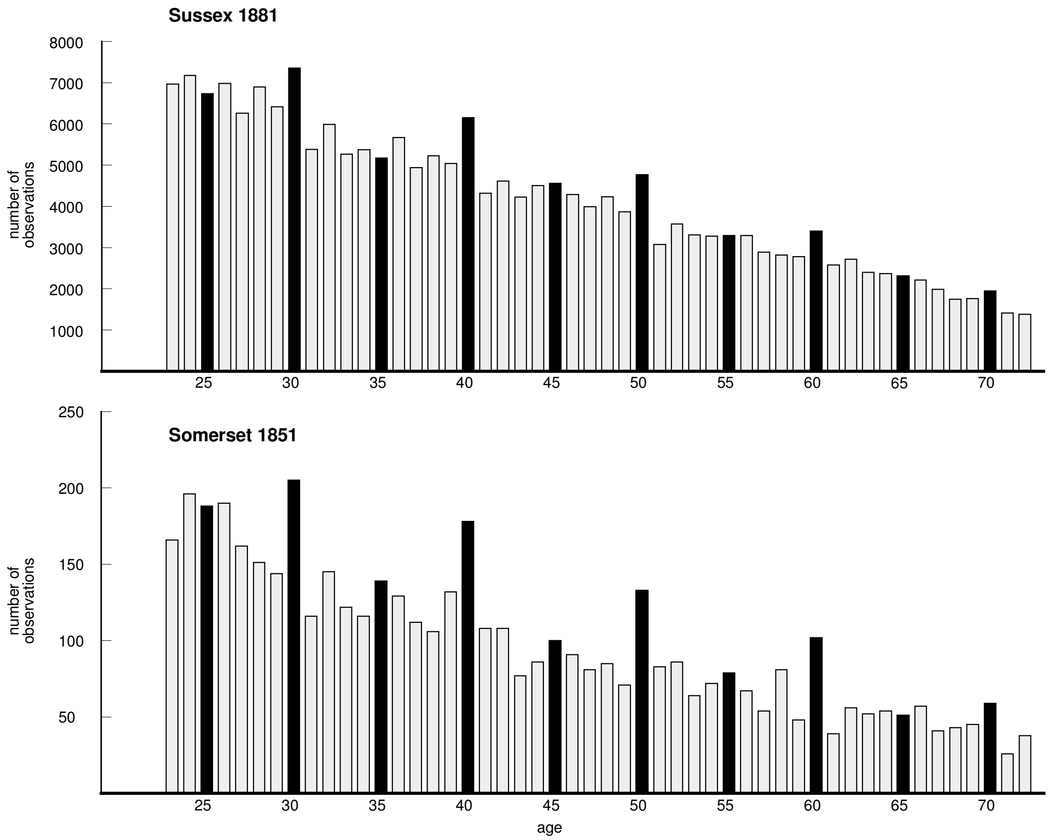

Figure 1

Age Distribution in Somerset 1851 (upper panel) and Sussex 1881 (lower panel)

