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Dear Joerg

Please find attached a much-shortened version of our submission 'Gender bias in nineteenth-century England' as you requested.

We have reduced the text to 26 pages with a further 6 pages of references and a paragraph of acknowledgements, so a little below the 34 pages you suggested. We have achieved this by moving much of the discussion of delayed growth trajectories and comparisons with modern standards and investigating possible biases in the factory data, along with associated tables and figures, to an appendix for on line viewing only. You suggested we should try to reduce our 14 figures and tables to just 10, unfortunately we found there were 19 figures / tables in our original so have not been quite so successful at achieving your target as we were with the text. However, we have removed more than the 4 you suggested, we have reduced the tables to just 5 and the figures to 7 (including the map), so 12 in total. We have dropped the previous table 6 which summarised our data sources as suggested by the referee. As we have moved much of the work relying on the additional data sets to the appendix, we felt the text and argument now flowed much more straightforwardly and so avoided the earlier confusion about different data, rendering this table unnecessary. We have also combined previous tables 3 and 4 into the current table 3 as there was a degree of repetition here. Overall we feel this achieves the length you recommended and we hope you agree. We also feel the paper has benefitted from this pruning, leaving the argument more in focus but the relevant supporting material also available to those who wish more detail.

We look forward to hearing from you further

With very best wishes

Sara

***Highlights (for review)**

- Heights of C19th factory children with earnings parity exhibit female disadvantage.
- We discount wholesale systematic age deception as causal.
- The ‘double burden’ is implicated as a source of discrimination against girls.
- We model how delayed growth traces a gender-specific U-form against WHO standards.

# Online appendix

## Appendix 1: Modelling the effect of delayed growth trajectory on comparisons with modern standards

One approach to modelling delayed growth is to examine a modern population which exhibits this pattern of slower-later-longer growth. India fits the bill. The following draws on recently published heights for 106,843 Indian school children aged 5-18 years, measured between 2006-9, randomly drawn from across the country from both government and private schools (Marwaha et al 2011, supplementary tables). At 18 years, the average male was nearly 2 inches below $WHO_{2007}$, and the average female 2.7 inches shorter. These data enable us to get an impression of how, even today, deprivation relative to the well-nourished populations that underlie the WHO standard would affect the timing of the growth spurt and thus how HAZ scores should be interpreted at different ages.

The children's growth trajectories are described in Figure A1, distinguishing growth intervals for a range of percentiles from 3 through to 97, with $WHO_{2007}$ the dark reference line. A clear progression emerges. The slower initial growth, the later and more muted the pre-adolescent growth spurt, and the greater the proportion still growing at age 18 years.

[Figure A1 here]

For simplicity, the discussion will now focus on the bottom of the distribution, on boys and girls at the third percentile. Their HAZ curves are reported in Figure A2. P3 girls at age 3 exhibit a $WHO_{2007}$ z-score of -2.4 and, at age 18 they also possess a z of -2.4. But, instead of z being constant throughout the growing years, a greater gap opens up between the deprived girls and $WHO_{2007}$ girls, with z falling down from age 9 to a trough of -3.2 at ages 12-13. This is because the well-fed, healthy $WHO_{2007}$ girls grow faster year-on-year, peak higher, then velocity falls sharply after age 12 (as a prelude to most girls in this group reaching menarche). For the deprived, growth persists. From the start, their rate of growth is below the modern average ($WHO_{2007}$ P50); the pre-pubertal growth spurt is subdued; and – very importantly – growth appears protracted so that from age 13 velocity is above $WHO_{2007}$ and terminal height is reached after age 18. This continuation of growth into early adulthood suggests the underlying data are composed of (diminishing proportions of) girls who are yet to reach puberty. The upshot is that the timing of the growth spurt matters to the shape of the female z-curve.

[Figure A2 here]

Likewise for the boys. Indian schoolboys at the third percentile commenced on a z of -2.5 at age 3, and at 18 had fallen to -2.7, slightly worse than the girls though boys would keep growing beyond this age and overall do better. Again, deprivation depresses gains in height, reduces the scale of the pre-pubertal peak, and elongates growth (moreso than for girls who complete growth earlier). Because peak growth is later for boys than girls, the deprived boys really start slipping further behind the $WHO_{2007}$ standard after age 12 when $WHO_{2007}$ boys are accelerating rapidly. P3 schoolboys dip to a low of -3.2 at age 15. P3 Indian boys hit a low equivalent to girls.

# Appendix 2: Investigating possible biases in the factory data

## A2.1 Systematic overstatement of girls' ages?

Is there something fundamentally wrong with Horner's measurements? Despite Horner's strictures on data collection there remains doubt. Horner himself found 'the averages obtained... correspond very nearly with those of Mr. Harrison and Mr. Baker' (1837 (99) p.4), who furnished earlier small studies,

> But from the extraordinary variety in height of children, nominally of the same age, which these returns exhibit, there is much reason to fear that in the greater number of instances, the real ages have not been ascertained with certainty, but have been set down from the statements of the children themselves, or from those of their parents; and upon neither can much reliance be placed (ibid pp.4-5).

These are not good grounds for rejecting the data. In fact, the standard deviations reported by the surgeons in 1837 were, if anything, on the low side compared with modern standards for this age group, which is consistent with delayed puberty (standard deviation increases with the pre-pubertal growth spurt). Horner's concern may have arisen more from the contemporary lack of knowledge about human growth, and of its variability by class and locality, than from inexactitude on behalf of the surgeons.

The bigger question is about possible systematic overstating of girls' ages from the moment they appear at the factory door. Was age at entry fudged? Whether parents were willing to disregard legislation designed to protect their children's welfare may come down to the strength of incentives and difficult household calculus, but was there any greater inducement to exploit daughters more so than sons? There was a financial incentive to place young children in work, but would this encourage parents to overstate a girl's age more than a boy's? As we have seen, both boys and girls could earn good wages in the factory (Table 1), so a girl could earn a 'boys wage' throughout childhood and, possibly, a higher wage than she might earn in an alternative occupation. For boys, wages elsewhere may have been more comparable. This might encourage parents to particularly aim to place girls in factories. But it is uncertain whether they would chose this option over alternative employments which, being unregulated, offered longer hours and, hence, higher earnings, such as in calico printworks and mines (Horner 1840 pp.122-4). An illustration of this process at work, albeit for a boy, is provided by Joseph Burgess who, on his 12th birthday, tried to gain full-time employment in a factory by representing his age as 13. In this case, the certifying surgeon detected the deception but it didn't stop Joseph working long hours, instead he moved into an ancillary textile process where the factory acts didn't apply (Humphries 2010, p.312).

Even if we assume that parents were incentivized to more readily disguise their daughter's age to get her into factory work so that 8 or 8½ year old girls were being passed off as 9 years, then we would expect the HAZ score for girls at age 9 to be below that of boys of the same age by at least half a standard deviation. There is only little (but nonetheless statistically significant) disparity at this age with girls shorter than boys at age 9, but this was also true at ages 8½ and 8 years when parents had no incentive to deceive. Thus there is no immediate evidence of systematic age lying, but we cannot unequivocally rule out the possibility. We return to this point below where we show that it is not feasible that age-lying is generating the z-score trajectories that we observe.

To help ascertain the reliability of Horner's data we turn to four other tables of mean heights taken from samples of children around the same period, collected by Samuel Stanway in 1833, James Harrison in1834, Robert Baker in 1836 and a later study akin to Horner's by Charles Roberts in 1876.[1] These samples differ from Horner's in their relative reliability and/

[1] Data reported in BPP (1833) pp.87-9; BPP (1837) p.4 and p.3 respectively; Roberts (1876).

or the incentives to lie at particular ages, thus would yield average heights that differ from Horner's at crucial thresholds if age-lying were occurring. The summary results are presented in Table A1, giving mean stature and HAZ score, by age and sex. The shaded cells indicate the age at which a full 12-hour day could be worked at the time of each survey.

[Table A1 here]

Returning first to Stanway's study of Sunday schools in Manchester and Stockport in 1833, we can see factory girls were a little shorter than other girls at age 9 by two-fifths of an inch, but comparison across ages is very inconsistent because of the very small sample of non-factory girls. Taking only those attendees who were classified as engaged in factory work, we can compare their heights with those of Horner's children in large towns in 1836. As already noted, it is probable that these Sunday school children came from the better-off end of the group of factory operatives so we would expect them to be taller, although this would potentially be mitigated in part by children at this time working 12-hour days. Sunday school children were indeed slightly taller at each age. At age 9 years, the difference is small: 0.15 of an inch between boys, one-quarter of an inch between girls. The gap then widens, especially for girls who, by age 14, are just over 2 inches shorter. The disparity between boys is a little less, 1½ inches. The large jump in the discrepancy around ages 12 to 14 might be indicative of age-lying in the Horner sample. Conversely, it may arise if the more affluent children in Stanway's study were earlier to enter their adolescent growth spurt. The difference in children's heights at each age taken from the two samples still fits within one standard deviation of modern height data ($WHO_{2007}$) therefore it is reasonable to think that the Horner sample is not beyond the realms of possibility, but it does remain anomalous.

As noted above (section 3.3), Dr Harrison had collected heights of factory children and he too had thought about this problem with the accuracy of ages. He must have collected his Preston data (1409 children measured between the ages of 11 and 18) in 1834 because he observed the first age at which 12 hours could be worked was 11 years old.[2] (It was not until March 1835 that 11 year olds were restricted to a 48 hour week, with a maximum 9 hour day.) To quote from Harrison's letter to Horner:

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[2] His correspondence with Horner is 16 August 1836, but it relates to "Mr Harrison[‘s] … letter to the late Mr. Rickards, which forms a part of the Report of the latter to the Secretary of State, printed by the House of Commons, in August 1834."

> The investigations were made on the first coming into force of the Factories Regulation Act, and as the children and their parents, with few exceptions, did not know for what object the inquiries were made, nor how they would affect their interest, they had no inducement to give in false statements of age. The greatest doubt must exist with regard to the average of the children represented to be between the ages of 11 and 12 years, as 11 was at the time of the examination the lowest period at which children were allowed to work 12 hours a day, and the parents of such children as were under that age had a strong inducement to make false statements; but as the parties did not then know much of the provisions of the Act, it may perhaps be regarded as an approximation to the truth. Above 11 there was no conceivable motive for practising deception. (BPP 1837 (99) p.4)

This yields a natural experiment. When Harrison collected his data the legal age for working twelve hours per day was 11 years. When Horner assembled his, the legal age was 13 years. If parents inflated their children's ages in order to increase their offsprings' working hours and earnings, then we should see 10-year-olds being passed off as 11 years in Harrison's sample and we should see 12 year-olds being passed off as age 13 in Horner's study. Do we see evidence of particularly undersized 11-year-olds in Preston, and of greater stunting among 13-year-olds in Horner's studies? A third sample offers a further comparison. Robert Baker, surgeon in Leeds, sent height data to Horner in 1836 (BPP 1837 (99) p.3). Eschewing data collected two years earlier because of the difficulty of ascertaining age with any accuracy he seems to have been satisfied with these data. If so, age lying would be indicated by relatively short stature in Horner's sample.

At age 11 years, factory girls in Harrison's study of Preston look the same as those measured by Stanway (who did not have an incentive to lie); both are marginally taller than girls in Baker's and Horner's more urban, less affluent samples. However, Harrison's factory boys were a little shorter than Stanway's, not just at 11 years but across all ages, positioning them in keeping with boys in the Horner and Baker studies. Preston seems to have been good for girls but not for boys.

Can we see evidence that Horner's 13-year olds were exceptionally stunted? Harrison thought he had accurate ages for 12-year olds and over as they were legally permitted to work 12-hour days (the 1833 Act had yet to affect their employment). As noted, Horner's boys were in keeping with Harrison's boys, but the girls were not. We have already noted that Preston girls seemed to do comparatively well, like the Sunday School girls. Horner's 13-year old girls look particularly short. But significantly, the divergence with Horner's girls was already opening at age 11 years – not 13 years as implied if lying, nor 12 if an artefact of a heavier workload. Reassuringly, the same discrepancy compared with Preston is apparent among the Leeds girls aged 11 and 12 years that Baker measured. Unfortunately, Baker recounts no stature for older ages. This finding suggests it was not deception around working a 12-hour day, but some other factor or factors accounting for divergence. Horner's data include children living in some of the largest towns with the worst environmental conditions, such as Manchester, a factor which adversely affected heights. Leeds was also a large town, hence the greater comparability with Horner's sample than found for the smaller town of Preston.[3] Thus the data fit with the interpretation we might place on the different environments faced by the children, although for boys the locational differences are not evident because Preston seems a less favourable environment for them.

Baker's and Horner's girls were more urban, less affluent, were not obviously lying about their ages in order to work longer days, and were excessively stunted, recording HAZ scores on par with the boys. The HAZ minimum for Stanway's factory girls was at age 11 years, Harrison's between 11 and 13 years, so the Horner girls' minimum at 12 and 13 is not out of keeping, although it is particularly deep. The depth of this trough could arise from the historic 12-hour burden that built from age 12 years in the sample (but why is it visible for girls and not the boys?). It could be age deception as parents prematurely pushed under-age daughters (but not sons) into a 12-hour day, itself a form of discrimination (but why also dissemble at ages 12½ and – especially – 13½?). Or it could be that the data are accurate as Horner instructed, and that it measures a genuinely perplexing discrepancy between the growth patterns for girls and boys working in England's north-west textile factories.

There is another record set which affirms the validity of the very large and persistent height discrepancy between Horner's boys and girls up to age 12, although frustratingly girls' stature then stops being recorded. It is a large study of factory children undertaken forty years later in 1876 by Charles Roberts (counting 11,000 children). By this time all children under age 13 were limited to a 9-hour day, and there had been some improvements in nutritional availability (Meredith and Oxley 2014). What is evident are HAZ curves of very similar shape to those of Horner. They are shifted up by about half one standard deviation, but follow the same downward slope. The boys show no disjuncture at age 12 and beyond, which might have been anticipated given the 12-hour burden that at least some of this age group would have suffered in Horner's study. This suggests the impact of switching to a 9-hour day, with its associated two-hours of education, perhaps had less positive impact than might have been

[3] The populations of these towns in 1831 were 182,000 in Manchester and 123,000 in Leeds, compared with only 34,000 in Preston and 36,000 in Stockport. Mitchell (1988) pp.26-7.

hoped, and consequently imposes less (if any) distortion on Horner's data. What is also noticeable is that the gender gap has widened further. Why these statistics help validate the gender gap findings is that from 1837 the General Registrar's Office was issuing birth certificates. Roberts' data involved both surgeons *and* birth certificates. While it is not impossible to imagine fraud might still be perpetrated – Roberts discusses this possibility and advocated the retention of surgeons to vet certificates – this development must have made deception far more difficult.

## A2.2 Counterfactuals that would generate the observed HAZ scores

A further possibility should be explored. What counterfactual would generate the pattern of HAZ scores that we observe in Horner's data? It requires wholesale, systematic age deception for all girls, and for no boys, at every age. We reduce all female ages by six months and recalculate HAZ scores using the appropriate lower-age $WHO_{2007}$ reference for mean stature and standard deviation. We leave male stature untouched. Overstating the age of all girls (not just those at the entry and threshold ages) by just 6 months is sufficient to remove much of the gender differential previously observed. The impact is to raise girls' z-scores, instating an early female advantage, largely removing the HAZ deficit; the girls' HAZ minimum reduces to -2.83 compared with the previous -3.13 making it considerably less than the boys'; and there is now a gap of 1 year between boys' and girls' minima occurring. But to increase the minima gap to the 18 to 24 months seen in other samples we would have to assume that the boys' age category '14 years' included not only boys aged 14 to 14.5 but also boys 14.5 to 15 years, a clearly unjustifiable assumption. Figure A3 presents the resultant curves.

[Figure A3 here]

This counterfactual indicates that parents systematically putting all girls into factory work at six months below the legal age limits could generate part of the anomalous z-score pattern observed earlier. If this were the case, to systematically single out girls for deliberately placing into arduous physical labour at ages known to be decreed by law to be harmful for the younger child to engage in, must itself constitute a form of exploitation and discrimination being exercised with the household.

Thus we can make the gender gap disappear, but only under conditions of extreme assumptions – pushing down all girls' ages and selectively reclassifying boys. This constitutes torturing the data. We judge this scenario unjustified. Overall, we conclude there is no large systematic bias in the height-for-age data collected by Horner that affects one sex more than the other, but we acknowledge the possibility that there may have been some age-lying around crucial thresholds even if it is difficult to detect. We test for the effect this would have on the results we report and still find no effect.

### A2.3 Age-deception and resultant HAZ

Under two sets of strong assumptions about selective age deception the significant difference in girls' and boys' z scores remain.

We have noted the possibility that parents may have lied about their children's ages particularly around the age of entry to factory work and at the 12 hour day threshold. Here we examine whether age-lying could be generating the z-score patterns we observe. We assume no gender specific incentives to lie about age (see pp.**). By looking at the $WHO_{2007}$ percentiles of height by age we can predict the percentage of younger children today who would exceed the median height of those 6 to 18 months older. Specifically, 20% of boys aged 8.0 would pass as age 9.0 and 9% pass as age 9.5, 32% of those aged 8.5 would pass as age 9 and 20% would pass as age 9.5. Averaging these percentages suggests that about 20% of 8 year old boys could pass as age 9 based on their heights. We calculate the percentages for other groups using the same method.

