Little Women

Sonia Bhalotra

Department of Economics and CMPO, University of Bristol, UK[§]

Preliminary and Incomplete: September 2007

To be completed by December 2007

Abstract

This paper analyses trends in the latter half of the twentieth century in the heights of Indian women. On average, there was some growth in height at maturity for the cohorts of 1950-1965 but the cohorts born in 1965-1975 experienced no growth. Many of the states exhibit trends similar to the country-average, with the notable exceptions of Kerala, which displayed monotonic growth, and Punjab & Haryana, which started off with the tallest women but then experienced a decline in average height. Both between and within-state variation in height is inversely correlated with infant mortality rates at birth, an indicator of the disease environment. The level of aggregate income at birth, a potential proxy for nutritional status, is positively correlated with height at maturity in the cross-section but this relationship is weak within states. The paper also examines levels and trends by socio-economic group. Higher caste women are taller and this differential is more or less constant over the quarter century for which we have data. Muslim women have grown faster than Hindu women. Height differentials by education and urban/rural location have widened over time although the trend in these differentials is likely to be influenced by compositional change.

[♣] I am grateful to Alex Barr and James Butter for excellent research assistance and to Sarah Smith and Jon Temple for helpful comments.

Little Women

Sonia Bhalotra

1. Introduction

1.1. Motivation and Summary

Indian women are amongst the shortest in the world, with average height today of just about 152 cm. This paper presents new evidence on trends in the heights of women born in India in the latter half of the twentieth century. It describes trends by social class and location, and attempts to explain the evolution of height in relation to trends in income and disease prevalence in early childhood.

Height matters because it predicts life expectancy, cognitive performance and socio-economic status (Strauss and Thomas 1998, 2007). Growth in heights in a society depends upon trends in nutrition and disease and, in this way, it indicates evolution in health and living standards (Fogel 1997, 2004, Deaton 2007). Genetic endowments from mothers and fathers create variation in heights within a population but are thought to have little effect on the population average (Steckel 1995). The process of height formation is cumulative, with heights being particularly sensitive to environmental conditions in early childhood when the velocity of growth is high. Indeed, adverse conditions in age 0-3 have been shown to have irreversible effects, affecting height at maturity (for a review, see Strauss and Thomas 2007: xx).

There is limited evidence on recent trends in heights in developing countries and even more limited systematic evidence on the determinants of trends or fluctuations over long periods of time. Indeed, the only papers I know of in this terrain are Moradi (2006) and Deaton (2007). I know of no previous study of women's heights in India. The main results are as follows. There was a small (0.7 cm) but secular increase in height at maturity for women born in 1950-1965, followed by virtually no growth in heights for the cohorts in 1965-1975. [comment on growth of income and mortality in these periods and remark at whether consistent] There is persistent inequality in heights within India by social class and ethnic group. There are remarkable differentials in height across the states. Women in Punjab and Haryana were about 7.5cm taller than women in Bihar, West Bengal and Maharashtra in 1950. In the birth-cohort of 1975, the inter-state differential had narrowed to about 5cm. Analysis of trends disaggregated by state reveals that the only women that have grown continuously through the period are in the state of Kerala, where they have gained a remarkable 3.4cm in 25 years. And the only women that have failed to grow at all are those in Punjab and Haryana.

1.2. Height as an index of wellbeing

In section 1, I argued the relevance of studying heights. This section sets out the many advantages of using heights data to look at health and wellbeing. Economic historians have exploited the availability of historical records on human heights dating as far back as the 1700s to study trends in living standards over periods of time for which there are no reliable income data (e.g. Steckel 1995). It is still difficult to get reliable and comparable income or consumption data over long periods of time for many developing countries. Where available, income data are noisy since it is inherently difficult to account for informal productive activity which has wide scope in these countries (e.g. Micklewright and Ismail, 2001). Also, the usefulness of income in analysing trends or making comparisons across regions is contingent upon the availability of a deflator that adequately reflects relative prices. In the Indian context, for example, Angus Deaton (2007b) has argued that the official cost of living index uses an outdated basket of goods. Heights data avoid most of these problems. They are real. Once group-averaged, they are comparable across time and space, even if the long-standing view that these comparisons provide insight into the wellbeing of populations (e.g. Steckel 1995, Strauss and Thomas 1998) is not unchallenged (Deaton 2007); more on this later. And, there is, all of a sudden, a wealth of good data on heights, at least for women, in developing and transition countries (see section 3). Although these are one-shot measurements, they are taken for women aged about 15-49 years, so that we can (with some caveats, discussed in section 3) construct a time profile of heights. In contrast, historical records of heights have typically referred to military conscripts or been inferred from skeletal remains.