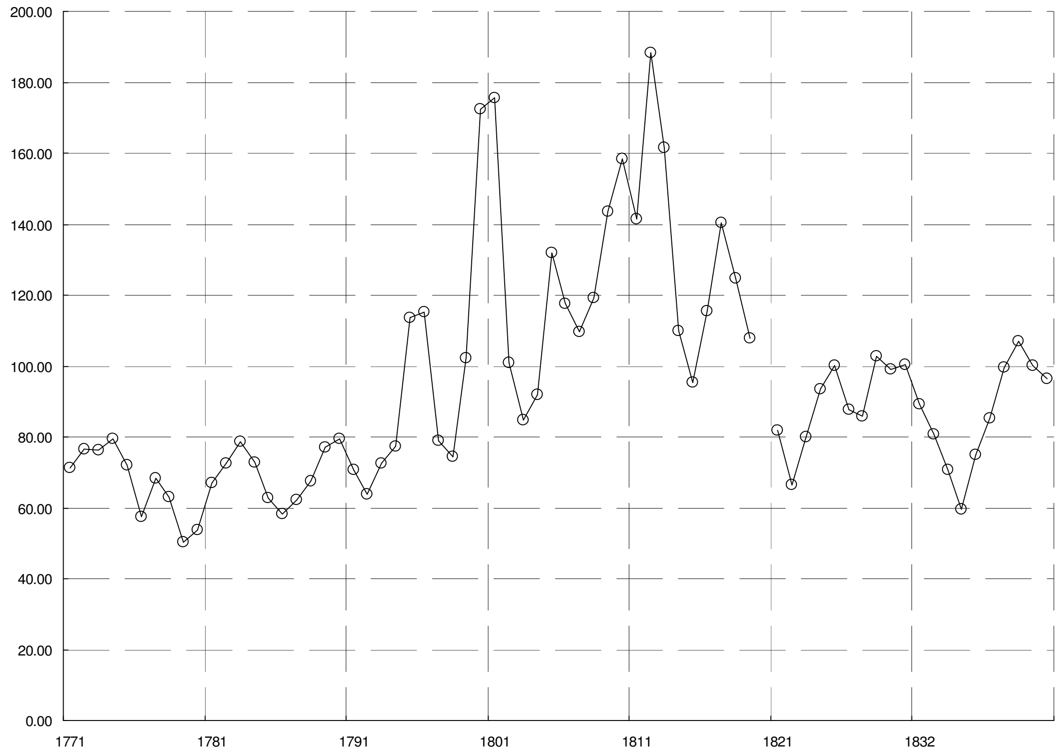

Figure 2

Grain prices in England (1800=100)

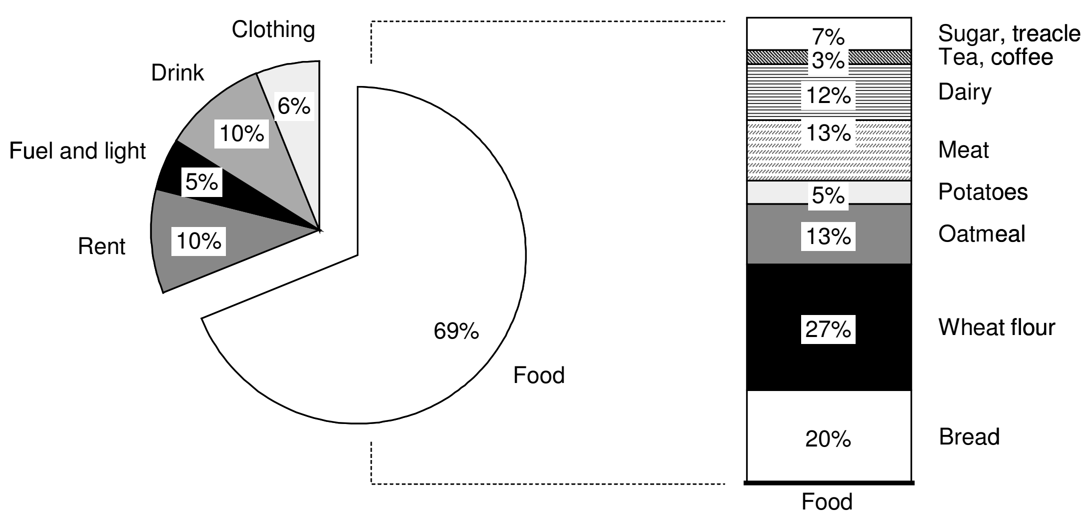

Figure 3

Composition of Working Class Expenditure, 1788-92

Source: Voth (2003)