[Table A2]

On the assumption that factory surgeons had wanted children to look at least the right height for the age group, we could assume the above percentages in Horner's survey had, in fact, elevated their ages. We now adjust their ages downwards and recalculate the z-scores based on the 'correct' age for these groups of children. We consider the pattern of these adjusted z-scores to see whether age-lying might be generating the pattern of results observed.

We use two different assumptions to select those children whose ages are to be reclassified (a) by reallocating the relevant percentage of children from the older to the younger age group randomly (b) by assuming the very tallest in the older age height distribution have lied about their and so reassign these children to the lower age group. This would be an extreme, and unlikely, representation of the misrepresentation of ages, leaving only those who were relatively short for their age in the older group. A realistic picture lies somewhere between the two methods used here.

Table A3 presents the regression results of HAZ on the whole year ages and for the reassigned age and related z-scores. The regression results show that under both age-lying scenarios, girls continue to have HAZ scores that are generally significantly below those of boys and the depth of the downturn in girls' z scores remains although in neither case is the double U shape as distinctive as found with the original data (figure A4 ).

[Table A3 here]

[Figure A4 here]

Overall, we conclude that the pattern of greater female deprivation is replicated and the evidence of gender bias against girls in this factory population remains robust even to quite extreme misclassifications of age in the original data. Age-lying is not generating the results we observe.

## Appendix 3: Was the supply of children to the labour market differentiated by gender?

A final area of possible gendered sample-selection bias in the height-for-age data is in the type of children found working in factories. Specifically, did only exceptionally poor families send girls to work in factories? If this were the case we would expect girls to have lower HAZ scores at all ages, instead young boys and girls in the sample exhibit similar levels of deprivation. Similarly were girls only sent to work in factories if household structure dictated, for instance if girls' work was necessary to shore up income only in the absence of working older brothers? In both cases it would suggest that we might see only particularly disadvantaged girls in the factory sample. The data collected by Horner has no information on the family circumstances of these children, but we can again bring an alternative source of household data to bear.

Censuses of the Poor were used to inform the Poor Law guardians about the potential claims on Parish resources. Generally they excluded those already dependent on relief and focussed on those who were on the margins of poverty: the aging, the infirm and those with young families. Maybe ten per cent of the population received some poor relief in the course of a year (Lindert 1998 pp.110-11) and many more would claim at some point in their lives, so these surveys covered large sections of the population and reflected the circumstances of ordinary working families, just those who might send their children into factory work.

We draw on two surviving Censuses of the Poor for townships in Lancashire: Tottington, located two miles from Bury in the west Pennines and surveyed in 1817 and Bedford, situated ten miles west of Manchester and surveyed in 1835-6 (see figure 1). Tottington offered employment in handloom weaving, cotton mills, coal mining and calico printing work. Bedford was initially agricultural but developed spinning and weaving industries in silk and cotton; it also had some mining.[4]These censuses recorded household

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[4] It is difficult to ascertain the proportion of the population surveyed in these areas with any accuracy. Samuel Lewis's *Topographical Dictionary of England* vol IV (1831) p.329 finds 1,728 inhabitants in Tottington higher and a further 7,333 in Tottington lower. The 1817 survey contains over 1,000 individuals. In John Marius Wilson's *Imperial Gazette of England and Wales 1870-72,* Bedford, Lancashire, is listed as having 1,323 houses with a population of 6,558. The Census 35 years earlier captured 60 households containing 330 individuals.

structure, income, and employment for all poor working households and we can use them to examine whether financial necessity or sib-set positioning affected participation and hence, by implication, the likelihood of girls from particularly poor families being found in the factory data.

Taking only those households containing a man, his wife and their children demonstrates much similarity in the circumstances of girls and boys found working (Table A4). In both surveys just over one quarter of children worked, the proportions working were very similar for girls and boys in 1836 Bedford, but girls were slightly less likely to be working (although not significantly so) in 1817 Tottington. No significant differences by whether children worked or by gender were found in paternal earnings, nor in whether mothers worked or for total household income. Consideration of household structure also reveals very little difference between those girls and boys who were working. In the surveyed households girls were as likely to be found working as boys and there was little to differentiate between those girls and boys who were found in the labour market.

[Table A4 here]

We use the Tottington survey to extend the analysis to consider the probability of any individual girl or boy working, using a probit regression of participation against the standard economic variables: own wage and other household income. As we are more concerned with the interactions with who is working in the household rather than responsiveness to each pound they contribute, we take the monetary value of father's earnings only but use dummy variables for whether the mother works, other income received such as a parish payment, and lodgers in the household, and include the numbers of older brothers and of older sisters who were working. We also control for a parent or sibling being ill, both of which are expected to precipitate the child into employment. To examine the sibset effects we include the number of older and younger, male and female siblings. A dummy variable is included if the child we are considering is female and this is interacted with the mother working, sibset structure and sibling working variables to determine whether household structure had a different effect on the participation of daughters compared with sons. To proceed we need to predict a wage for all children of working age. We do this by regressing the earnings for those working on age, a female dummy variable and an interacted female age variable for those aged 6 and upwards. Children under this age were never reported as working so were excluded from the subsequent analysis as being ineligible to work. A Heckman two-stage procedure was used to capture the effect of unobserved characteristics of workers on the wage they commanded.

[Table A5]

The regression reveals standard economic variables, such as own wage and the income of others, operating in the expected directions on child's participation. All children were more likely to work if they had younger siblings and if they had older brothers working. The only independent effect for girls was an increased likelihood of working if they already had older sisters in the labour market. This may reflect the availability of jobs for girls in the local labour market but may also intimate that undertaking work was more respectable when older family members were also present (Horrell and Humphries 1995, pp.501-2, p.509).[5]

There is no evidence here that girls were more protected from working than their brothers. As found elsewhere, children, both boys and girls, tended to be put to work as soon as they were old enough to do the jobs available and were all expected to contribute to the household's coffers (Horrell and Humphries 1995). This gives no reason to think that the home environments differed substantially between the boys and girls that Horner observed working in factories.

## Appendix 4: Factory workers' food consumption from household budgets

There are 11 budgets for households with children working in factories in Manchester and West Yorkshire for the early 1840s: BPP (1842) Children's Employment Commission, BPP (1843) Children's Employment Commission (Horrell and Humphries 1992).

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[5] A similar regression was performed for the 1836 survey but here the lower number of observations meant it was less well specified. The only significant effect on children's participation once a wage had been imputed was the restraining effect of younger siblings on girls' participation. May be girls were kept from work if they could be usefully engaged in childminding, a role which may have been correlated with the particularly high level of mothers' participation in this survey.

The fathers worked as spinners, combers, weavers, and handloom weavers but the children all worked in factories. The types of jobs they did were cardsetter, piecer, winder, comber, weaver, and spinner. We convert the food purchased by each household to calorie and protein availability[6] and use an equivalence scale to adjust for the age composition of the household.[7]

[Table A6]

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[6] The conversion of expenditure to quantities purchased uses retail prices in Manchester in 1841 from Neild (1842, t.3 p.332), supplemented by Smith (1865 p.235) for cheese, eggs and beer. McCance and Widdowson (1991) is used to convert the quantities into kilocalories and grammes of protein.

[7] Man = 1.00; woman 0.90; child aged 11-14 0.90; aged 7-10 0.75; aged 4-6 0.40 and aged 1-3 0.15 (US Congress 1891 p.621).

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APPENDIX TABLES

Table A1 Average height by age (P.P. 1837 (99) Factory Children) (in inches)

| Age band | Stanway Non-factory 1833 | Stanway Factory 1833 | James Harrison (Preston) 1834 | Robert Baker (Leeds) 1836 | Horner 1836 | Horner (large towns) 1836 | Roberts 1876 |
|---|---|---|---|---|---|---|---|
| | Girls' Heights | | | | | | |
| 8 to 9 | | | | | 45.7 | 46.2 | 46.5 |
| 9 to 10 | 48.4 | 48 | | 48.3 | 47.7 | 47.7 | 48.4 |
| 10 to 11 | 49.4 | 49.6 | | 49 | 49.4 | 49.1 | 49.9 |
| 11 to 12 | 52.1 | 51.2 | 51.3 | 50.3 | 50.7 | 50.4 | 51.7 |
| 12 to 13 | 53.7 | 53.7 | 53.8 | 52.3 | 52.2 | 51.6 | 53.2 |
| 13 to 14 | 55.1 | 55.6 | 55.3 | | 53.9 | 53.3 | |
| 14 to 15 | 58.2 | 57.7 | 57 | | 56 | 55.7 | |
| 15 to 16 | 59.2 | 58.5 | 58.8 | | | | |
| 16 to 17 | 58.1 | 59.8 | 59.5 | | | | |
| 17 to 18 | 60.8 | 60.4 | 60 | | | | |
| 18 to 19 | | | | | | | |
| | Girls' HAZ | | | | | | |
| 8 to 9 | | | | | -2.3 | -2 | -1.9 |
| 9 to 10 | -2 | -2.2 | | -2.1 | -2.3 | -2.3 | -2 |
| 10 to 11 | -2.5 | -2.4 | | -2.7 | -2.5 | -2.6 | -2.3 |
| 11 to 12 | -2.3 | -2.7 | -2.7 | -3 | -2.9 | -3 | -2.5 |
| 12 to 13 | -2.6 | -2.5 | -2.5 | -3.1 | -3.1 | -3.3 | -2.7 |
| 13 to 14 | -2.7 | -2.4 | -2.6 | | -3.1 | -3.3 | |
| 14 to 15 | -1.9 | -2.1 | -2.3 | | -2.6 | -2.7 | |
| 15 to 16 | -1.7 | -2 | -1.9 | | | | |
| 16 to 17 | -2.3 | -1.6 | -1.7 | | | | |
| 17 to 18 | -1.3 | -1.4 | -1.6 | | | | |
| 18 to 19 | 0.2 | -0.6 | | | | | |
| N | 201 | 652 | 702 | 173 | 8041 | 1653 | 5000 |
| | Boys' Heights | | | | | | |
| 8 to 9 | | | | | 46.3 | 46.4 | 46.9 |
| 9 to 10 | 48.6 | 48.1 | | 47 | 47.9 | 48 | 49 |
| 10 to 11 | 50.7 | 49.8 | | 50 | 49.3 | 49.4 | 50.6 |
| 11 to 12 | 51 | 51.3 | 50.5 | 50 | 50.7 | 50 | 52.1 |
| 12 to 13 | 53 | 53.4 | 51.5 | 52.5 | 52.1 | 51.1 | 53.8 |
| 13 to 14 | 55 | 54.5 | 54 | | 53.5 | 53 | 55 |
| 14 to 15 | 56.6 | 56.6 | 56.3 | | 55.8 | 55.1 | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 15 to 16 | 58 | 59.6 | 58.5 | | | | |
| 16 to 17 | 63.2 | 61.6 | 60.5 | | | | |
| 17 to 18 | 64.1 | 62.7 | 60 | | | | |
| 18 to 19 | 69.9 | 63.3 | | | | | |
| | Boys' HAZ | | | | | | |
| 8 to 9 | | | | | -2.1 | -2.1 | -1.8 |
| 9 to 10 | -1.9 | -2.1 | | -2.6 | -2.2 | -2.1 | -1.7 |
| 10 to 11 | -1.8 | -2.1 | | -2 | -2.3 | -2.3 | -1.8 |
| 11 to 12 | -2.4 | -2.3 | -2.6 | -2.7 | -2.5 | -2.7 | -2 |
| 12 to 13 | -2.5 | -2.3 | -3 | -2.6 | -2.8 | -3.1 | -2.2 |
| 13 to 14 | -2.6 | -2.8 | -3 | | -3.1 | -3.3 | -2.7 |
| 14 to 15 | -2.9 | -2.9 | -3 | | -3 | -3.2 | |
| 15 to 16 | -3 | -2.5 | -2.9 | | | | |
| 16 to 17 | -1.8 | -2.3 | -2.7 | | | | |
| 17 to 18 | -1.7 | -2.2 | -3.1 | | | | |
| 18 to 19 | 0.2 | -2.1 | | | | | |
| N | 227 | 410 | 636 | 154 | 8361 | 1659 | 6000 |

Shaded cells indicate the first age where a full 12-hour day could be worked.
Stanway BPP (1833); Harrison and Baker in Horner BPP (1837); Roberts (1876)

Table A2: Percentage of $WHO_{2007}$ exceeding the median stature of those 6-18 months older

| $WHO_{2007}$ | boys | girls |
|---|---|---|
| % age 8 pass as age 9 | 20 | 15 |
| % age 11 pass as age 12 | 18 | 15 |
| % age 12 pass as age 13 | 11 | 24 |

Table A3 Regression of z-score before and after reclassification of children's ages to account for the possibility of age-lying
(age in whole years)

| | Z score Original data | | Z score Random reclassification | | Z score Tallest have age reclassified | |
|---|---|---|---|---|---|---|
| | *β* | *t* | *β* | *t* | *β* | *t* |
| Constant | -3.180 | -118.3** | -3.180 | -114.5** | -3.180 | -109.1** |
| Age 8 | 1.056 | 25.2** | 1.232 | 30.6** | 1.542 | 36.8** |
| Age 9 | 0.989 | 26.0** | 0.970 | 23.2** | 0.627 | 14.1** |
| Age 10 | 0.873 | 23.3** | 0.873 | 22.6** | 0.873 | 21.5** |
| Age 11 | 0.695 | 19.4** | 0.831 | 23.7** | 1.062 | 28.8** |
| Age 12 | 0.406 | 11.7** | 0.494 | 13.7** | 0.583 | 15.5** |
| Age 13 | 0.052 | 1.6 | 0.058 | 1.7 * | -0.188 | -5.2** |
| | | | | | | |
| F x age 8 | -0.128 | -2.7** | -0.137 | -3.1** | -0.145 | -3.2** |
| F x age 9 | -0.122 | -3.1** | -0.107 | -2.4** | -0.044 | -0.9 |
| F x age 10 | -0.181 | -4.9** | -0.181 | -4.8** | -0.181 | -4.6** |
| F x age 11 | -0.395 | -11.3** | -0.363 | -11.5** | -0.421 | -12.5** |
| F x age 12 | -0.310 | -9.8** | -0.151 | -4.9** | 0.006 | 0.2 |
| F x age 13 | 0.063 | 2.5** | 0.034 | 1.1 | -0.202 | -6.3** |
| F x age 14 | 0.475 | 12.7** | 0.475 | 12.3** | 0.475 | 11.8** |
| | | | | | | |
| N | 16402 | | 16402 | | 16402 | |
| Adjusted $R^2$ | 0.155 | | 0.153 | | 0.252 | |
| F | 231.6** | | 228.9** | | 426.5** | |

t-ratios in parentheses
** indicates significance at 5% level or above
Source: data from Kirby (2010) BPP (1837)

Table A4 Household structure and children's labour force participation rates as revealed by Censuses of the Poor

| | 1817 Tottington, Lancashire | | | 1835-6 Bedford, Lancashire | | |
|---|---|---|---|---|---|---|
| | Boys | Girls | Sig. test[a] | Boys | Girls | Sig. test[a] |
| No. in whole sample | 320 | 299 | | 122 | 98 | |
| % sample | 51.7 | 48.3 | | 53.3 | 46.7 | |
| % working[b] | 26.9 | 21.6 | $X^2$ 2.27 (0.14) | 27.5 | 28.7 | $X^2$ 0.036 (0.85) |
| Minimum age found working | 6 | 6 | | 9 | 9 | |
| Average earnings of father (£ per week): | | | | | | |
| Child working | 0.457 | 0.464 | | 0.488 | 0.484 | |
| Child not working | 0.492 | 0.474 | Anova F 72.43 (0.12) | 0.490 | 0.492 | Anova F 0.021 (0.89) |
| % mothers working | | | | | | |
| All children | 37.2 | 33.8 | $X^2$ 0.78 (0.38) | 53.2 | 53.2 | $X^2$ 0.01 (0.94) |
| Working children | 18.5 | 20.0 | $X^2$ 0.24 (0.62) | 43.3 | 59.3 | $X^2$ 1.15 (0.28) |
| Total income all others in household (excluding own earnings) (£) | | | | | | |
| Child work | 0.903 | 0.915 | t-test -0.15 (0.88) | 0.858 | 0.879 | t-test -0.39 (0.70) |
| Child not work | 0.885 | 0.883 | t- test 0.21 (0.84) | 0.910 | 0.938 | t-test -0.24 (0.81) |
| t-test | -0.42 (0.68) | -0.66 (0.51) | | 0.66 (0.51) | 0.79 (0.43) | |
| Children working only | | | | | | |
| Mean age | 12.38 | 11.89 | t-test 0.92 (0.36) | 13.37 | 13.89 | t-test -0.96 (0.34) |
| No. in household – range | 4 - 11 | 3 - 11 | | 7 - 11 | 7 - 11 | |
| No. in household – mean | 8.39 | 8.36 | t-test -0.68 (0.50) | 8.62 | 8.41 | t-test 0.83 (0.41) |
| Household structure | | | | | | |
| No. younger siblings | 4.49 | 4.65 | -0.55 (0.58) | 4.80 | 4.74 | 0.19 (0.85) |
| No. older siblings | 0.93 | 0.92 | 0.53 (0.96) | 0.83 | 0.67 | 0.74 (0.47) |
| No. older siblings – female | 0.42 | 0.48 | -0.53 (0.60) | 0.47 | 0.22 | 1.96 (0.06)* |

| | | | | | | |
|---|---|---|---|---|---|---|
| No. older siblings – male | 0.51 | 0.43 | 0.55 (0.58) | 0.37 | 0.56 | -1.04 (0.30) |
| No. younger siblings – female | 2.28 | 2.20 | 0.38 (0.71) | 2.30 | 2.26 | 0.13 (0.90) |
| No. younger siblings - male | 2.21 | 2.45 | -1.03 (0.30) | 2.50 | 2.48 | 0.06 (0.95) |
| No. older brothers working | 0.48 | 0.42 | 0.51 (0.61) | 0.37 | 0.33 | 0.21 (0.83) |
| No. older sisters working | 0.35 | 0.38 | -0.37 (0.71) | 0.47 | 0.30 | 1.23 (0.23) |

Notes:
[a] significance level in parentheses
[b] children in households where a parent is stated as old or ill are excluded from this and the subsequent analysis
Source: Tottington, Lancashire – A survey of the poor, 1817; Survey of the poor of Bedford Township, 1836.