Heights data present advantages even in the presence of good consumption data. First, they are results-based. In particular, heights reflect nutrition assimilated after netting out the effects of disease. Consumption does not imply nutrition, for example, because quality of diet matters, and infectious diseases like diarrhea can prevent the retention and assimilation of nutrients. Moreover, there will be individual heterogeneity in metabolic rates, work activity or exposure to pollution that influence net health, and this is conveniently reflected in height. In these ways, height as a measure of welfare falls into line with Amartya Sen's capabilities approach (Sen 2000). A second advantage of heights over consumption data is that they are naturally measured at the individual level. Consumption expenditure is typically recorded for households because allocations of food and other health inputs within the household are hard to recall and measure. There is considerable indirect evidence of consumption inequality within households and, in India, there is evidence that both nutrition and health care allocations favour boys (e.g. Behrman and Deolalikar 198x, Basu 199x, Rose 2000).

2. Related Literature

A fairly substantial literature charts the relationship between average height and income per capita or wages (see for instance Steckel (1995), Floud (1994) and Strauss and Thomas (1998)), although most of these studies look at historical evidence from Europe or the US. There is relatively little analysis of this relationship in today's developing countries (although see Bazzoli et al. 2007, Moradi 2006, Deaton 2007), where it may be expected to quite strong, given the importance of physical strength for work and the higher incidence of poor nutrition in childhood (Strauss and Thomas, 2007).

Moradi (2006) uses data on over 200,000 women in sub-Saharan Africa to compare their nutritional status and economic development from 1950-1980. He finds that the ranking of the countries by stature does not match up to the ranking according to income. The reason for this irregularity seems to be explained though by the prevalence of livestock farming, which does not generate high incomes but does offer an important nutritional advantage by providing a good source of proteins. However Moradi observes that the lack of any rise in adult female stature or even a fall in height does closely reflect the deceleration in economic growth or even negative growth over this period.

The evidence from the transition period for Russia in the 1990s provides some insight into the effect that relatively prolonged periods of privation can have on a long-term measure of standard of living such as height. Miranov (2007) uses the height and weight of mothers born from 1929-1989 to analyse changing standards of living from the end of the Second World War. He finds that average height steadily increased from this time until 1990, whereas the data for women reaching maturity after 1990 indicate that living standards began to deteriorate at this point, with a fall in stature of as much as 1.3cm over the decade and a trough reached in the mid-1990s. Measurements of the length and weight of babies born from 1980 to 2005 mirrors this picture and the signs of the strains of the transition are apparent in the measures of economic performance over this period, with a fall in GDP per capita of 39% from 1990-1996.

Tarozzi and Mahajan 2007) find … rural/urban, states/regions, gender inequality that corresponds to regional evidence on son-preference, but also corresponds to regional evidence on poverty, inequality (Dreze and Deaton 2002). Period of growth. …………

Esther Duflo (2003) has exploited the expansion of the old age pension programme in South Africa in the early 1990s and the availability of anthropometric data on children to investigate intra-household discrimination. She found that when the pension, which was equal to approximately twice the median income in rural areas, was received by a grandmother it had large positive effects on the anthropometric condition of granddaughters. No such effects were found on the boys in the household, nor when the pension was received by a grandfather.