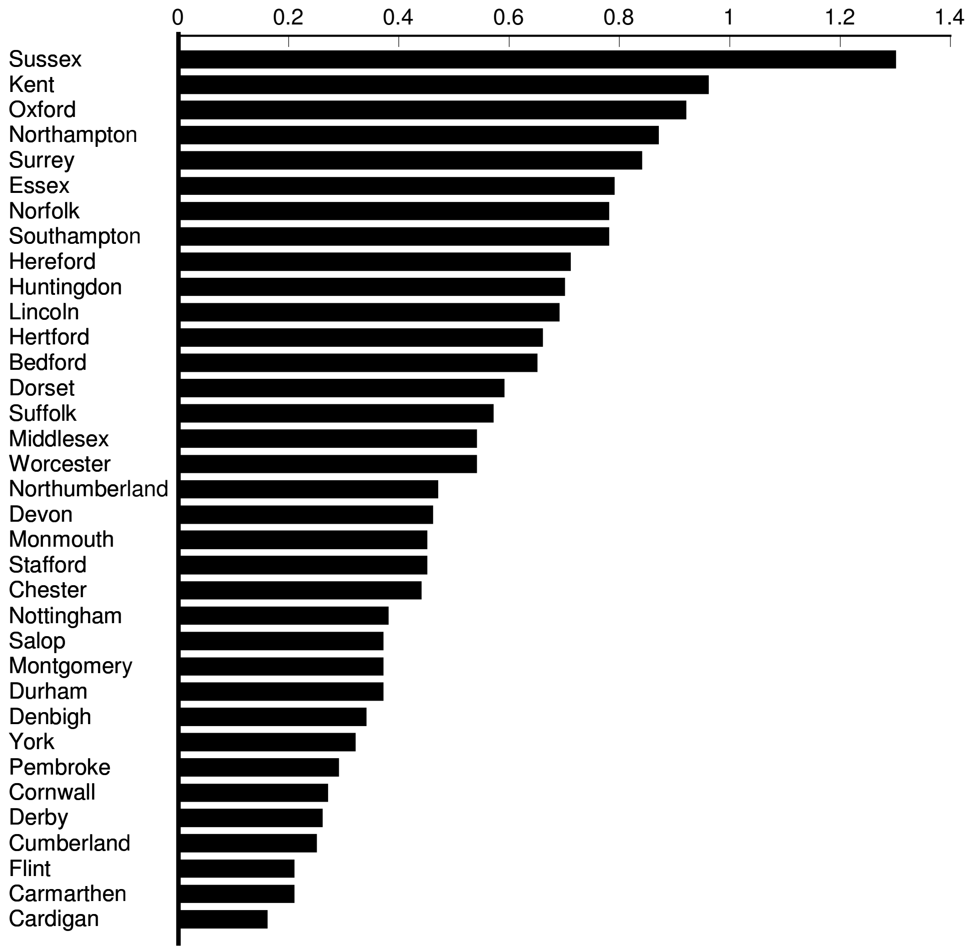

Figure 4

Poor relief per capita, in shilling

Source: Boyer (1990).