Table A5. Regression analysis of children's participation, Tottington, 1817
(method: probit model with Heckman sample selection)

| | $\beta$ | $z$ |
|---|---|---|
| *Earnings:* | | |
| Age | 0.016 | 6.42** |
| Female | -0.203 | -2.07** |
| F x age | 0.036 | 2.58** |
| F x age$^2$ | -0.0015 | -3.15** |
| Constant | 0.049 | 1.48 |
| *Child works (0,1):* | | |
| Age | 0.342 | 5.08** |
| Female | -3.084 | -2.12** |
| F x age | 0.491 | 2.25** |
| F x age$^2$ | -0.025 | -3.56** |
| | | |
| Father's earnings (£) | -1.392 | -2.33** |
| Mother works | -0.349 | -1.06 |
| unearned income | -0.543 | -3.78** |
| Lodgers | 0.271 | 0.65 |
| No. in household | -0.785 | -2.75** |
| Younger siblings – female | 0.971 | 3.04** |
| Younger siblings – male | 0.783 | 2.59** |
| Older brothers working | 0.588 | 1.72** |
| Older sisters working | 0.511 | 1.47 |
| Sibling ill | 0.644 | 1.10 |
| Parent old/ill | 0.264 | 0.61 |
| F x mother work | -0.026 | -0.06 |
| F x Younger siblings – female | -0.051 | -0.27 |
| F x Younger siblings – male | 0.198 | 1.05 |
| F x Older brothers working | 0.008 | 0.03 |
| F x Older sisters working | 0.479 | 1.73* |
| Constant | 0.194 | 0.16 |
| | | |
| $\lambda$ | -0.038 | |
| N observations | 319 | |
| Wald $\chi^2$ | 49.3** | |

** p Z significant at 0 to 5% level, * p Z significant at 5 to 10% level
Source: as table A4.

Table A6 Regression analysis of factory workers' food consumption

| | Calories | | Protein | |
|---|---|---|---|---|
| | Per capita | Adult equivalent | Per capita | Adult equivalent |
| Constant | -2654.46<br>(-0.88) | 2315.35<br>(3.20)* | -632.10<br>(-0.73) | 67.55<br>(3.68)* |
| Total household income | 48734.53<br>(1.94)$^x$ | 276.03<br>(0.47) | 1596.17<br>(2.40)* | 13.10<br>(0.88) |
| No. in household | 5828.68<br>(0.98) | | 260.05<br>(1.65) | |
| % household members work | 219.74<br>(0.54) | -1.44<br>(-0.13) | 8.23<br>(0.76) | 0.04<br>(0.13) |
| % household members female (as a proportion of adult equivalents) | -180.78<br>(-0.41) | -1.01<br>(-0.08) | -7.97<br>(-0.68) | -0.11<br>(-0.32) |
| | | | | |
| Adjusted $R^2$ | 0.59 | -0.38 | 0.75 | -0.25 |
| Sample size | 11 | 11 | 11 | 11 |
| F | 4.56$^x$ | 0.08 | 8.67* | 0.34* |

*Indicates significance at 5% level or higher, x at 10% level, t-ratios in parentheses.
Source: Horrell and Humphries (1992), see text

# APPENDIX FIGURES

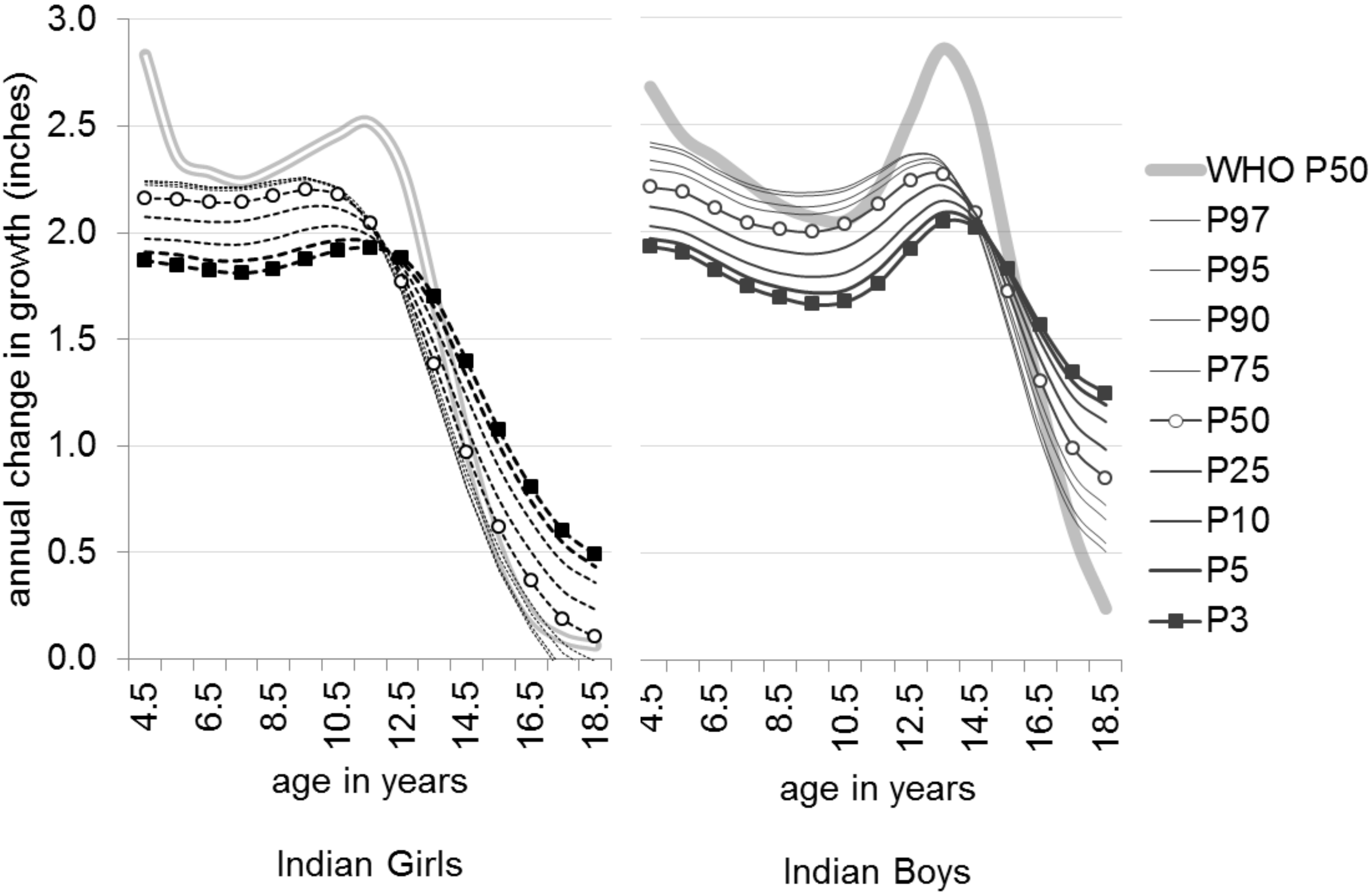


Figure A1. Annual growth intervals of Indian schoolchildren, 2006-9, and $WHO_{2007}$

Source: Data from Marwaha et al (2011)

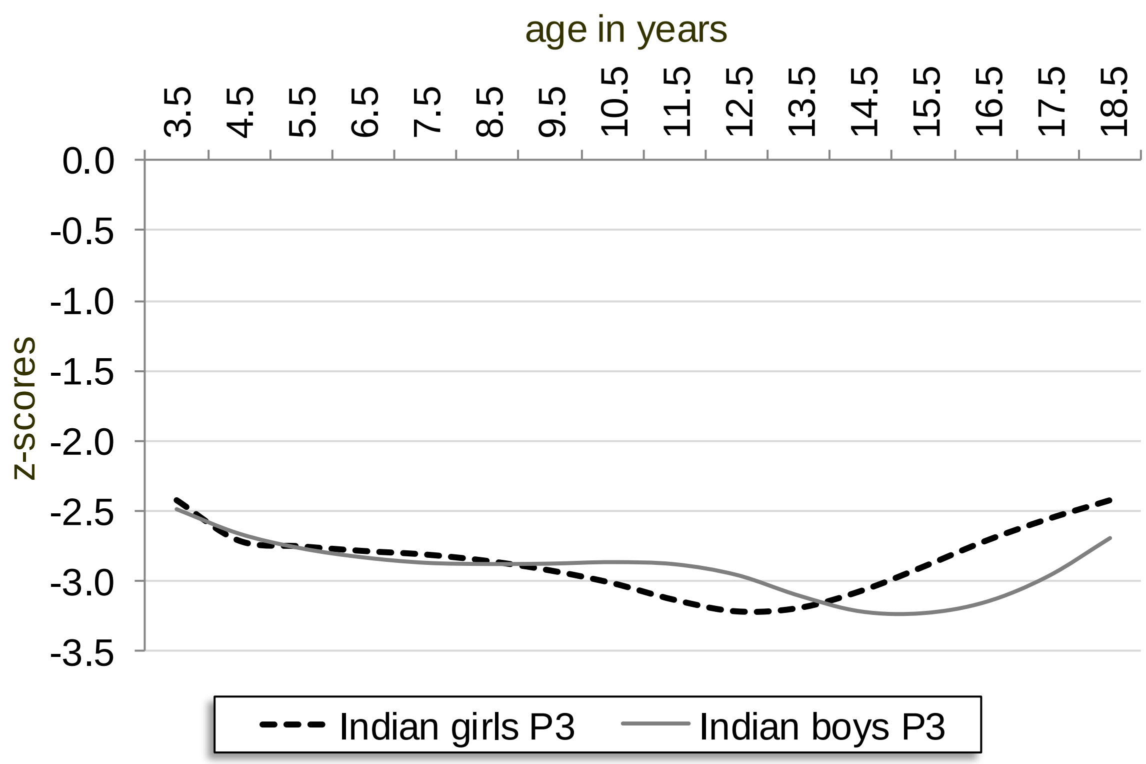


Figure A2. HAZ of Indian school children, 2006-9, at the third percentile

Source: Data from Marwaha et al (2011)

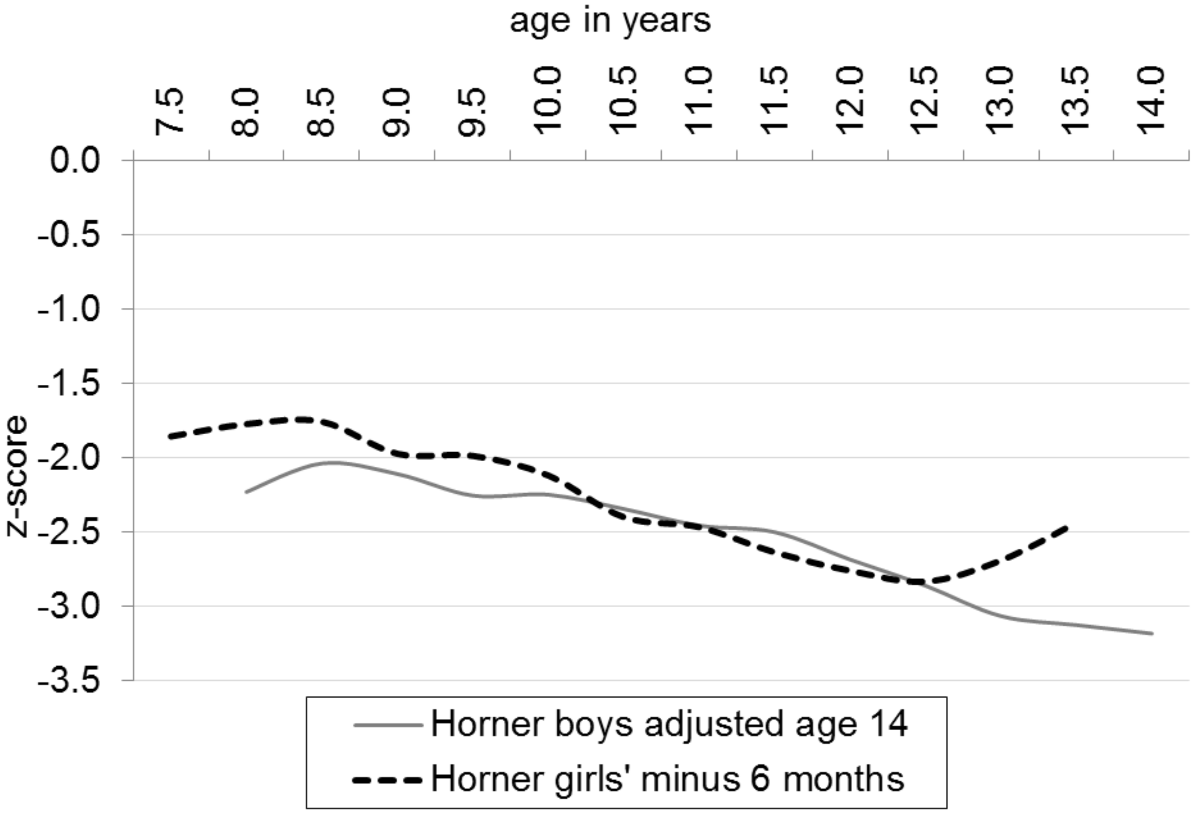


Figure A3. Factory children HAZ under conditions of female age deception & male misclassification at age 14 years

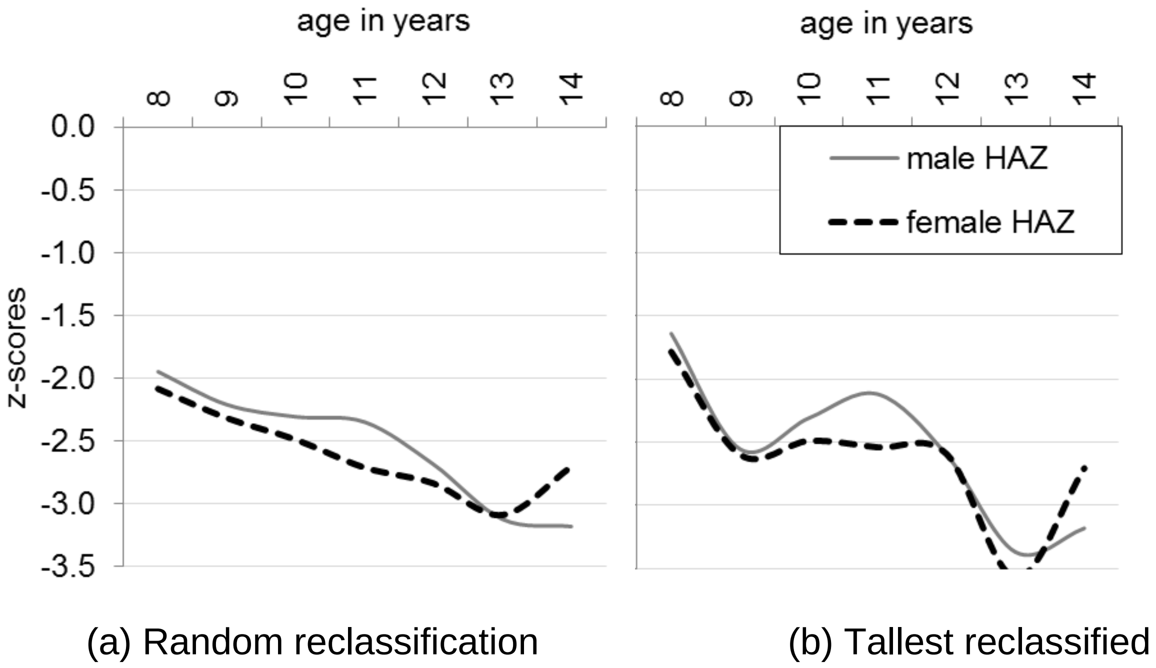


Figure A4. HAZ under age reclassification

# Gender bias in nineteenth-century England: evidence from factory children

## 1. Introduction

The existence of gender bias has been of interest to development economists and historians alike. While unequal treatment of girls is evident in a number of countries today, there is less certainty about whether it existed in the industrialising countries of the past. Evidence for nineteenth-century British households has been mixed. Reduced employment opportunities for women and girls over the course of industrialisation have been linked to poorer treatment within the household as a result of their diminishing contribution. Some findings point in this direction: declining opportunities to provide resources through agricultural labour, gleaning and common rights may have worsened women's nutritional intake in rural areas and was reflected in their declining heights (Humphries 1990; Horrell and Humphries 1997; Nicholas and Oxley 1993); older women suffered higher rates of mortality in rural areas (Humphries 1991; McNay, Klasen and Humphries 2005); and high rates of female mortality have been ascribed to the large incidence of tuberculosis brought about by malnourishment in low female employment areas of Cornwall (Ryan Johanssen 1977). Differences in literacy too suggest bias against females in human capital acquisition. Nationwide while over 60 per cent of men were able to sign their names in the Parish register on marriage in the nineteenth century, this was true for only 43 per cent of women (Schofield 1973 p.453). But here the links with women's economic activity and ability to generate resources for the household are opaque, and may even be inverted; female illiteracy was particularly high in the industrial areas, where more women worked for wages (Sanderson 1972, Laquer 1974). Indeed other evidence induces scepticism about the existence of overt discrimination. Female disadvantage has not been found among medieval and early modern children and the lack of differential mortality observable between girls and boys in more recent times refutes the idea of systematic gender bias (Harris 1998, pp.413-21, 2008, pp.159-69). Closer examination of the possible existence of gender bias in nineteenth-century England is required.