Caste, class

Investigators have also noted class differences reflected in the stature of groups within countries. Floud, Wachter and Gregory (1990) have done so for England in the 1800s, exploiting military records to highlight substantial height differences between the aristocracy and the inhabitants of the London slums. Steckel (1995) compares the heights by profession during the same period in the US and Komlos (1990) shows that children of the aristocracy were up to 8-10cm taller than children of lower classes in eighteenth century Germany. ………………By comparison, in the developing world rates of growth can still be high when the right conditions prevail. Particularly notable however, is the inequality in growth rates across different groups. Taking Vietnam as an example, of the individuals born from 1922-55 mature stature rose by 1.9cm per decade among those from the poorer North, which was 25% faster than among those from the South. Hence there appeared to be a narrowing of inequality during a period of general growth. However after 1955 the general trend upwards in stature stopped whilst the growth was reversed in the North, with only those at the top of the height distribution experiencing any further growth. It seems then that inequality, as measured by height, was exacerbated and that it was the worst-off that were most adversely affected by the hardships of the war period (Strauss and Thomas, 1998).

3. Research Design

Heights at maturity are largely determined in childhood when the velocity of growth is especially large, and environmental conditions tend to exert their largest impact quite early on, at about the age of 0-3 years. Even at the individual level, the role of heredity is small early in life Tanner (1978, ch. 9). This paper therefore analyses the impact of nutritional and disease conditions prevalent in the year of birth, allowing for some lags and leads. The data are for women born in 1950-1975 for whom heights were measured in 1998/99, when they were of age 23-49 years, an age range in which we might assume (with possible error at the lower end) that full height has been attained.

The influence of environmental conditions on height is stronger when environmental stress is acute (e.g. Silvertoinen 2003). So we may expect larger effects in a developing country, and we may need to allow for the possibility that, over a time span as long as 25 years, these effects are non-linear.

A virtue of anthropometric data is that they tend to be free of measurement error that is systematically related to the characteristics of the individual being measured (Strauss and Thomas 1998). Heights in the DHS are measured by the surveyor rather than reported, and so are not subject to the reporting errors associated with subjectivity.

Selection and scarring…….

Between and within……….

By virtue of using information on aggregate income and public expenditure at birth, the evidence in this paper refers to the effects of poor nutrition or weak public health in childhood on heights at maturity. This is not conflated with the effects of height on income via productivity as these would be evident in the contemporary income levels (ie income levels at maturity).

Income distribution also matters (steckel 1995)

4. Data and Selection Issues

The data are drawn from the second Indian National Family Health Survey (NFHS-2), which is one of the family of Demographic and Health Surveys (see www.measuredhs.com). NFHS-1 (1992/3) did not collect information on heights and NFHS-3 (2005/6) is yet to be released. NFHS-2 interviewed 84348 women aged 15-49 at the time of the survey, across a twelve month period in 1998-9. Women in this sample are born in 1949–1984. As discussed below, women born in 1976-1984 are dropped to limit selectivity bias. I also drop women in 1949 because there are less than 1000 women born in this year. The span of birth cohorts for which we analyse trends is therefore 1950-1975. Analysis of the relationship between heights at maturity and conditions in childhood is restricted on account of data constraints to 1962-75. The construction of the data for the multivariate analysis is described in section xx below.

The heights of women were measured by the surveyor rather than reported, so they are not subject to subjectivity error. There are between 1500 and 3500 women in each birth-cohort. For the graphs, the average height of a cohort is obtained using sample weights contained in the data. Weighting lowers average height, suggesting that shorter women were under-represented in the sample.

Data on heights are missing for 4579 women, 6.63% of the sample analysed. Missing values are roughly uniformly distributed by birth-year. They are less uniformly distributed across the states. In the major states, the percentage of missing values ranges between about 2 and 6.4, with the exception of Uttar Pradesh, for which 30.6% of women have no recorded height. We will therefore treat the analysis for this state with some scepticism and present results for all-India with and without this state. For the graphical analysis, I drop all observations for which height is missing. For the regressions, I impute mean height to each missing case and include as a regressor an indicator for whether height is missing. Correlations of this indicator with demographic indicators are presented in Table xx (redo these excluding UP). Height is more likely to be missing amongst the high caste population, which is taller (see Figure xx). Otherwise there is no strong correlation of the probability that height is missing with, for example, rural location or education.

Two alternative methods for removing outliers were investigated. First, I dropped women whose heights were recorded as less then 4 feet or greater than 6 feet;

these were 47 and 77 women respectively. The alternative was to drop women with heights that were more than three standard deviations away from the mean, and this resulted in a loss of 125 short and 135 tall women. I chose the former method but, in neither case did the deletions influence the results.