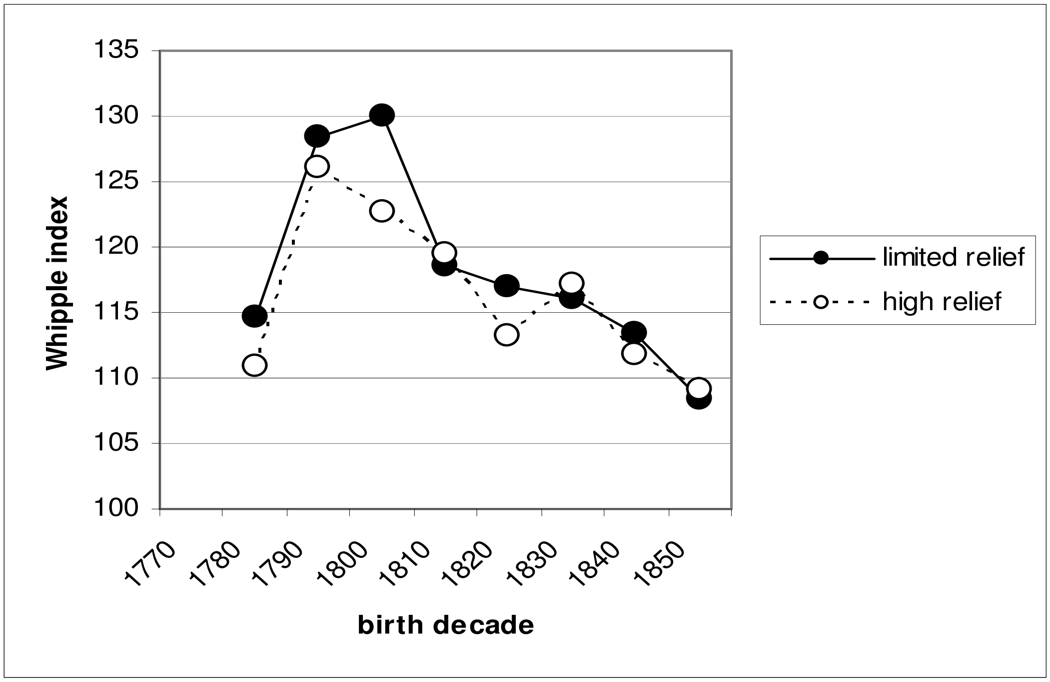

Figure 5

Median Whipple Indices over Time, by Generosity of Poor Relief

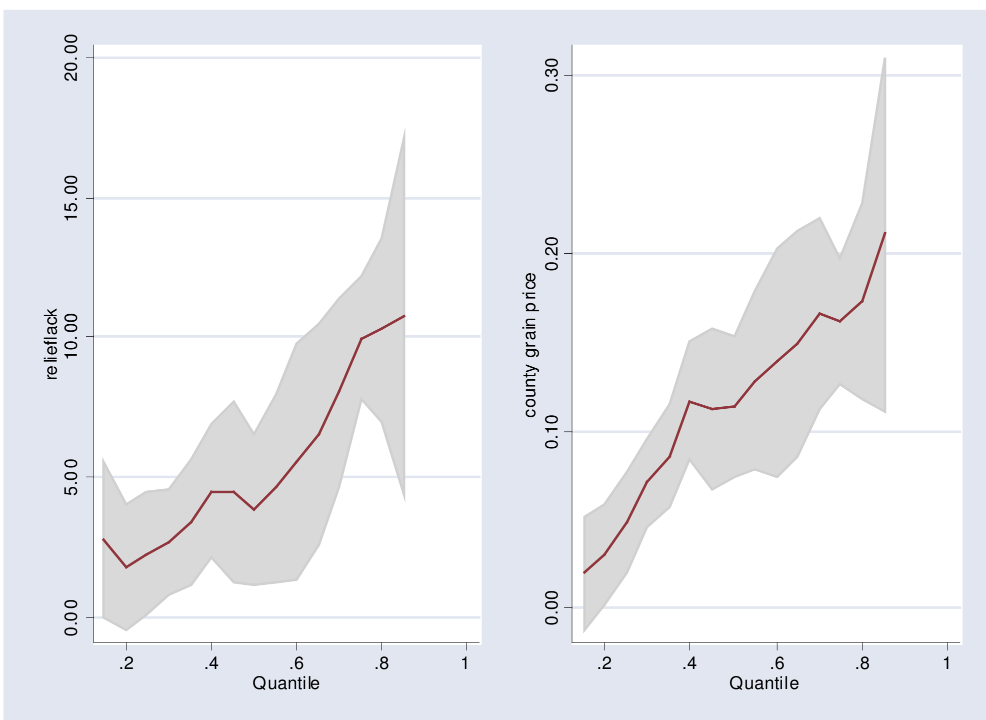

Figure 6

Quantile Regression – Coefficient on Relieflack and Grain Price

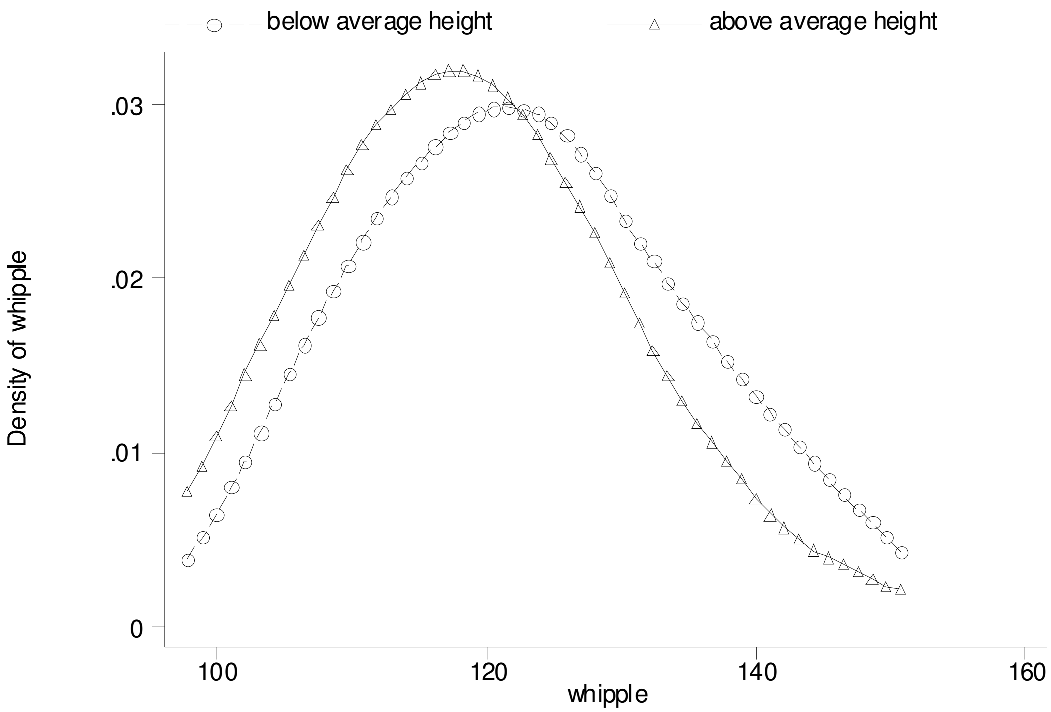

Figure 7

Kernel Density Estimates – Numeracy in Counties with above/below Median Heights

Appendix

One crucial assumption underlying our work is that heaping of reported ages is a good proxy for cognitive ability. To test this assumption, we use the 1993 Assets and Health Dynamics Among the Oldest Old (AHEAD) dataset from the Health and Retirement Survey. This contains information on the individual, health, cognitive, and income characteristics of the American elderly. In total, there are 8,222 individual returns.

The AHEAD survey contains numerous measures of cognitive ability. One involves counting backwards from 100 in steps of 7. This is used as an overall indicator of numerical ability. There is also word recall (number of words remembered correctly, of a list of 10) and the current day, month, and year. We use all of these as measures of cognitive ability.

Age in the AHEAD survey is not self-reported. However, individuals are questioned about the age of death of their parents. This is not exactly the same as the information we would ideally like to use (self-reported age), but it is similar to the information from which measures of age-heaping are derived (i.e. the age given on Roman tombstones, etc.). We find that in a sample of 7,317 respondents reporting the age of their father's death, 2,073 provide an answer that is a multiple of five. In a random sample, we would expect no more than 1,463 responses giving a multiple of five. This corresponds to a Whipple index of 142.