We examine gender discrimination in this period using data on heights of 16,402 children working in factories in the northern textile districts of England collected by Leonard Horner, Inspector of Factories, in 1837, and reproduced in BPP 1837 (99) *Factory Children*, pp.6-11.[1] These height data capture two important elements of welfare: nutrition and work effort.

Height captures cumulative net nutritional status from conception to maturity and reflects nutritional intake and demands on that intake from fighting off disease and physical work effort at a young age. Thus height measures food consumption, admittedly only one aspect of total consumption but probably the most important at this time.[2] Height also captures leisure as the corollary of work, another aspect of welfare in which we are interested. Height is particularly responsive to resources at young ages (conception to two years), and during the adolescent growth spurt, but remains plastic until adulthood. Prolonged catch-up growth can, however, lead adult height to understate disparities experienced in childhood. A more sensitive measure than terminal stature is children's height for age by gender. Happily, we have data for children aged 8 to 14 years old, with equal numbers of boys and girls. These boys and girls have already been compared with each other, and it has been argued that girls and boys were on par (Kirby 2013 p.111-14). Instead we compare factory children's heights with modern standards to see whether girls and boys show equal degrees of stunting as a result of the deprivation experienced in this era and use this as an indicator of the existence of gender bias.

Additionally, Horner's height data are particularly suited for this task as they allow us to control for discrimination in economic opportunity when considering gender bias in treatment. Gender discrimination in access to economic opportunities may lead to observable inequality in outcomes, such as nutrition and longevity. However, it can be argued that this does not necessarily arise because parents endorse inequality; instead allocative decisions within the household can be seen as rational responses to the prevailing opportunities. Specifically, in a simple two-person model of the household that trades off work against leisure, if a boy is able to earn higher wages than a girl and/ or contribute to the household

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[1] We are grateful to Peter Kirby who has expanded and computerised Horner's tabulation of the frequency of each height observation by age. Peter Kirby, The Physical Stature of Children in Northern English Textile Districts 1837. UK Data Archive 2010 SN6426.

[2] Expenditures on, for instance, rent, fuel and maybe even clothing would be small and less likely to be differentiated by gender.

income for a longer period of time then, ceteris paribus, the boy would put more hours into the labour market and, given the objective of achieving equal utility with his sister, would require higher material consumption to compensate for his loss of leisure.[3] Observed higher nutrition for boys, for example, would not necessarily imply higher overall welfare, nor overt discrimination within the household, but differential rewards for greater efforts. Gender bias, on the other hand, can be imputed if parents make allocative decisions within the household that irrationally (non-economically) disadvantage girls in either their consumption of goods or of leisure. To identify gender bias we need to observe the treatment of boys and girls in a setting where their economic opportunities are equivalent, so negating the impact of earning power on intrahousehold distributions. In nineteenth century Britain, rarely did boys and girls have the same economic opportunities but, as we will show below, work in the textile factories of North West England constitutes an exception.

Unfortunately Horner's data does not record the earnings of the children he surveyed so we have to turn to alternative sources to describe earning opportunities of factory children in Lancashire. These demonstrate the atypical similarity in earnings of girls and boys in these occupations. We also use additional sources to consider the economic worth of children to their families. Having established that there is no *prima facie* reason based on economic rationale to expect these girls to be treated differently to boys within their households, we then turn to Horner's height data to establish whether gender bias in outcomes was evident. The height data was collected against the backdrop of regulation of children's hours of work in factories. This legislation not only motivated Horner's survey but also has implications for observed heights at different ages because of changes in the ages for which hours were regulated over time. We thus discuss the provisions of the legislation to understand the potential impact before analysing the height data itself. The data does indeed demonstrate significant gender bias against girls. These nineteenth-century girls fell further behind modern height standards than comparable boys. However, the comparison of the data with modern height standards raises issues about the appropriate yardstick and the impact of gendered height trajectories, in particular changes over time in the onset of puberty and the consequences of this for observed growth at specific ages. We discuss and develop suitable comparators, with supplementary material available online (Appendix 1). Our results continue to indicate considerable disadvantage to female children.

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[3] See Horrell and Oxley (2013) for a formal statement.

The remainder of the paper turns to the source of this bias. An online appendix examines the reliability of the age data and questions whether parents exploited under-aged daughters more than sons, thus distorting recorded heights (Appendix 2). Attention is also paid to whether girls were from poorer families, so invalidating the gender comparison (Appendix 3). Unable to falsify the gender gap, the main body of the paper considers competing explanations for the apparent bias. Again there is no direct data from Horner with which to test these explanations. Instead our discussion relies on supporting evidence from elsewhere and must remain in the realm of speculation. We consider differential access to food as one possibility, different susceptibility to disease environment as another, and systematic differences in physical workload as a third. The discussion of each leads us to conclude that of these candidates through which female disadvantage may operate the most likely was greater work effort than the physical frame allowed. Girls may have been overworked, both relative to their male siblings and in relation to their own physical capabilities. We point up the largest element of this overwork as girls' involvement in housework duties alongside their paid work in the factory. The research here can only provide suggestions as to the source of gender bias but, we hope, will open the discussion and may prompt future research on this aspect of girls' lives.

The conclusions drawn here have relevance beyond the historical. They emphasise the need to appropriately modify height standards to accurately reflect prevailing circumstances when using them to make judgements about welfare and offer an example of how this might be done. They also highlight the importance of incorporating unremunerated domestic work into assessments of welfare, an important element of the type of labour performed by children in many developing countries today.

## 2. The economic worth of girls and boys employed in the northern textile factories

As outlined above, crucial to our analysis of using children's heights to identify gender bias is establishing the comparable economic worth of girls and boys to their families. Fundamental to this is the similarity of earning experience for factory girls and boys. Horner's data only details height by age for the factory children so we turn to alternative sources to establish this experience.

## 2.1 Relative earnings

In 1835, 56,000 children under age 13 worked in textile factories in the UK, constituting about 16 percent of the total textile workforce (Nardinelli 1990 p.4, 68). This employment was concentrated in Lancashire, Yorkshire and Cheshire. Children with fathers in textile factory work were very likely to be working themselves. Fifty five per cent participated in the labour market compared with one quarter of children in families overall in 1817-39 (Horrell and Humphries 1995 pp.492-3). Their contribution to household income could be substantial. Although children in low-wage agricultural households only contributed around 4.6 per cent of total income, they contributed some 28.2 per cent of household income in factory families (ibid p.491).  Children whose fathers worked in outwork or agriculture delayed their entry into the labour force until ages 10 or 11, but those with factory fathers might start work at age 8 (Horrell and Humphries, 1997 p.53). Plentiful work and good earnings meant children were economic assets to these industrial families. But were girls and boys equally valuable?

[Figure 1 MAP here ]

Yes they were, according to two sources of data on earnings collected just a little before Horner's study but covering the same textile factory districts. Figure 1 shows the location of the northern textile districts within England, then, in this region, the location of surgeons who reported height measurements to Horner and the locations of the additional data we use to supplement and verify the height data, such as those textile factories that provided wage data to the Factory Commissioners.[4]

Mr Cowell collected data on earnings, heights and weights of around 1,300 children attending Sunday schools, two in the Manchester area and one in Stockport, and these were tabulated and mean values reported by Samuel Stanway in the Parliamentary Report of 1833 (1833 (450) Factories Inquiry Commission, D.1, pp.87-89). For the 1,133 children working in factories the close correspondence between male and female earnings at each age is evident (Table 1). Although there are just under 200 observations for children in non-factory work,

[4] Digital boundaries are for 1851 and were provided through EDINA UKBORDERS with the support of the ESRC and JISC and uses boundary material which is copyright of the Great Britain Historic GIS Project, Portsmouth University.

the comparisons show the general pay advantage for both boys and girls in Horner's age range (8 to 14) of being in factory work.[5]

[Table 1 here]

How representative were these Sunday school children of factory children more generally? The first Sunday schools were set up by volunteers from the 1780s to enable working children to gain basic literacy skills in an era before compulsory education. They were particularly designed to complement rather than crowd out work and so operated on the day when the factories were closed. Attendance at Sunday schools has been estimated as 1.2 million children by the 1830s. The Stockport school was one of the earliest and largest, set up in 1784 it built a school to hold 5,000 scholars in 1805 and had 5,244 attendees in 1833. Girls and boys were equally represented.[6] Although the majority of these children would have been factory children it is reasonable to think that they may have come from the slightly better-off end of the working class. In her study of boys' autobiographies, Humphries (2010, p.32) finds that nearly one-third of these writers acquired their literacy through Sunday school and attendance had a significant, positive effect above the time spent in schooling on their subsequent (adult) occupational status (ibid, p. 322, p.348).[7]

Paul Minoletti's detailed analysis of the information on earnings, employment and occupation contained in the Factory Inquiry Commission (BPP 1834, XIX, pp.427-435) provides a second source (2011, app. B; 2013). Maybe one quarter of factories made returns and, as this was voluntary, there is a suspicion that the sample favoured larger employers who might have been better placed to make a return, but the coverage is wide and there is no reason to believe that the earnings and relative employment reported were unrepresentative of those in the industry. Indeed, District Commissioners were instructed to visit as many as they could of the smaller factories where many children were likely to be employed (Minoletti 2011, p.37). The jobs done by girls and boys in eight cotton factories are reported. Both were piecers and scavengers for mule spinners and both were weaving on powerlooms. Although it was mainly girls who spun on throstle spinners, some boys were also engaged in this task

[5] Unfortunately in this and other supplementary sources used we cannot test for statistically significant differences by gender as only mean values and sample sizes are reported.
[6] https://en.wikipedia.org/wiki/Stockport-Sunday-School, accessed 30/11/2015.
[7] We later note (online appendix table A1) that the girls in the Sunday school sample are also taller than the factory sample.

(Minoletti 2013, p.139). A summary of the information extracted from the Report shows the broad similarity in wages by gender from ages 8 to 14 for Lancashire cotton factories and West Riding woollen mills (Table 2). Indeed, girls' pay often slightly exceeded that of boys, this has been attributed to differences in the quality of cloth produced (Pinchbeck 1977, pp.192-4). In both the cotton and woollen industries girls' and boys' wages were similar until age 15, then pay for females fell rapidly behind. This gender wage gap has been variously attributed to different physical strengths (Burnette 2008 pp.138-53, 172-85), protection of male jobs by trades unions (Clark 1995, p.134) and women being denied access to supervisory roles or jobs which required recruitment, payment or supervision of assistants because of a prevailing ideology which rejected female authority over other workers (Minoletti 2013). Girls working with flax fared less well, achieving parity only at very young ages, although wages for girls remained comparable with those in the other textiles industries. Although English flax production was largely concentrated in Yorkshire and was a particularly female-dominated industry, flax employed fewer than ten percent of the number of girls employed in cotton in 1847 (BPP 1847, pp.610-14, quoted in Minoletti 2011, p.5. n.17). Generally, for the ages for which we have heights data (8 to 14 years), girls' and boys' pay in the textile factories was broadly equivalent.[8]

[Table 2 here]

## 2.2 Economic worth of children to their families

However, economic value to the family, and hence treatment, will depend on 'lifetime' (defined as time within the familial home) contribution to the household (Anderson 1971). Boys earned more than girls in all three industries from age 16 so they may have been considered more valuable assets to their parents. But the overall value will depend on the probability of achieving those higher earnings, the value of alternative options, and the length of time the child remained in the household.

The longer working life of adults precluded the absorption of all factory children into adult jobs (Nardinelli 1990, p.106). The limits of demand meant attrition for both sexes. Although boys could earn more than girls from the age of 15 they also suffered rapidly

[8] This parity appears unusual. Girls in the woollen industry in Gloucestershire and Somerset achieved only 88-94% of boys' wages at these ages (Minoletti 2011, A3, A4). Unfortunately there is little on the earnings of children by gender in other occupations.

declining employment opportunities relative to females in these factories (Table 2). In 1835 boys aged 13 and over and men constituted 38 percent of the textile factory labour force, females in the same age range made up 47 percent (Nardinelli 1990, p.106). For instance, despite high wages, limited job opportunities meant that adult males accounted for only 6 percent of the workforce in Bradford's worsted factories in 1833 (Koditschek 1990, p.360). Women tended to leave the factory labour force around ages 22 to 24 (Minoletti 2013, pp.137-8), consistent with marriage and setting up their own households for many. Young men left to pursue other occupations (Nardinelli 1990, pp.89-90). Maybe as few as one third of the boys would go on to achieve higher earnings than their sisters through factory work. But boys' outside options may not have been unfavourable (Table 1). For girls there was no relative earnings incentive to move into non-factory work but for the older boys in the, admittedly small, Sunday school sample (84 boys in non-factory work) it would appear that slightly better earnings could be had elsewhere. However, we should question the representativeness of this Sunday school sample. Whereas there is little reason to believe that the socio-economic background would differ between boys and girls within the sample, there is reason to suspect that Sunday school attendees may have come from a better-off end of the working population. Their earnings in factory work were considerably higher than those reported in the Factory Inquiry Commission and the occupations listed for the seventeen-year old non-factory boys indicates the same bias: bleacher, painter, joiner, grocer, farmer's servant, machine maker, wire drawer, tailor, brush maker, flour dealer, handloom weaver, brazier, hatter and silk weaver. Is it reasonable to expect boys who had spent their early years in arduous factory work to then be able to enter these more select trades? Probably not. Outside options were more likely unskilled or semi-skilled manual work, offering lower pay than that available in the factories and so reducing any 'lifetime' income advantage boys might have over their sisters. Jane Humphries' (2010, pp.231-2) analysis of working class autobiographies finds that boys working in factories as piecers or cardroom hands reported wages of between 1s 6d and 6s per week, comparable with the range observed in Table 2 here, but those engaged in non-textile work earned only 1s 1d to 3s 6d per week and those in casual work, including delivery and shop boys, only 1s 6d to 3s per week. Particularly prosperous opportunities were available only to the small proportion of boys that remained in factory work.

Of course, boys may have contributed resources to the household for longer than their sisters, thus making their 'lifetime' contribution more valuable. We only have evidence from a later period but the analysis of information on industrial workers' families in Britain collected by the US Bureau of Labor in 1889-90 revealed both boys and girls in textile families being equally likely to remain within the household and to both have an estimated average age of leaving home of 19.2 years old (Horrell and Oxley 1999, pp.515-16). This contrasted with the earlier exit of children of both sexes in metal working families and girls in mining families. Overall then there is little reason to believe that sons were any more valuable to these factory families than were daughters. Indeed, we should note that early years investment in any child offered a very uncertain return in the high mortality environment of the second quarter of the nineteenth century. Furthermore, in the crucial years for the impact of net nutritional status on height, mortality and morbidity (ages 0 to 2) boys had a large mortality disadvantage. Nationwide mortality per thousand was 136.3 for girls in their first year of life, compared with 151.3 for boys in 1825-37 (Harris, 2008, pp.157-204). In large towns the disadvantage was even more pronounced and was not reversed until after age 14.

Boys and girls in the factory districts were starting work around the same age, were engaged in similar tasks, received near equivalent remuneration until age 15, and were very probably equally valuable to their families subsequently. Any differences in treatment at young ages cannot be attributed to any economic rationale, instead they could be indicative of culturally deep-seated gender bias.

## 3. The height data

We now use the height data collected by Horner to investigate whether there is evidence for gender bias in this measure of outcomes. But first we explain the legislative background to Horner's study and describe the staged introduction of protection, which has implications for how we interpret our results.

### 3.1 The legislative background

The main regulation of employment in factories in this period came from the Factory Act 1833. Although previous legislation had been enacted, it related only to cotton mills and, initially, apprentices. The Health and Morals of Apprentices Act 1802 limited the working hours of apprentices aged under 21 in cotton mills to 12 hours per day. The Cotton Mills and Factories Act 1819 extended this to all child employees aged 9 to 16 and precluded the employment of any child under 9 years of age in cotton mills. Notably parents were responsible for verifying the child's age. Subsequent amendments to this Act were made in 1825, 1829, and 1831 with the main provision of the last being the outlawing of nightwork for people under 21. But the substantial extension of regulation came with the Factories Regulation Act 1833, 3 and 4 Will. IV. c.103 (Labour of Children, etc., in Factories Act 1833 (Althorp's Act)). This extended coverage of textile factories from cotton to also encompass wool and flax (silk remained exempt), outlawed the employment of children under 9 in the textile factories; ensured children aged 9 to 12 worked no more than nine hours per day and no more than 48 hours per week and additionally insisted on two hours of education per day for this age group; children aged 13 to 18 were not to work more than 12 hours per day; no child under 18 was to work at night (8.30pm – 5.30am); and for those working a 12 hour day an additional 1½ hours were to be allocated for meals. The Act came into effect 1st January 1834.