The Indian survey, like many but not all of the DHS surveys, interviewed only ever-married women. The age of these women at the date of interview ranges in 15-49 years. See Table xx and Figures xx, which describe the distribution of and the trend in age at first marriage for all-India and each state.[1] Only 25% of women in the sample analysed are married by age 15. In the sample of women who are over the age of 29 at the time of interview – a sample that is less likely to be censored- the 25th percentile is still 15. So, for the later (younger) cohorts, there is selection on age at first marriage.

Table xx shows that this selectivity is non-random, as shorter women in India tend to marry earlier. A woman in the fifth quintile of the height distribution marries a year later than a woman in the first quintile. These results are consistent with height being positively correlated wealth and education, so that shorter women have limited alternatives. In column 3 of Table xx I look at the effects of height on age at marriage conditioning upon the woman's education, cohort, caste, religion and rural/urban location. Taller women still marry later although the difference between the first and the fifth quintile is now down from a year to a quarter of a year. Education differentials are huge. Women with secondary or higher education marry 4.5 years later than uneducated women. Rural and scheduled caste women marry a bit younger and, somewhat surprisingly, there are no (conditional) cohort effects. Columns 4-6 show the same equations estimated on the sample of women who are at least 30 years old at the time of the survey, so that we can assume that these women are married if they were ever going to be. Then, if there are no important cohort effects, this is the more representative (uncensored) sample. The results in columns 4-6 are very similar to those in columns 1-3.

Marriage selection will tend to bias downwards heights of younger women. As a result, it may produce the appearance of slower or even negative growth in heights towards the right-end of the birth-cohort scale (the x-axis in Figures xx). To limit this problem, I have dropped women under the age of 23, which is the 95th percentile of

[1] The mean (median) age at first marriage are 17 (16), with inter-quartile range (15, 19) and the 95th and 99th percentiles are 23 and 28. Henceforth we will refer to this as age at marriage since most Indian women marry once.

the age at marriage distribution. This restriction also serves the purpose of allowing for the possibility that women in India continue to gain height in the age range 15-23, even if women in richer countries tend to attain their full height by about the age of 18 (e.g. Deaton 2007). The sample analysed therefore includes women aged 23-49.

We have already discussed mortality selection in childhood, which is when most deaths occur. There may be some further mortality selection at maturity. If women who die before the date of interview are, on average, shorter, then our data will carry an upward bias on height. This bias will tend to be more pronounced in the high-risk ages which are around child-bearing (the mean age at birth in India is 22 and the interquartile range is 19-26) and at the older ages, close to 49 years. The bias can therefore affect both ends of our data span.

The mean height of women over the period is 151.64cm, with a standard deviation of 5.56cm. Figure X displays the standard deviation of the log of height in each period, as a measure of the way in which inequality in heights has changed over time (comment xx).

Xxx Remember to make pt that time profile in hts can be constructed from CS of data and pt in strauss-thomas 2007 that unlike other measures of health ht is s.t. less ME and it does not fluctuate so not so impt to model dynamics (unless focused on effects in childhood like hoddinott.

5. Trends and Dispersion in Heights

Figure 1 presents the all-India trend in height at maturity for women born in 1950-75. Three functional forms are displayed. The quartic trend looks indistinguishable from the lowess fit, but the more restrictive quadratic fit produces a stronger appearance of a decline in heights towards the end of the period. In any case, the scatter of actual average height (weighted to account for survey design) in each year is displayed so the fitted functions are only visual aids. Women's heights increased secularly between 1950 and about 1964 but, in the next decade, they stagnated. The total gain in height over the period is only about 0.8cm (150.7 to 151.5).