If age heaping is a valid indicator of numeracy, the HRS measures of intellectual ability should be correlated with the likelihood of reporting the father's age of death as a multiple of five. This is what we find. In Table A1 we show that those *not* reporting the age of their father as a multiple of five were more likely to remember a large number of words correctly, to know the current year, and to perform a series of subtraction exercises without error.

Table A1: Heaping in reported ages and cognitive ability

Dependent variable	Number of words remembered correctly	Current year correctly remembered	Number of subtractions correct
Panel A:			
Age of fathers death NOT	0.025^{*}	0.1^{*}	0.044^{***}
reported as multiple of 5	(1.96)	(1.79)	(2.5)
Estimator	Poisson	Probit	Poisson
(Pseudo)-R2	0.0001	0.0011	0.0003
Panel B:			
Age of NEITHER parents	0.055^{***}	0.34^{***}	0.11^{***}
reported as multiple of 5	(2.71)	(4.3)	(3.4)
Estimator	Poisson	Probit	Poisson
(Pseudo)-R2	0.03	0.006	0.0005
N	7163	7363	7382

t statistics in parentheses

$^{*}p < 0.10$, $^{**}p < 0.05$,$^{***}p < 0.01$

Many of those reporting the age of their father when he died will remember it correctly. That both parents died at an age that is a multiple of five is much less likely. We construct a second variable that takes the value of 0 if only one or none of the ages of the parent's death are reported as a multiple of five, and 1 otherwise. In our sample, if age of death was random, only 329 individuals should be reporting both parents having died at an age that is a multiple of five. In actual fact, 655 reported that this was the case, suggesting that the rate of mistakes is particularly high. We use this new explanatory variable in Panel B of Table A1. As expected, the size and significance of the coefficient rises markedly compared to Panel A, where we only used the age of the father's death. These results strong suggest that that age-heaping in modern day data, just as in historical data, is a good indicator of cognitive ability.