However, the 9-hour day restriction was phased in: from the passing of the Act on 29th August 1833 there would be six months grace on the employment of 9 and10 year olds, 18 months for those aged 11, and 30 months before the Act applied to 12 year olds. Thus it was not fully operational until March 1836. Among the children in Horner's study, measured in later 1836, those aged 9 to 11½ had the full benefit of the Act, in theory at least never working more than nine hours per day. Children 12 to 13, if continuously employed in factories, would have experienced (progressively more of) the 12-hour regime; while those aged 13½ and 14 received no protection at all from this legislation. Such varied workloads may have adversely influenced growth  and could account for some anomalous patterns we identify, especially in growth intervals between ages. Therefore the paths we describe should not be thought of as the trajectory a single child would traverse, but should be considered in cross-section by age. Importantly, our concern is with gender comparison and whether boys and girls were equally affected.

As these regulations were age based, the determination of the age of working children became critical. Prior to the certification of births from 1837 the nearest proof of age was from baptism but there was no requirement to baptise and it was not practiced on young children by many non-conformist religions, so parental honesty often had to be relied upon. Parents had an incentive to pass their children off as older than they were either to gain employment before age 9 or to be allowed to do a full 12-hour day before age 13. Employers seeking child workers likewise had an incentive to collude. The 1833 legislation changed the onus for verification from the parent to the employer who was required to use a surgeon to certify the child's age. These surgeons were local, often the General Practitioner and, it is thought, willing to collude in certifying older ages (Kirby, 2013, pp.105-6). To monitor their honesty, the legislation also provided for routine inspection of factories and appointed four inspectors, to cover (rather ambitiously) some 4000 mills. This only changed with the Factories Act 1844 which allowed the inspectors to appoint certifying surgeons.

## 3.2 Motivation for collection of the height data

Leonard Horner, appointed Inspector of Factories, was concerned about the amount of deception practised in the certification of children's ages. Mr Harrison, a factory surgeon who had undertaken an earlier study of Preston in 1834, had alerted Horner to the difficulty of getting at the real ages of children below the limit at which they could legally work 12 hours: 'With respect to such children the truth is very rarely told, and most every conceivable expedient is adopted to produce an erroneous impression on the minds of the surgeons' (BPP 1837 (99) p.3). Horner saw the need to develop a clearer standard for what the Act described as 'the ordinary strength and appearance' of children at different ages. For this he turned to an empirical study of stature.

It is against this backdrop that Horner collected the heights data published in March 1837. He wanted to enable Factory Medical Inspectors to use stature to accurately judge the age of children thus preventing the employment of those deemed too young. An international search for a standard proved useless (ibid, p.2). To create an applicable standard, on the 12th October 1836, Horner requested the surgeons to volunteer some of their leisure time to undertake an additional survey. They were required to make returns of children's heights by age, specifying they should

> confine the observation to the children of the working classes; to measure only those whose real ages can be ascertained with tolerable certainty; to distinguish the males and females; to exclude those who are not in an ordinary state of health, and to distinguish the measurements by differences of half-years (Horner, BPP 1837 (99) p.2).

Observations were recorded for those aged from 8 to 14, and the data were also classified by the location of the surgeon: large town, small town and rural district (see figure 1).[9] The large

[9] Sample: 8041 girls (49% of total sample), 20.6% large, 38% small, 41.4% rural; and for 8361 boys 19.8% large, 36.6% small and 43.5% rural.

towns covered were Leeds, Manchester, Bolton, Halifax, Preston and Stockport. The children do largely seem to be factory children. Kirby (2013 p.111) considers them all to be applicants for factory work and a careful reading of the report partly corroborates this view. Horner notes (1837 (99) p.5) ‘The measurements were confined, I believe, to the children of the working classes, but not exclusively to those employed in factories’ (hence the under 9s). Some may have had other occupations, but it is impossible to discern which children. The observation that, ‘Many factories being situated in the vicinity of the smaller towns, the persons employed in them partake, in some degree, of the character of a rural population’ (ibid p.5) again endorses the idea that these were largely children measured for factory work. It is thought that the measurements were taken at the time of applying for a factory job, which could be at any age. They may also have included those already in situ: Horner’s advertisement issued in 1836 stated that without a certificate “No child between 9 and 13 years of age can be employed, or even allowed to remain, in such factory”, which reiterated the ruling made in the 1833 Act.[10] Some pre working-age children were also measured.

### 3.3 Gender discrimination as indicated by the height data

Horner’s data on heights (Table 3) shows girls to be taller than boys from the age of about 10.5 to age 14.0, significantly so from age 13.[11] On the face of it, the greater height of girls would appear to argue against gender bias in Horner’s factory sample. A similar difference came as a surprise to Harrison when he examined his Preston data and he wrote to Horner:

> The most remarkable feature of the present table is, that the average height of the females examined, with two exceptions, exceeds that of the males. This is a result for which I was not prepared, and …. it would seem to indicate that between the ages of 11 and 16 the growth of the female is more rapid than that of the male.[12]

Harrison’s surprise at girls growing taller implies widespread experience of excessive female stunting and bespeaks how differently contemporaries understood human growth.

[Table 3 here]

Girls *should* be taller than boys at certain ages (today around 9 to 13.5 years). This is down to puberty. The differential timing of puberty, and the rapid phase of growth that

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[10] London Gazette 24th June 1836, reproduced in 1837 BPP [73] Reports of Inspectors of Factories, p.20.
[11] Conversion factor: 1 inch = 2.54 cm.
[12] Letter 16 August 1836. In BPP (1837) (99) p.3.

precedes it – the ‘adolescent’ or ‘pre-pubertal growth spurt’ – places girls and boys onto different growth trajectories. Typical individual velocity curves, showing growth in inches with each year advance in age, are illustrated in Figure 2, reproduced from the classic study by Tanner, Whitehouse and Takaishi (1966) which established British standards in the 1960s. In young children there is little sexual dimorphism but around age 9 girls start their adolescent growth spurt, peaking around 12.1 years, just prior to menarche. Growth then diminishes rapidly. Boys start their spurt around three years later, leaving them shorter than girls in the pre-teen years but catching up around age 14 when their growth peaks. Girls then complete their growth two years earlier than boys, so reaching lower terminal heights. There is natural variation between individuals in the timing of these events. Environment is also influential. Under conditions of poor net nutrition, typically growth is lower, puberty later, and the road to maturity longer.

[Figure 2 here]

In 1897, Karl Pearson, Professor of Applied Mathematics and later Eugenics at University College London, wrote despairingly, ‘The difference of the ages of puberty in boys and girls renders it in fact impossible to make any comparison from about the age of ten to an adult age’ (1897, p.296). Today, a widely used solution to this problem has been to develop sex- and age-specific standards for mean height (μ) and standard deviation (σ). What then should the standard be? A useful starting point is an established and accepted benchmark produced by the World Health Organisation, most recently updated in 2007 (henceforth $WHO_{2007}$). It is “designed specifically for the … purpose, and … been recommended for use as a WHO reference for use in maintaining the nutrition of countries or subpopulations within countries” (Tanner, 1989, p.206). It is based on the cross-sectional measurement of heights of American children aged 5-19 years (National Centre for Health Statistics 1977). $WHO_{2007}$ offers a model of human biological potential – of the growth pathways of healthy and well-nourished girls and boys – against which we can measure the performance of other populations, past and present.

The difference between a study group and the $WHO_{2007}$ standard can be measured in metres, centimetres or inches. A more powerful and intuitive gauge of distance is the z-score, which is based on the normal distribution and is measured in standard deviations from the centre. The z-score measures the relative distance of an individual value away from (above or below) a specified standard μ with standard deviation σ, both of which are specific to each age-sex combination[13]:

$$z = \frac{X_i - \mu}{\sigma}$$

This yields a height-for-age z-score, or HAZ. One advantage of this method over, say, the use of percentiles is its infinitely finer gradations (many historical populations cluster in the first percentile) (Wang and Chen 2012). Its other great merit is that it is easy to read, as z-scores are measured in standard deviations. So, from the rule of a normal distribution, 68% of the population falls within one standard deviation of its centre (z = ±1). Thus, a z-score of -1 would imply the individual has a height that falls one standard deviation below the mean placing that person in the 16th percentile of the height distribution, +1 at the 84th percentile. Both would appear normal for the population. Conversely, at z = ±1.96 (the 2.5th and 97.5th percentiles), individuals are considered 'significantly different'.

$WHO_{2007}$ gives us our modern standard for healthy, well-nourished growth by age, and we use z-scores to tell us just how far below the modern standard ($WHO_{2007}$ 50th percentile) were the nineteenth-century factory children. Our computations use height for given age range in Horner's data (e.g. 8 to 8.5 years) and compare these with the relevant $WHO_{2007}$ mid-point (for this example, 8.25 years). Let us explain how we expect z scores to reflect deprivation and gender bias. A z-score less than 0 indicates height below average, the further below the greater the disadvantage. Deprivation – 'stunting' – is signalled by HAZ at or below -2. Gender bias would be indicated by a gap in the z-scores, specifically gender bias against girls would be implied by z scores that fall below those of boys, implying greater deprivation for girls. This is what our data show (Table 3 and Figure 3 and, later, Table 5 which upholds the significance of these gender differences in regression analysis).

[Figure 3 here]

Factory children were unequivocally shorter – significantly so – compared with modern children. When measured, not simply against each other, but against what might be considered their biological potential – the modern pattern of growth for well-nourished girls

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[13] Technically, z-scores are calculated with a more complicated formula that includes a term correcting for skewness (the power of the Box-Cox transformation); as this is unity for the $WHO_{2007}$ height data, the equation resolves itself into the simple form we cite above.

and boys today – it appears that factory girls were at an even greater disadvantage than the boys. Girls' HAZ were significantly below boys' from age 8.5 to age 13 inclusive and, as they got older, girls were falling further behind modern standards than were boys. This changed at 13.5 and 14 years of age, when girls became significantly taller than boys and their position relative to $WHO_{2007}$ improved. The Horner data show *prima facie* evidence of gender bias.

## 4. Appropriate standards for anthropometric comparisons by gender

It is at this point that we wish to complicate matters. Interpreting HAZ is not as straight-forward as generally held. It is claimed that, 'as standardized quantities, they are comparable across ages, sexes, and anthropometric measures' (Wang and Chen, 2012, p.29). It is typically assumed that variations in the timing of puberty are adequately accounted for by the widening distribution of standard deviations with age. We suggest they are not.[14] These only accommodate natural variation within well-nourished modern populations. They cannot capture the shifts in the tempo of growth inflicted by the extensive nutritional deprivation often seen in historical populations.

### 4.1 The timing of puberty in historical populations

Horner's data show the deprivation suffered by factory children and there is reason to think this deprivation, along with changing secular trends, would have been associated with delayed puberty and an altered timing of the growth spurt. What is known about the historical timing of puberty? Puberty is quite plastic. A recent study of 20th-century Danish children found declining ages for both the onset of pre-pubertal growth and peak height velocity over the space of just four decades (Aksglaede et al 2008). Velocity is clearly related to puberty and, for girls at least, this is reasonably easily ascertained by age at menarche, with this representing the end of growth. Table 4 details the gleanings on age at menarche and there is evidence of a widespread decline over time. In parts of Europe menarchal age appears to drop from around 16-17 years in the mid-19th century, to 12.5 to 14 years of age one hundred years later, hovering around 12.5 years thereafter (Gohlke and Woelfle 2009, p.381). The USA,

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[14] A similar note of caution has been sounded regarding body mass, see Silverwood et al (2009). Thanks to Evan Roberts for drawing this to our attention.

Japan, and China, among others, all exhibit similar trends.[15] We would thus expect peak height velocity for girls in the nineteenth century to occur around or after age 14, an age that is at the limit of our factory data. These factory girls had growth trajectories that were somewhere between 1½ and 3 years behind today's girls (see Figure 4). For boys the pattern is harder to discern, signs of puberty are more varied and less immediately obvious and so more difficult to accurately date. The second section of table 4 summarises the information available. From this it would appear that puberty for boys in historical populations may have been delayed by between ½ to 2 years behind today's population, with peak height velocity being reached around age 14.5 to 15 rather than around 13 years old as observed today. Of course, boys may be less delayed than girls if they were less deprived, therefore a different delay to puberty may itself be indicative of gender bias.[16]

[Figure 4 here]

[Table 4 here]

## 4.2 Implications for comparisons with modern standards

Shifts in the timing of puberty intimate variations in the tempo of human growth. In turn, this complicates the relationships between a deprived or historical population and a modern standard, and should modify our expectations regarding HAZ for girls and boys. Individual velocity curves measure how one individual grows over time and show a significant peak around puberty. However, the adolescent growth spurt can occur for any individual within quite a wide range of ages (Tanner et al 1966, p.461) so that numerous individual growth curves that are out of phase with each other make the average trajectory of growth look different: the individual is peaky, the aggregated more flat. The more dispersed are the underlying data, the flatter the combined curve.

Most height reference standards are not constructed with longitudinal measurements, but with cross-sectional data, and velocity measures the interval between average stature at different ages. This is largely true of $WHO_{2007}$ and applies to Horner's data as well. Here the

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[15] For a recent meta-analysis of current medical literature, see Yermachenko and Dvornyk (2014).

[16] It is also possible that the growth of girls and boys has been differentially affected by historical changes in migration, epidemics and other socio-economic factors, or even that their 'natural' evolutions differ as resources improve. We are not in a position to test these alternatives so proceed on the basis that the WHO standard may not adequately reflect the changes that have occurred in timing of puberty and thus consider whether gender bias is still evident if an appropriate adjustment is made to the standard.

problem is not summing individual velocity curves, but in aggregating individuals who may be at different phases of development, a problem most prominent around puberty when rates of growth first escalate then plummet. Mixing individuals maturing at different rates again dampens group velocity and, concomitantly, standard deviation widens. Late developers will depress peak velocity, pulling the average down, while growth will appear elongated by the presence of late developers pushing the average upwards at later ages. This has particular implications for deprived growth. Deprivation typically delays growth and flattens the aggregate growth curve. We can see how, even within the affluent $WHO_{2007}$ data, natural variation means that growth varies between the top and bottom of the distribution (Figure 5).

[Figure 5 here]

Because of these different trajectories, we should not expect a deprived population to exhibit a constant negative z-value over the growing years, because nutritional deprivation reduces height *and* changes the tempo of growth, reducing absolute velocities prior to puberty, delaying entry into the adolescent growth spurt, but raising velocities after the peak.

### 4.3 The comparative shape of girls' and boys' HAZ scores with deprivation

The differential timing of the adolescent growth spurt – between disadvantaged girls and well-fed $WHO_{2007}$ girls, disadvantaged boys and well-fed $WHO_{2007}$ boys, and between disadvantaged girls and disadvantaged boys – throws the z-curves out of synchronicity. We should therefore expect to see a very particular pattern in the z-curves of two equally deprived populations of girls and boys. There should be a double U-shape in the z-curves between the ages of 9 and 18 years, the first U being female, the second being male. The upswing on each U should coincide with the rapid decline in $WHO_{2007}$ velocity as it is overtaken by the sustained growth of the disadvantaged. The pattern is itself determined by the degree of deprivation, with Us being more pronounced the later the onset of pubertal growth. Because puberty in girls and boys is roughly two years apart, the observed Us should likewise be two years apart. Empirical support for these contentions is to be found in the online Appendix 1, which models delayed growth trajectories for boys and girls using modern Indian data (Marwaha et al 2011).

Thus it is not in the absolute values of z-scores alone that we see gender difference; discrimination is to be found in divergence from these predicted forms. Arguably, equality would make the male U deeper. Because boys typically experience a more pronounced adolescent growth spurt (in Tanner's study, over 4 inches per annum, while girls are closer to 3.5 inches) we would expect a slightly greater deficit between deprived boys and the $WHO_{2007}$ standards, than between girls and the $WHO_{2007}$ standard. Elsewhere, this is what we find. It becomes a recurring theme in other historical samples illustrated in Figure 6. If we compute z-scores based on $WHO_{2007}$ for the average girl and boy from the 1965 British standard presented by Tanner, Whitehouse and Takaishi (1966, Figure 6c), this predicted shape is evident. The same pattern is observed in earlier twentieth century data for Scotland (Figure 6b), among mid-nineteenth century prisoners in England (Figure 6c) and early-nineteenth century convicts transported to Australia (Figure 6d). Even children working in mines, on farms and in English woollen mills in 1841 demonstrate the lower dip for males, which occurs some two years after that for females (Figure 6e).

[Figure 6]

So, if boys and girls are equally disadvantaged across their growing years, we would expect to see two z-curves approximating a double-U (male deeper, minima two years apart) occurring between 9 and 18 years of age. Before and after these ages, the z-scores should be essentially the same. Any comparatively deprived population should exhibit a form of these curves.

### 4.4 Comparison of the nineteenth-century factory data with the 'new standard'

Where does this leave our analysis of the Horner data? Clearly, both factory girls and boys in Horner's survey were suffering from undernourishment, with their average figures more than two standard deviations below modern healthy, well-fed girls and boys. These children would become stunted adults. Our *prima facie* evidence suggested that, compared with boys, these girls suffered inferior net nutrition: we conclude that this was, indeed, the case. This is not simply because girls' z-scores fell below boys up to and including age 13, which they do by as much as 0.4 standard deviations: as we have argued, girls' z-scores *should* be lower than boys' for a limited time, although not this low nor for so sustained a period. The real evidence of disparate and unequal growth is that girls' z-scores dip so low that they are on par with the later trough in boys' scores – and this should not happen under conditions of equal treatment. The greater peak velocity of boys should lead to males exhibiting a more profound U than girls: here, they are the same (see Figure 2). While we do not know what happened to boys after age 14, the evidence does not point to a lower, later trough: there is evidence of upswing by age 14 and the results appear secure, based on large samples (952 boys at age 14).[17] What is also striking is that the two Us are separated by a mere six months, not two years. Factory girls in Horner's survey were, for whatever reason, falling far behind in the growth stakes.