Region

There are remarkable differentials in height across the states, and limited convergence over time (Figure 2).[2] Within-state trends are unlikely to be influenced by inter-state migration since this is very small (e.g. Munshi and Rosenzweig 2005, Topalova 2006). The level differences are much larger than any improvements over time. Women in Punjab and Haryana (with Rajasthan close behind) were about 7.5cm taller than women in Bihar, West Bengal and Maharashtra in 1950. A quarter century later, this inter-state differential had narrowed to about 5cm. Many of the states exhibit a trend not dissimilar to that for the country, with some growth until the mid-60s cohort and then a levelling off (xx- look at my detailed notes on this).[3] The only women that have grown continuously through the period are in the state of Kerala, where they have gained a remarkable 3.4cm in 25 years. Starting with heights below the Indian average, they are amongst the tallest women in India by the end of the period. Equally striking is the fact that the only women that have failed to grow at all are those in Punjab and Haryana, indeed these states exhibit a slight decline in average height over time. Since Punjab and Haryana were a single unified state until 1966, I will henceforth refer to both as “Punjab”. [xx Rajasthan behaves a lot like Punjab. Check if this is correct and check its imr and income levels and trends. Or just bring it in when discussing gender ineq, to say that the fact that Ra behaves like Pu and that TN, KA.. behave like KE is consistent with gender ineq as an expln.]

The relationship of height with the disease environment and income at birth is explored more systematically below but, for now, consider whether these variables might explain these two striking cases. Kerala and Punjab stand out in that both had a lower risk of infant mortality than any other state, with the exception of the small North-Eastern states. Over the period 1962-75, this risk declined faster in Kerala, at a rate of 0.15% p.a. (p=0.19) than in Punjab, where the rate was 0.03% p.a. (p=0.86). This is consistent with Kerala showing faster growth in height than Punjab. The two states contrast in their level of per capita income, Punjab being richer than Kerala.

[2] The states with the shortest women at the start of the period show a slight increase in height but, at the end of the period, they remain at the bottom of the regional distribution.

[3] [The states of Andhra, Karnataka, Tamil Nadu, Gujarat, Madhya Pradesh and Uttar Pradesh show trends similar to the all-India trend.]

And, in 1960-75, Punjab grew faster.[4] So, although there is a positive relationship of the levels of income and height across these two states, their divergent trends cannot be explained by differential income growth. In contrast, their differential trends in infant mortality rates are consistent with their divergent height trends. [The two outlying cases of Kerala and Punjab would seem to illustrate the more general pattern evident in Figures xx and xx [which show that, while there is a clear between-state relationship of income and height, the within-state relationships are all over the place. The within-state association of height with income at birth is negative in Punjab and even if income growth was slow in Kerala, there is a positive association of height and income in this state.]

A third potential explanation of the outstanding behaviour of Kerala and Punjab lies in the relative status of women. Punjab is characterised by high levels of gender inequality that have persisted or even intensified despite its (increasing) wealth, while Kerala has of indicators of the living standards, attainments and autonomy of women that are hugely better than the average for all other Indian states. There are two possibilities. One is that, in a society where women are more educated and have greater power at the level of household, community and government, *both* men and women are healthier, other things equal (e.g. Duflo 2006, Thomas 1991 xx). The other is that in a society with greater gender inequality, women will gain health less rapidly than men (xxrefs therein). It is difficult to discriminate between these hypotheses as there are no data on men's heights.

However, there are data on the heights of girls and boys in the NFHS, albeit for more recent cohorts. Using these data, Tarozzi and Mahajan (2007) analyse changes in gender differences in the heights (and weights) of children aged 0-3 years between the two periods for which anthropometrics are recorded, 1991-92 and 1998-99. They define the Southern region to include Kerala and the Northern region to include Punjab [and Rajasthan]. Consistent with our first hypothesis, they find that both boys and girls are about 30% less likely to be stunted (shorter than 2 standard deviations less than the mean) in the South than in the North and East. They also find some support for the second hypothesis in that, in the rural North, there is evidence of

[4] Punjab and Haryana grew at a significant rate of about 3% p.a. in 1960-75, while Kerala showed no significant growth, the trend rate per annum being 0.32%. Over the period, the per capita income of Punjab and Haryana was the highest in the country, while Kerala's was below the India-mean.

increasing gender inequality, with the average height of girls registering a small decline despite rapid economic growth in the intervening years. In contrast, the South shows no change in the relative health of girls measured as height-for-age. [The authors highlight that, while these regional and urban-rural differences coincide with traditional differences in son preference and gender bias across India, other measures of gender inequality such as child mortality, fertility, access to health care, school attendance and women's labour force participation rates appear to have become more moderated across the country, so that the spatial pattern in the evolution of gender differentials in height is somewhat puzzling. The puzzle does not seem to be resolved by consideration of spatial differences in the relative rate of decline of mortality for boys and girls.]