What do these results imply? First, there is no evidence that girls were suffering discrimination, or gender bias, from birth. Their velocity of growth between ages 8 and 9 was close to $WHO_{2007}$, and there was no significant difference between boys' and girls' z-scores at age 8.0 (Table 3) implying that if there was discrimination the effect was not strong. This would link with analyses of mortality that find little evidence of direct gender bias in childhood but do see this emerging in later life, typically in adulthood (Harris 2008, Humphries 1991). Instead the gap opens up from age 8.5, when Horner's girls' velocity plummets, at a time when it should be accelerating. Gender differences from age 8½ may imply economically-driven bias against lower earners but, as seen earlier, these factory girls were as valuable to their families at these young ages as their brothers. The heights data unequivocally show the greater disadvantage of pre-pubertal girls in nineteenth-century factory areas.

Below we explore some of the possible explanations. The online appendix explores whether the data really are trustworthy: we examine if widespread exploitation of under-aged daughters meant girls were in fact younger than stated in the records (Appendix 2), or if the supply of girls was qualitatively different from boys (Appendix 3). Using other data on heights of factory children at different points in time during the enaction of the legislation (see figure 1) we show there is no evidence that parents were systematically overstating the ages of their daughters. Indeed, the highly unrealistic assumption that wholesale, systematic age deception was occurring for all girls, and no boys, at every age is required to generate the gender differences observed. Using data from two household surveys (figure 1) we aslo explore whether the families who sent their daughters to work in the factories did so only

[17] Tanner (1981, p.149, Figure 1) graphs boys' velocity of growth from Horner's, Harrison's and Stanway's data used together. This clearly shows the upturn around age 14.

because they were exceptionally poor. Again we find this not to be the case. Unable to corroborate these possible threats to validity and so discard our findings, the next section examines a series of possible causes for gender inequality. These include: occupational sorting, a differential impact of the disease environment, discrimination in food allocation, and greater work effort required in relation to physical capacity, including both paid work and other uses of time. We should emphasise that we are trying to determine feasible explanations. Horner's data, while furnishing valuable information on stature by age and sex, does not permit empirical testing of these competing causes for gender differences in outcome. This must remain an agenda for future research.

## 5. Possible areas of differential treatment by gender

We conclude there is a gender gap in HAZ. It manifests in the size of the discrepancy, the near parity of the HAZ minima (when girls should not fall as much as boys), and in the close timing of the upswing (with a gap of just six months, instead of two years). What might cause this gender gap?

### 5.1 Occupational sorting?

Occupational sorting is one possible cause of the gender gap . Were healthier boys (but not girls) self-sorting into factory occupations? Peter Kirby has done extensive work on children's sorting and concludes that quite the reverse was occurring: it was the less strong boys who sorted into factory work instead of occupations demanding greater strength, such as mining. He considers there is 'considerable evidence that slender and disabled children were positively selected to work in factories' (2013, p.77) and quotes W. H. Hutt (p.178), 'children who were insufficiently strong for other employments were sent to the cotton factories because of the lightness of the work there' (Kirby, 2013, pp,122-3). If such sorting was occurring among boys, it was less likely among girls, who had access to fewer alternative jobs. Occupational sorting offers little to explain the inferior heights of factory girls.

## 5.2 Disease environment?

Heights not only capture the effects of nutritional intake but also the demands on that intake, in particular, physical demands from working at young ages and the demands of fighting off disease. What about the disease environment? Were girls more susceptible than boys to poor sanitation and associated disease? Poor sanitation does lead to reduced height (Humphrey 2009). Environmental enteropathy caused by repeated faecal contamination reduces nutrient absorption which may lead to stunting, and at its more severe to malnutrition and cognitive defects, even without necessarily manifesting as diarrhoea. But, if there is a gender dimension, medical evidence suggests that boys may be more vulnerable than girls. On the other hand, based on mortality evidence, girls aged 10 to 14 have been deemed more susceptible to respiratory disease, particularly tubercular infections, than boys (Harris 1998, p.446; 2008 pp.170-3). This has been attributed to physiological differences in vulnerability rather than occasioned by poor diet, although the effects are difficult to tease apart as poor diet is known to elevate risk (Ryan Johansson 1977).

If it is differential resistance to disease that is driving the gender difference we observe, we would expect the difference in z-scores between girls and boys to differ by the extent to which they were exposed to urban disamenities. We can divide up the Horner sample by the location in which the data were collected – rural, small town and large town – and include this information in regression analysis of HAZ by age (Table 5). The values on the dummy variables clearly show the impact of increasingly poor environment on the height-for-age score.[18] But in all locations girls have an advantage over boys, furthermore this relative female advantage is particularly pronounced in large towns. This argues against differential resistance to disease driving the gender disparity in heights that we observe.

[Table 5 here]

[18] Locational effect on z-score (calculated from Table 5 for children aged 14)

| | Male | female | difference (f-m) |
|---|---|---|---|
| Rural | -2.903 | -2.532 | 0.371 |
| Small town | -3.001 | -2.641 | 0.360 |
| Large town | -3.158 | -2.751 | 0.407 |

### 5.3 Differential allocation of food?

Another possibility for the more deprived situation of factory girls relative to boys is that despite working and contributing equally to the family's coffers, girls were given fewer resources, in particular less food within their homes. There is general acceptance that a 'female diet', eaten by women and children or, more generally, the 'non-laborious', had emerged by the mid-nineteenth century.[19] Typically women survived on bread and sweetened tea, while the small quantities of meat, cheese and other dairy products affordable to the labouring household were saved for the hard-working man.

Is it the case that differences in the food eaten underlies the differences observed in girls' and boys' heights? In factory areas, reasonable earnings allowed relatively varied food consumption. Mrs B-, the wife of a fine spinner with five children, one of whom was a daughter working for her father as a piecer, reported feeding her family on porridge, bread and milk for breakfast, potatoes, bacon and white bread for dinner, tea, bread and butter in the afternoon, and, usually, oatmeal porridge and milk for supper. Sometimes eggs and bacon were also consumed and Sunday rang the changes with flesh meat and cheese also on the menu (BPP 1833 Factory Inquiry Commission, D1 Manchester, f.649). Similar diets were recorded elsewhere in the report (D2 Manchester p.142). Although female diet was mentioned, it differed little in specifics to the diet of Mrs. B-'s family. Female work people ate oatmeal porridge, milk, tea or coffee with sugar, and bread and butter in the mornings, potatoes and bacon or maybe bread and cheese for dinner at the mill, and a Sunday lunch of meat at home (D1 Manchester f.687; C1 Leeds p.73, f. 407). Mill lads ate much the same (C1 Leeds, p.67, f.401). Elsewhere the report affirms that children ate meat alongside their parents and it draws no distinction between the diet of girls and boys (D2 Manchester p.142).

Even if the type of food eaten did not differ by gender, were girls fed smaller amounts? Utilising the very few accounts of household expenditure available for textile working families amongst the budgets collected by Horrell and Humphries (1992) we investigate adult equivalent calorie and protein intake and see if this systematically differed according to whether the household contained boys or girls.[20] Controlling for household incomes, regression analysis showed no significant relationship between the proportion of

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[19] See discussion in Horrell and Oxley (2012) pp.1369-74

[20] We have 11 budgets for households with working children in Manchester and West Yorkshire for the early 1840s: BPP (1842) Children's Employment Commission, BPP (1843) Children's Employment Commission.

females in the household and total calorie or protein availability, thus giving no obvious indication of any substantial difference in food intake of these factory girls and boys (see online Appendix 4).

### 5.4 Gender-differentiated effects of nutritional deprivation?

If girls and boys were fed equally, could our pattern of gender disadvantage arise from factory girls suffering differentially from the effects of nutritional deprivation? Modern standards for daily energy requirements suggest boys need more calories than equivalent girls, especially after age 12. If fed the same, we would expect boys to fall further behind girls: this is *not* what we observe and acts to further highlight how unusual the relative z-curves are. But there is a further category we need to consider. While developing, humans require a tiny number of calories every day for storing as fat and protein needed for growth. These are additional to those used synthesising new tissue, and they are non-negotiable: without them, the body cannot gain weight and the needs cannot be met by diverting energy expenditures from elsewhere if intake is marginal (Torun 1980, Waterlow 1981). It seems plausible, then, that children are most susceptible to nutritional shortfall when the need to deposit energy is greatest, and the ability to reduce physical activity is limited. For Horner's age range the energy deposition needs varied between 16 and 33 kcal/day (FAO 2001, p.21). If these factory boys and girls were as underfed as appears from their z-scores, these might be 20-30 calories that could not be found. Modern FAO data on the proportion of daily energy intake needed for growth by boys and girls at each age (figure 7) show that girls' needs anticipate those of boys from age 7, in both absolute and relative terms, but the difference is tiny – just 5 kcal/day at most. If such a small amount matters then, even if equally underfed, the timing of growth means nutritional shortfall would have a more deleterious effect on girls younger than 12, and then on boys over 12. Work hit Horner's factory children at the moment when the need to develop new tissue and deposit fat and protein was escalating, and for girls before boys.

[Figure 7 here]

Potentially, physical immaturity had a feedback effect through strength. Year for year, there is no evidence of any notable difference in the strength of girls and boys prior to puberty (Holm et al 2008, Lundgren et al 2011). More important than gender is age. For both boys and girls, strength improves with age. The key here is that, as the factory girls were falling further behind factory boys, they came to resemble biologically younger children. This made girls just a little bit weaker. To match boys on output, but with less strength, they had to expend more energy. A vicious feedback loop then ensued: insufficient calories for growth reduced size and strength, requiring more effort; excessive effort reduced the calories available for growth; and so on. Disadvantage accumulated. While this mechanism is certainly plausible, what is hard to credit is that a daily difference in energy needs of just 5 calories could be sufficient to drive a pattern of disadvantage that left factory girls' growth so delayed that their upswing in HAZ nearly coincides with the boys'.

### 5.5 Unequal work demands

So, if it was not unequal nutrition doing the damage, was it unequal work demands? A further possibility is the amount and type of work these children were doing. As we have already seen, girls and boys were doing very similar jobs in the factories, so it is unlikely that type of work itself explains the differences in heights observed. But girls may have had less genuine leisure than boys if girls were expected to contribute to household labour in addition to paid work. This would increase their work effort and effectively give them a 'double burden'. If there is no compensating increase in energy intake the extra effort could result in increased stunting and trigger the feedback loop proposed above.

It is difficult to ascertain the contribution to domestic labour. Certainly housework seems to have been the responsibility of women. In relation to Midlands metal workers where men, women and children all worked long and arduous hours, particularly as the end of the week approached, Pinchbeck comments: "Monday was usually spent in idleness and drinking, but this appears to have been a holiday only for men; women and girls were compelled to use this time for domestic duties, 'don't work on a Monday', said Elizabeth Pritchard in 1843, ' don't play, but do washing, and fetch coals, and other work for the home'[21]." (1977, pp.279-80). In textile districts there is extensive commentary deriding factory women as poor housewives who sent out for food and paid for their laundry to be done, suggesting that domestic work was minimised in the factory towns (BPP 1833). However, opinion on these women's inadequacies in providing domestic comfort is divided and it was probably no worse than any others of the working class who were living in straightened conditions with poor habitation (Pinchbeck 1977, pp. 309-10). Urban dwellers

[21] BPP (1843) XV p.q.76 quoted in Pinchbeck 1977 pp.279-80.

were more reliant on the services of butcher, brewer and baker for their food than those in rural areas (Burnett 1989, pp.42-3). Maybe in towns, girls contributed little time to these tasks and other domestic work, such as collecting water and minding younger siblings, was not gendered. If we return to the regional differences in height (section 5.2 and Table 5), the reduction in female locational advantage in small towns and rural areas may bespeak just such an effect of girls engaging more in domestic labour with the shift from the retail and service amenities of urban areas to the less well-provided countryside.

Is it then plausible that the extra physical demand of housework with no compensating energy intake could generate the disproportionate stuntedness of girls that we observe? A realistic calculation suggests that it could. Daily physical activity levels are calculated at 1.98 and 1.81 for girls and boys respectively, allocating two extra hours of housework to girls.[22] Using the Harris-Benedict formula (derived from men and women observed in 1917-18) on Stanway's height and weight data for factory children shows that the factory girls would have needed between 300-400 kcal per day more than the boys for doing these two hours of housework each day.[23] A slightly larger calorie deficiency (440 kcal) has been associated with a much larger z-score reduction of -1.32 in height amongst Australian gymnasts when compared with a control group (Bass et al 2000).

## 6. Conclusion

Factory labour by children of 9-12 hours per day was excessive and stunting. Short of wholesale misrepresentation of the ages of their daughters – but not their sons - the data on factory children's heights unambiguously shows disadvantage for girls relative to boys in the nineteenth century. This disadvantage apparently was not inherent in earlier childhood years, so cannot be described as gender bias, and it occurred prior to girls having significant agency in decisions, so nor was it female or maternal sacrifice. Despite being of equal economic value as their brothers, these girls had lower net nutritional intake. As far as we can ascertain,

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[22] On top of 8 hours of factory work, an hour of walking to and from the mill, 2 hours for education and meals, 2 hours of childcare and one hour of general cleaning, girls also did one hour of laundry and one hour of floor cleaning. Boys took these two hours as leisure. Computed from Floud et al (2012, p,.45).

[23] Harris and Benedict (1919) available on http://www.bmi-calculator.net/bmr-calculator/bmi-formula.php. Modern studies treat age and weight as highly correlated so omit age, this is not necessarily a valid assumption for our period and a formula derived for earlier populations is deemed more appropriate.

Women BMR = 655 + (4.35 * weight in lbs) + (4.7 * height in inches) – (4.7 * age in years)

Men BMR = 66 + (6.23 * weight in lbs) + (12.7 * height in inches) – (6.8 * age in years) occupational sorting does not underlie the difference nor does greater female susceptibility to disease. We do not find direct evidence that this arises from unequal allocation of food, although there is perhaps some room for doubt. The biological argument – of girls anticipating boys in registering stunting – would also apply to other deprived populations and does not explain why Horner's girls are so much more disadvantaged than boys; it also requires too much work from a shortfall of just five calories a day in differential energy needs. That leaves additional work and exploitation as the main contenders. The double burden engendered by engaging in both factory work and domestic labour may have placed particularly high physical demands on girls, with no compensating nutrition. The impact of arduous physical and mental effort associated with unpaid domestic labour has been pointed up as a factor in women's high mortality (Harris 2008, p.184). We contend that the extension of women's involvement in the domestic sphere to daughters left factory girls undertaking more physical work than their brothers and this was reflected in disproportionate stunting. But families may have been even more complicit in overworking girls. They may also have sent them into work at younger ages than their brothers. The 'double burden' and differential treatment of girls both constitute forms of gender discrimination.

Ivy Pinchbeck's (1977) comprehensive survey of the position of women workers through the Industrial Revolution concludes that, while changes in agriculture and domestic industry may have worsened the situation of women in rural areas, the expansion of textile factory employment enhanced the status of urban women. It paid individual, relatively high wages, could procure higher standards-of-living for the household and, for many women, offered a taste of 'economic independence' (ibid, 1977, p.313). Indeed, relocation of manufacturing work from home to factory may have allowed an ideology of domestic comfort to be promoted. The findings presented here intimate some rebalancing of this picture.

Factory work did not obviate the need for domestic work. For the factory girls we observe, the excessive burden of physical housework along with arduous paid work is, we argue, evident in their stature. Maybe the possibility of devolving some activities, such as cooked food and laundry, to outside providers worked to offset this burden for girls in the large towns but for female factory workers elsewhere the evidence presented here is suggestive of an excessively heavy 'double burden'. The gendering of activities within the household is pointed up as a productive focus of future research on gender inequality.

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Table

# Tables

Table 1. Comparative earnings of factory and non-factory children

| Age (years) | Sample size | | Earnings in factory work (d per week) | | Factory/ Non-factory earnings (ratio) | |
|---|---|---|---|---|---|---|
| | Female | Male | Female | Male | Females | Males |
| 9 | 29 | 18 | 34.41 | 30.11 | 1.27 | 0.77 |
| 10 | 46 | 48 | 41.41 | 37.85 | 1.57 | 0.89 |
| 11 | 56 | 52 | 45.96 | 47.84 | 1.25 | 1.58 |
| 12 | 86 | 42 | 54.88 | 52.57 | 1.45 | 1.16 |
| 13 | 72 | 46 | 68.86 | 64.39 | 1.34 | 1.34 |
| 14 | 92 | 52 | 78.72 | 71.88 | 1.12 | 1.09 |
| 15 | 87 | 54 | 91.02 | 88.68 | 1.10 | 1.23 |
| 16 | 100 | 52 | 98.00 | 96.65 | 1.07 | 0.85 |
| 17 | 80 | 26 | 105.53 | 108.80 | 1.08 | 0.85 |
| 18 | 73 | 22 | 116.09 | 113.04 | 1.08 | 0.93 |
| Sample size | 721 | 412 | | | 721/114 | 412/84 |

Source: Calculated and stated by Samuel Stanway from data collected by Mr. Cowell from Sunday Schools in Manchester and Stockport. P.P. [450](1833) Factory Inquiry Commission. D1. p.88 f.698
Note: standard deviations were not reported precluding the computation of statistical tests for significant differences in the mean earnings by gender.

Table 2. Wages and employment in factories

| Age (years) | Wage (shillings per week) | | | | | | Numbers employed | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Lancashire cotton | | West Riding wool | | Leeds flax | | Lancashire cotton | | West Riding wool | | Leeds flax | |
| | F | M | F | M | F | M | F | M | F | M | F | M |
| 8 | 2.00 | 2.00 | 2.77 | 2.00 | - | - | 1 | 1 | 31 | 26 | - | - |
| 9 | 2.25 | 2.29 | 2.75 | 2.27 | 2.81 | 2.94 | 32 | 41 | 63 | 85 | 12 | 16 |
| 10 | 2.96 | 2.54 | 2.79 | 2.75 | 2.77 | 2.81 | 122 | 204 | 100 | 100 | 33 | 38 |
| 11 | 3.17 | 3.15 | 3.33 | 3.27 | 3.13 | 4.15 | 198 | 195 | 117 | 121 | 105 | 83 |
| 12 | 3.65 | 3.58 | 3.58 | 3.67 | 3.38 | 4.46 | 241 | 245 | 114 | 140 | 134 | 125 |
| 13 | 3.81 | 4.21 | 4.92 | 4.33 | 4.04 | 4.67 | 233 | 233 | 117 | 162 | 127 | 90 |
| 14 | 4.96 | 4.71 | 4.77 | 4.77 | 4.48 | 5.25 | 236 | 256 | 143 | 164 | 128 | 71 |
| 15 | 5.67 | 5.25 | 6.15 | 5.73 | 5.00 | 5.90 | 215 | 240 | 133 | 113 | 140 | 47 |
| 16 | 6.04 | 6.96 | 5.44 | 7.19 | 5.65 | 5.81 | 256 | 204 | 140 | 124 | 138 | 30 |
| 17 | 6.48 | 7.38 | 5.75 | 7.54 | 5.67 | 7.75 | 245 | 141 | 118 | 90 | 150 | 38 |
| 18 | 7.54 | 11.75 | 7.15 | 9.71 | 5.81 | 10.42 | 279 | 164 | 108 | 115 | 124 | 23 |
| 19 | 8.17 | 11.52 | 6.88 | 12.04 | 5.96 | 11.92 | 251 | 135 | 113 | 81 | 104 | 21 |
| 20 | 8.13 | 13.44 | 7.04 | 12.23 | 6.04 | 13.88 | 209 | 92 | 80 | 65 | 80 | 22 |

Average (weekly) net payments to each worker. 'Standard' 69 hour week
Source: Minoletti, P. (2011, app. A, pp.222-4, 232-3) from B.P.P. 1834 XIX pp. 279-289.

Table 3 The stature of textile factory girls and boys from Horner 1837 (collected 1836)

| Age | Sample size | | Height (inches) (1 inch = 2.54cm) | | | *t*-test difference in mean height | | HAZ-score (standard deviations) | | *t*-test of difference in mean HAZ | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Female | Male | Female | Male | Difference | girls compared with boys | | Female | Male | girls compared with boys | |
| 8.0 | 267 | 327 | 45.08 | 45.60 | -0.52 | -2.65 | ** | -2.30 | -2.23 | -0.84 | |
| 8.5 | 272 | 339 | 46.31 | 46.93 | -0.62 | -3.53 | ** | -2.22 | -2.04 | -2.41 | ** |
| 9.0 | 438 | 527 | 47.40 | 47.65 | -0.25 | -1.83 | * | -2.20 | -2.11 | -1.71 | * |
| 9.5 | 375 | 418 | 47.96 | 48.17 | -0.21 | -1.34 | | -2.41 | -2.25 | -2.64 | ** |
| 10.0 | 507 | 574 | 49.03 | 49.04 | -0.01 | -0.13 | | -2.43 | -2.25 | -3.58 | ** |
| 10.5 | 529 | 441 | 49.82 | 49.68 | 0.14 | 1.02 | | -2.56 | -2.34 | -4.26 | ** |
| 11.0 | 576 | 664 | 50.24 | 50.31 | -0.07 | -0.62 | | -2.83 | -2.45 | -8.32 | ** |
| 11.5 | 478 | 558 | 51.21 | 51.19 | 0.02 | 0.16 | | -2.88 | -2.50 | -7.96 | ** |
| 12.0 | 712 | 767 | 51.90 | 51.77 | 0.13 | 1.15 | | -3.04 | -2.68 | -8.24 | ** |
| 12.5 | 618 | 661 | 52.64 | 52.45 | 0.19 | 1.54 | | -3.10 | -2.85 | -5.81 | ** |
| 13.0 | 1260 | 1269 | 53.40 | 53.11 | 0.29 | 3.55 | ** | -3.13 | -3.07 | -2.28 | ** |
| 13.5 | 980 | 844 | 54.61 | 54.18 | 0.43 | 4.10 | ** | -2.93 | -3.13 | 5.22 | ** |
| 14.0 | 1029 | 952 | 55.98 | 55.75 | 0.23 | 2.14 | ** | -2.63 | -3.00 | 10.10 | ** |
| Total | 8041 | 8361 | | | | | | | | | |

Source: Data from Kirby (2010) BPP (1837)
** indicates significance at 5% level or greater, * at 10% level or greater
Notes:
The original data were collected age for the half-year, as stipulated by Horner, so ranges 8.0 – 8.5, 8.5 – 9.0, and so on. In computing HAZ (height for age *z*-scores), we assess these against the mid-point 8.25 (8 years and 3 months), 8.75 (8 years and nine months), and so on, from the World Health Organisation 2007 reference standard.

Table 4 The timing of puberty

| Girls' puberty | | Boys' puberty | | |
|---|---|---|---|---|
| (time/place) | Age at menarche (years) | (time/ place; age) | | |
| 1616-54<br>Culpepper directory archive | 14 ½ - 15 | | | |
| Early 1700s<br>Jampert, Berlin orphanage | 17 + | 1723-50<br>Bach's choir Leipzig | Voice breaking<br>16 ½ - 17 years | Modern figure UK<br>13 – 13 ½ years |
| Mid 1700s<br>Buffon, N. Europe countryside | 14 | Mid 1700s<br>Buffon, N . Europe countryside | Pubic hair?<br>16 years | |
| 1781<br>Edinburgh | 13 – 15 | 1772-94<br>Carlschule Stuttgart, well off | Peak height velocity 15 ½ - 15 ¾ years | Today, Britain 14 years |
| 1781<br>Denmen, London | 14 – 18 | | | |
| 1830<br>Whitehead, Manchester factory girls | 15.6 | 1800s<br>Marine Society, London; Factories, 1833 | Peak height velocity<br>15 years | Tanner (1981) ½ - 1 ½ years behind today |
| 1828-9<br>Robertson, Manchester charity lying-in hospital | 15.2 | | | |
| 1830s<br>London | 14.9 | | | |
| 1845<br>Guy, London | 15.1 | | | |
| 1869<br>Rigden, UCL, working class | 15.0 | | | |
| 1910<br>Edinburgh | 15.0 | | | |
| 1960s<br>N. England working class | 13.6 | | | |
| 1960s<br>S. England | 13.1 | | | |

Source: Tanner (1981) pp.20-21; pp.83-84; pp.88-89; p.94; p.112; p.114; pp.155-6; p.158; pp.286 ff.

Table 5. Regression analysis of height on age
Dependent variable: individual z-score (HAZ)

| | Regression (without location dummy variable) | | | Regression (with location dummy variables) | |
|---|---|---|---|---|---|
| | coefficient | *t*-statistic | | coefficient | *t*-statistic |
| Constant | -2.998 | -113.59** | | -2.903 | -101.67** |
| Age 8.0 | 0.772 | 14.80** | | 0.768 | 14.82** |
| Age 8.5 | 0.955 | 18.53** | | 0.955 | 18.64** |
| Age 9.0 | 0.889 | 20.10** | | 0.874 | 19.87** |
| Age 9.5 | 0.745 | 15.59** | | 0.730 | 15.33** |
| Age 10.0 | 0.750 | 17.43** | | 0.738 | 17.23** |
| Age 10.5 | 0.663 | 14.13** | | 0.654 | 14.01** |
| Age 11.0 | 0.550 | 13.35** | | 0.528 | 12.89** |
| Age 11.5 | 0.502 | 11.56** | | 0.487 | 11.27** |
| Age 12.0 | 0.320 | 8.10** | | 0.298 | 7.59** |
| Age 12.5 | 0.144 | 3.49** | | 0.126 | 3.07** |
| Age 13.0 | -0.067 | -1.92* | | -0.071 | -2.05** |
| Age 13.5 | -0.128 | -3.34** | | -0.114 | -3.00** |
| *Female dummies:* | | | | | |
| F x age 8.0 | -0.069 | -1.02 | | -0.444 | -5.84** |
| F x age 8.5 | -0.174 | -2.63** | | -0.551 | -7.32** |
| F x age 9.0 | -0.089 | -1.69* | | -0.461 | -7.23** |
| F x age 9.5 | -0.160 | -2.76** | | -0.525 | -7.70** |
| F x age 10.0 | -0.177 | -3.57** | | -0.546 | -8.90** |
| F x age 10.5 | -0.225 | -4.29** | | -0.610 | -9.58** |
| F x age 11.0 | -0.386 | -8.32** | | -0.753 | -12.80** |
| F x age 11.5 | -0.389 | -7.66** | | -0.768 | -12.33** |
| F x age 12.0 | -0.358 | -8.44** | | -0.719 | -12.89** |
| F x age 12.5 | -0.249 | -5.45** | | -0.625 | -10.74** |
| F x age 13.0 | -0.065 | -2.01** | | -0.434 | -8.93** |
| F x age 13.5 | 0.194 | 5.10** | | -0.188 | -3.59** |
| F x age 14.0 | 0.370 | 10.11** | | | |
| *Location dummies:* | | | | | |
| Female | | | | 0.371 | 9.32** |
| small town | | | | -0.098 | -4.90** |
| large town | | | | -0.255 | -10.60** |
| F x small | | | | -0.011 | -0.37 |
| F x large | | | | 0.036 | 1.05 |
| | | | | | |
| n | 16402 | | | 16402 | |
| Adjusted $R^2$ | 0.151 | | | 0.161 | |
| F | 117.5** | | | 109.3** | |

** indicates significance at 5% or greater, * at 10% or greater
Source: Data from Kirby (2010) BPP (1837)

**Figure**

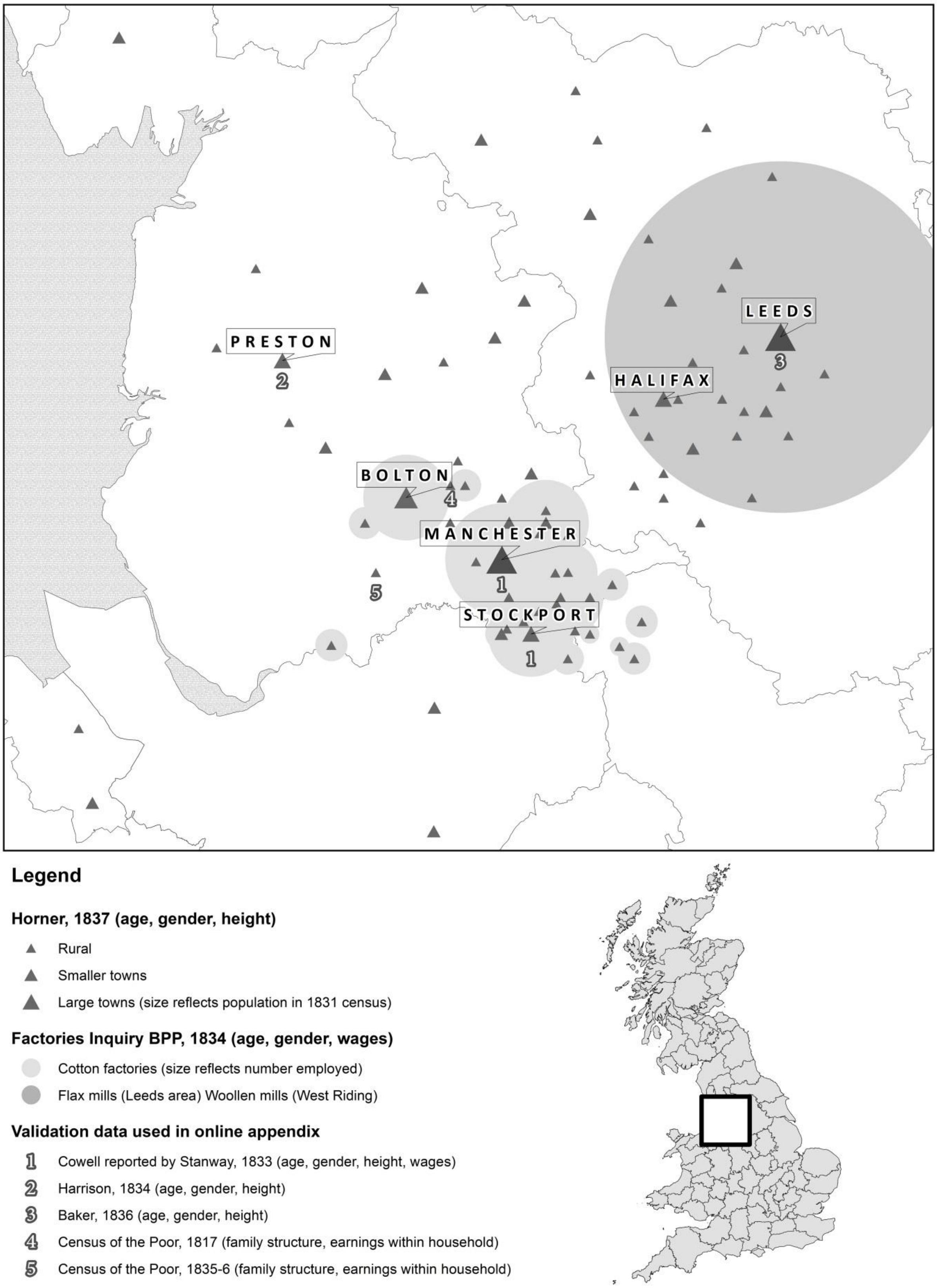


Figure 1 Location of data sources

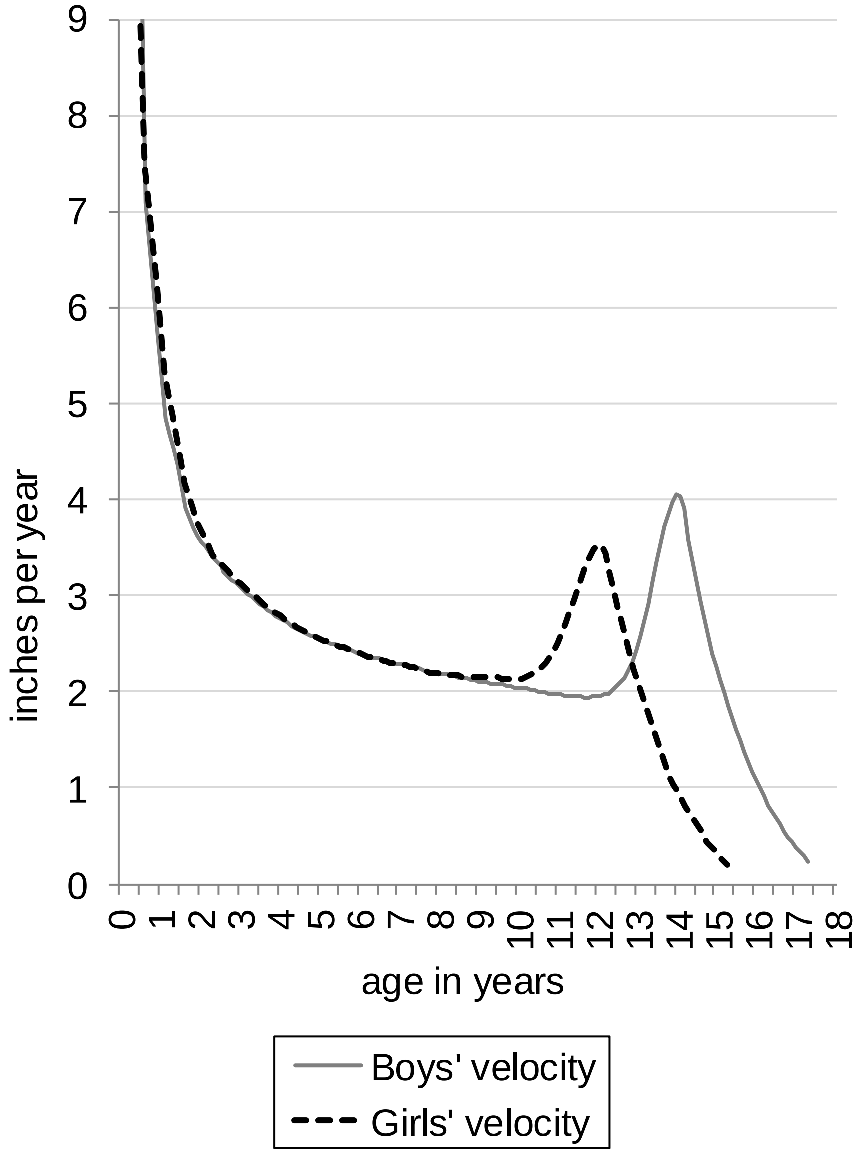


Figure 2. Individual velocity curves (peak velocity centred) redrawn from Tanner, Whitehouse and Takaishi (1966) p.466