Social Class

This section describes level and growth differences in height by different indicators of social class. Trends in these sub-samples will tend to be influenced by compositional change. Given trends in women's education and in urbanisation, this is especially true when social class is indicated by education group or by rural v urban location. Although people seldom migrate between caste and religion groups, inter-marriage creates the possibility of compositional change. I have no information on trends in marriage that crosses caste or religion barriers. With this caveat, refer Figures 3-6. The overall picture is of persistent inequality in heights within India by social class.

Figure 3 shows the trends for low and high caste women. In 1950 the average height of lower caste women is 150.2 cm, 1.2 cm less than that of high castes. Between 1950 and 1964, both groups gained height but there was some divergence. After 1964, the heights of low caste women continued to increase while heights in the high caste group leveled off. Across the 25 years, the gap between the castes had narrowed by just 0.1 cm.

Figure 4 plots height trends for Hindu and Muslim women. Their initial heights are similar, Muslim women being about 0.1 cm taller on average. Until 1960, both increase, with Muslims gaining height more rapidly. After that, however, growth amongst Muslims loses momentum more quickly, flattening and even declining, while growth amongst Hindus only ceases around 1970. Nevertheless, at the end of our observation window, the differential has widened in favour of Muslims to 0.3 cm.

Trends for rural and urban women are displayed in Figure 5. However, as discussed, these trends reflect both within-sector variation and cross-sector migration. To the extent that there was a trend in urbanisation in the period analysed and migrants were better-off (more educated, taller) than non-migrants, average height in the rural sector will carry a spurious (composition-driven) downward bias. If it is the case that urban women are, on average taller, then rural to urban migration will also result in a downward bias in the urban trend. [xx discus graph here and in discussion bring in following facts] [xx not sure there was, report trend in rpop from table at end of file, at end of this sentence] [xx urban women are only very slightly taller on average and, controlling for characteristics, are shorter]. [xx- tarozzi- finding-join in] Overall, we find that, in urban areas, child nutritional status in India improved substantially during the 1990s. In rural India, which accounts for the bulk of the total population, our results show large improvements in shortterm measures of nutritional status, while height-for-age (a measure of long term nutritional status) improved much less.]

Figure 6 shows trends for women with no education and women with some education. Xx discuss graphs here. A similar argument holds when we sub-sample by education, the analogue of migration being an overall trend in education. In 1950-55, 58% of women were uneducated and 8.6% had secondary or higher education. By 1970-75, these percentages had changed to 51% and 11.9% respectively. There is a clear positive association in the data between a woman's education and her height, consistent with both reflecting family background or childhood circumstances. So if, as seems plausible, it is the better-off households in the uneducated group that, over time, send women into education, then the uneducated group will, at the margin, lose its better (taller) women and the height distribution in the educated group will be fed "from below". As a result, both groups will carry a downward bias in trends over time that reflects compositional change.

Height at Maturity and Income and Disease Environment at Birth

This section explores the relationship of heights with real per capita state income and childhood mortality rates in the year of birth. In fact adult height is sensitive to environmental conditions not only at birth but up until age 3 or even 5. to allow for this, the multivariate regression analysis presented in the next section allows for leads. Although heights data are available for birth cohorts 1950-75, the availability of income and mortality data is restricted (effectively) to 1962-75. This means we cannot explore whether the structure of the relationships determining height was different pre-65, when heights were growing. However, there is no a priori reason to expect that it is. It seems plausible that the production function by which health, expressed as height is determined has parameters that are stable within periods as short as about 25 years. Data on state incomes are available from 1960 onwards but only for the 15 major states- which account for more than 90% (xx) of the Indian population. Pooling retrospective fertility histories of mothers interviewed in both rounds of the survey (NFHS1 and NFHS2), I have information on births and mortality for children born in 1951-1998 across each of the 26 Indian states. However cell sizes, especially by state, are very small prior to 1962, and this creates unreliable variation in average mortality rates. I therefore restrict the analysis in this section to start in 1962.