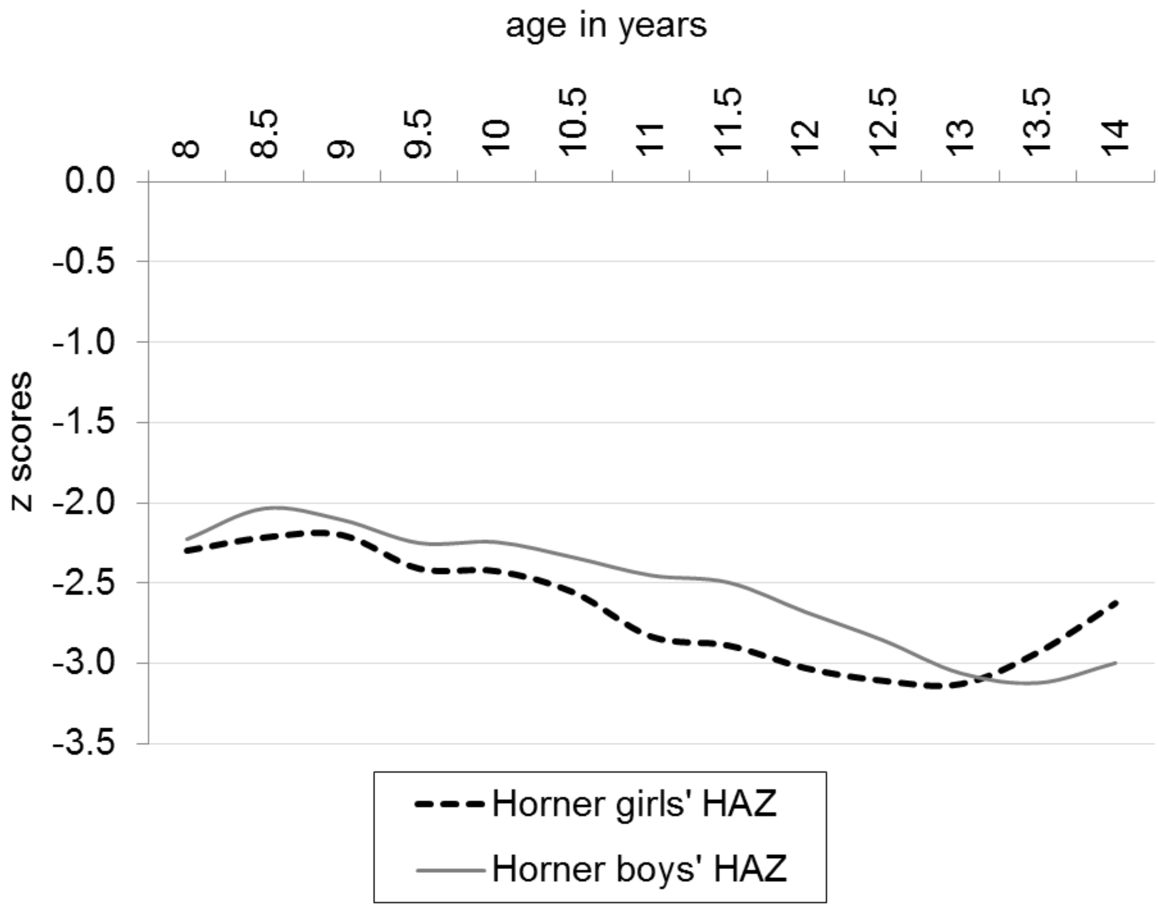


Figure 3. Height for age z-scores for Horner's factory children

Source: data from Kirby (2010) from BPP (1837)

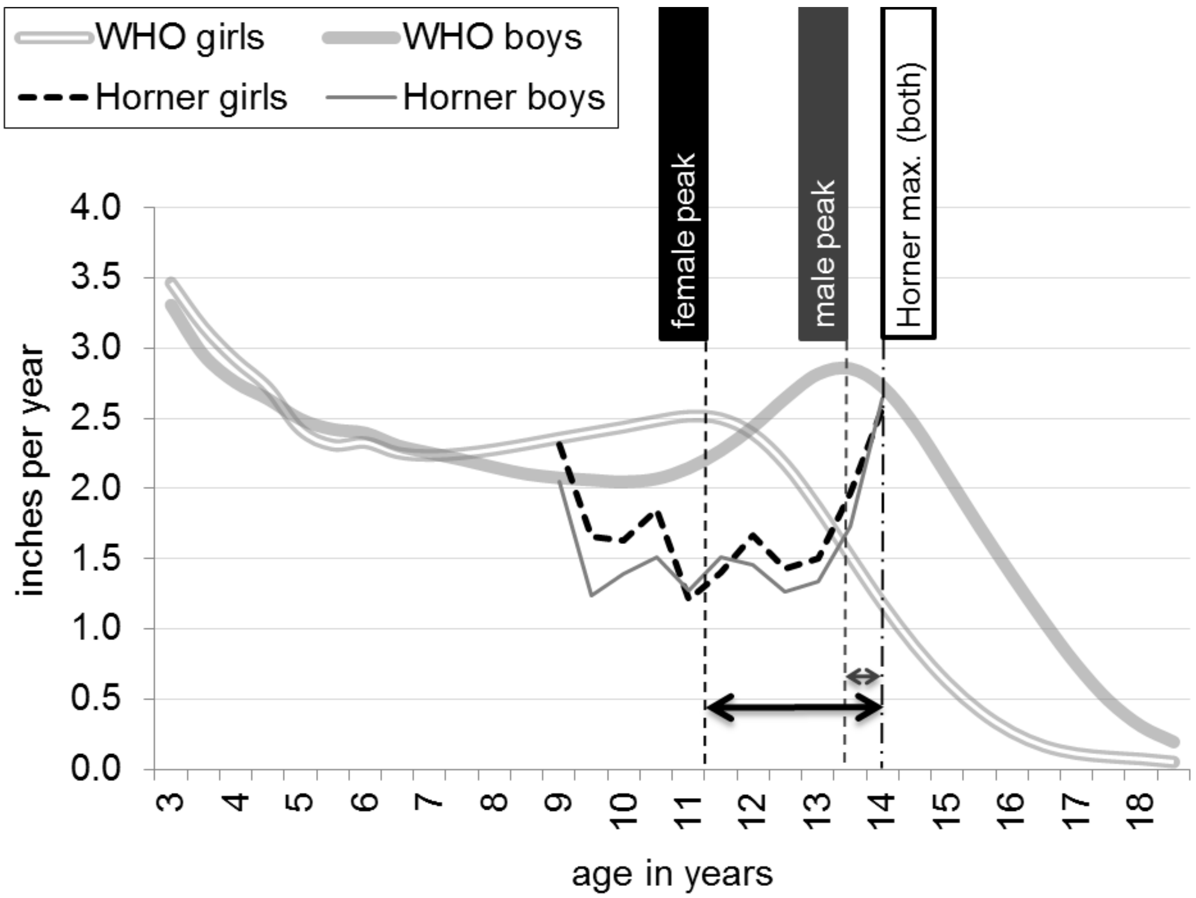


Figure 4. Inches increase over preceding twelve months (e.g. age 8.0 – 9.0, 8.5 – 9.5 etc.) WHO$_{2007}$ and Horner's factory children, 1837.

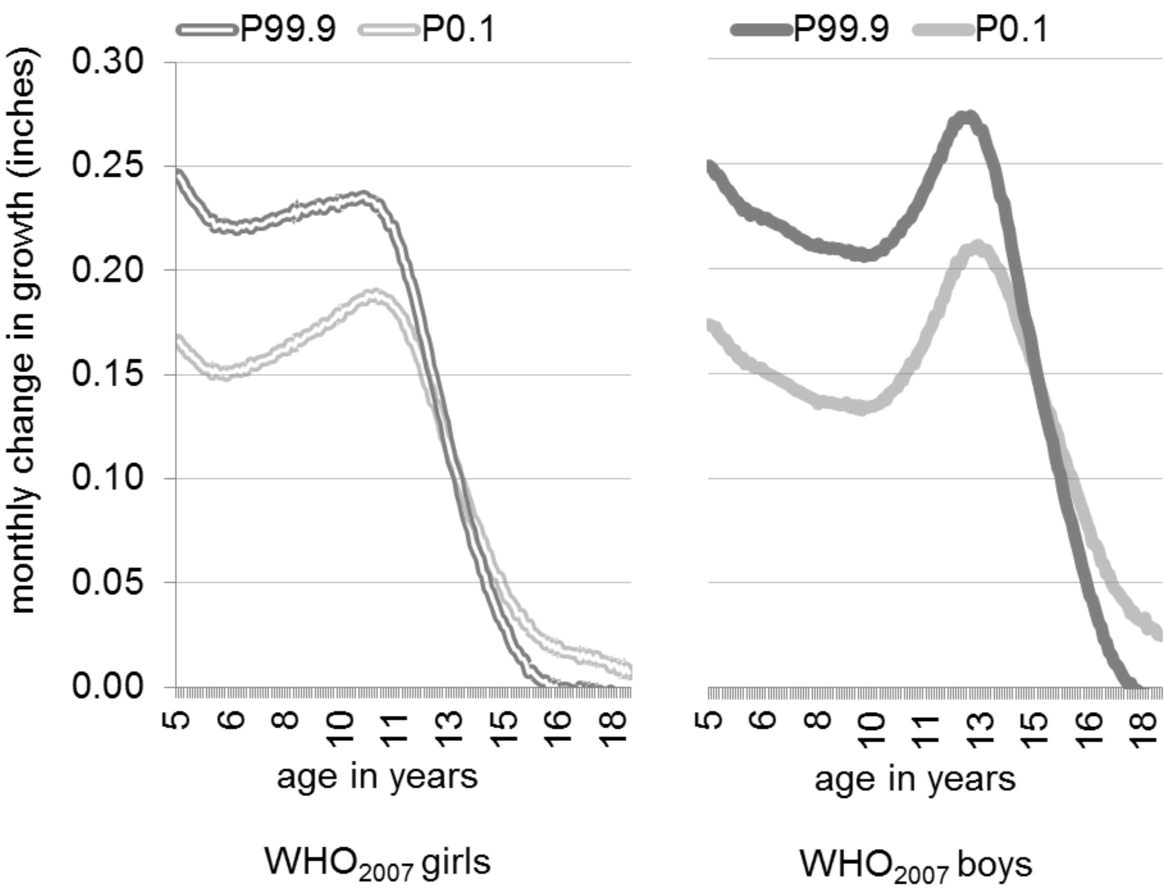


Figure 5. Monthly growth intervals for $WHO_{2007}$ percentiles 0.1 and 99.9

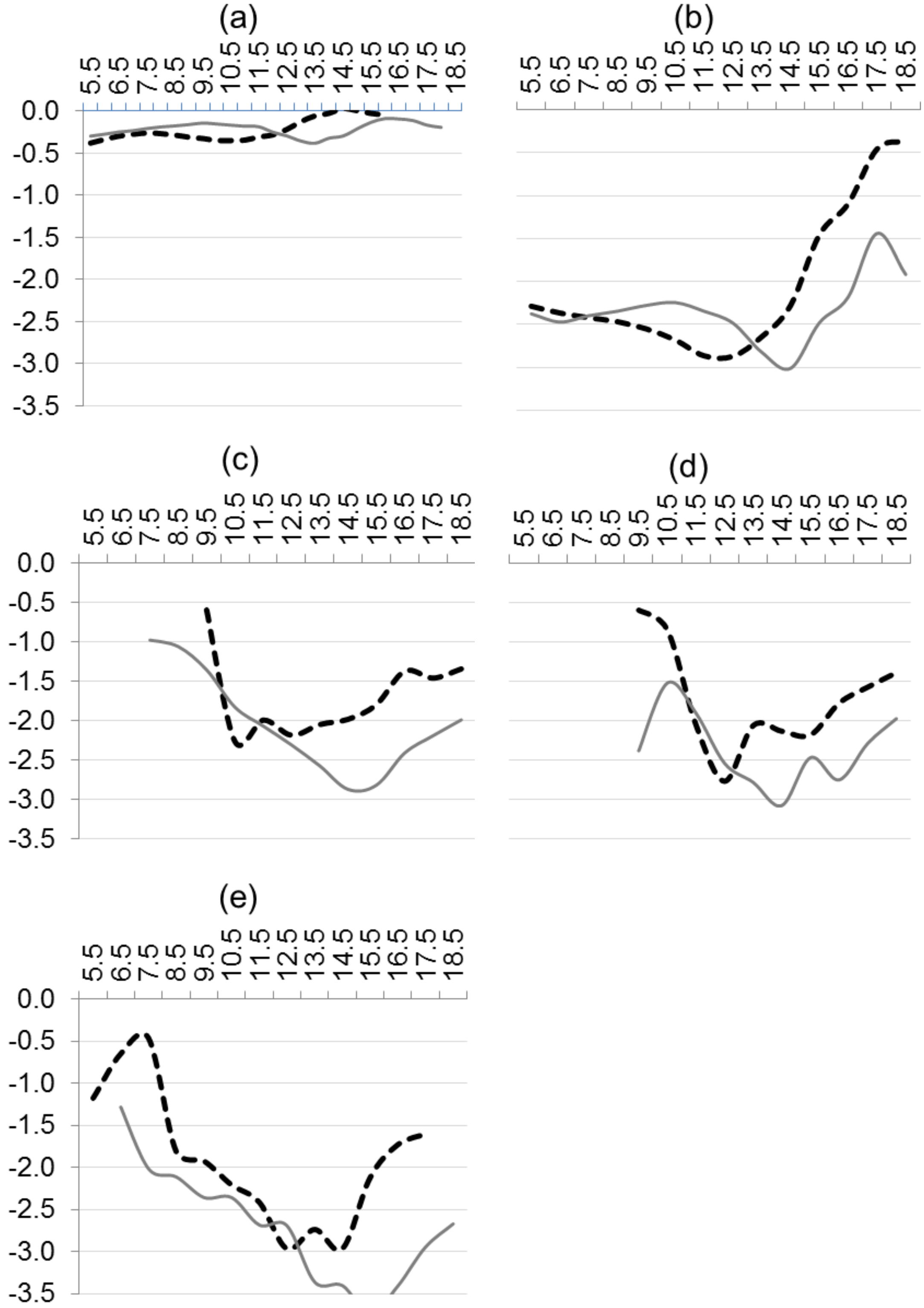


Figure 6. Historical examples (a) 1965 British standard, (b) Glasgow schoolchildren 1907 BPP 1907 [Cd.3637], (c) Prisoners from the Wandsworth House of Correction 1848-75, (d) Convicts transported to New South Wales, Australia c.1818-40, (e) Scriven's and Symon's colliery, farm and worsted mill workers, 1841. BPP (1842) XVII, BPP (1842) XVI

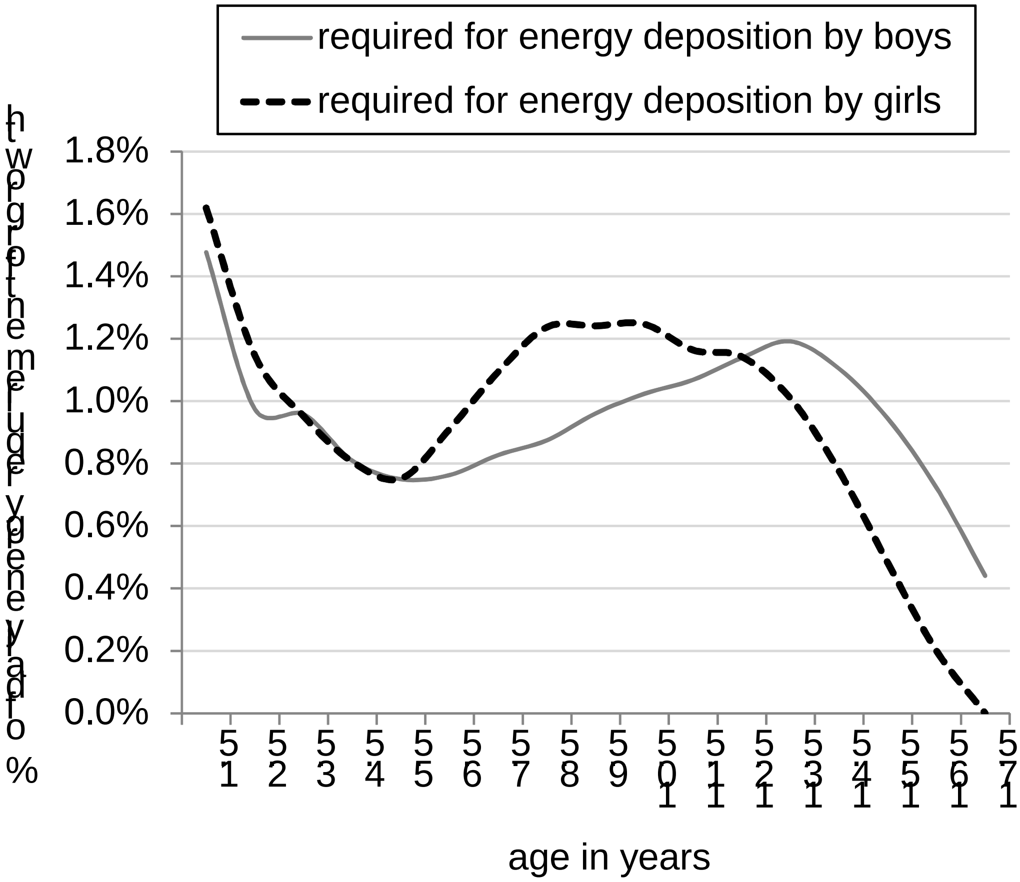


Figure 7. FAO Human energy requirements (2001), pp.26-27