Figure 7a plots a scatter of heights averaged by major state and birth-year against per capita state income in the year of birth. The variation here is both across and within states. As states are colour-coded, it is easy to distinguish the between and the within state variation in the scatter. The linear fit on this scatter is positive and the slope of the line is xx, p=xx [directly from simplreg, then translate]. Women in Kerala, Rajasthan, Punjab and Haryana are all taller than predicted by the all-India fit, while women in Bihar, Maharashtra and West Bengal are shorter. Figure 7b collapses these data so as to display just the between-state variation. There is again a significantly positive association of height with income at birth, the slope is xx, p=0.075. The within-state variation is isolated in Figure 7c, which plots state-specific linear fits. Only 6 of 15 states show a positive association. A within-groups regression on these data produces a coefficient on income of xx [p=xx].

Figures 8a-8c similarly describe the relationship of women's height with infant mortality rates at birth. This is negative and significant in each case, with slopes xx, xx and xx [p=xx]. Although infant and under-5 mortality are closely related, it is useful to consider whether the relationship is stronger for under-5 mortality since this might afford a better description of the disease environment: see Figures 9a-9c. The slopes are now xx, xx and xx [p=xx].[comment on whether relation is stronger, dep on mean mort].

Draw these graphs also by state and social class.

Refer to scarring and selection and to deaton results

Possibly refer to reg results that look at deviations in another paper, or here.

Multivariate Analysis

Using the microdata, I estimated equations of the form

$$(1)\ H_{ist} = a_s + h_t + a_s.t + b\ lnY_{st} + g\ M_{st} + q' X_{st} + l' Z_{ist} + e_{ist}$$

H is the height of woman *i* born in state *s* in year *t*. Y is real per capita net domestic product, M is the infant (or under5) mortality rate and X is a vector of other state-year varying covariates including food prices, the poverty rate, inequality and rainfall shocks. State fixed effects, a_s, are included to capture the effects of time-invariant or sluggish factors like diet, ethnic composition or agrarian arrangements. The year dummies, h_t and state-specific trends, $a_s.t$, pick up the effects on height of trended unobservables like medical technical progress, and any aggregate macroeconomic or natural shocks. They will also capture cohort effects. Z is a vector of individual demographic controls including birth-month, caste and religion. These are not displayed in equation (1) to avoid clutter, but I experiment with leads and nonlinear effects of the key regressors. I also explore some interactions designed to assess whether height is more sensitive for women from lower socio-economic strata. Standard errors are clustered at the state level to allow for autocorrelation within states as well as arbitrary forms of heteroskedasticity.

Redo data file and organise regs and explain issues of construction of file here. Reshaping, woman, child, 15 v 26 states, rainfall region, etc.
Be clear about changing sample size, different range of variables
try diff measures of rainfall. Refer dean yang paper.
Highlight here or earlier that it is unusual to have annual mortality data over long period or annual income data by region. And interesting to look at Z, indiv variation in hts.
Month of birth. Season. Play up. Interact.

6. Discussion

Vegetarian diet

Muslim v hindu

Trends v fluctuations

Simulation of trends in IMR predicting trends in height at maturity.

Data on children born more recently is not encouraging suggests There is little evidence of that these trends are improving. Children born in the last decade are amongst the shortest in the world.

It is instructive to consider trends in American heights through the nineteenth century, analysis of which indicates the potential role of income levels and inequality, infectious disease, diet quality and war. Around 1800 American men were the tallest in the world despite being relatively poor in the income sense. Possible reasons suggested for this mismatch include the good diet in the US at the time, the low population density, low incidence of infectious diseases and the relatively low inequality compared to Europe. Moreover the pattern of growth in stature in the US since then has not been consistently linear. For example military records indicate that there was a decline in average height in the second half of the 1800s, and this is supported by skeletal evidence. This was in spite of continued economic growth, although income may not have conferred as much of a health advantage as it did after the epidemiological advances of the early 1900s. The fall in stature is thought to have been associated with a rise in infectious disease created by expanding trade and migration between industrialising countries and crowded, unhygienic workplaces (in which a sizeable proportion of children also toiled). The hardships caused by the Civil War in the 1860s will have been an additional trauma for health and stature (Steckel, 1995). There is some debate as to whether a rise in inequality also occurred over this time period, which could also help to explain the downturn in average heights (Shammas 1993 v. Steckel 1995). Komlos (1987) explains part of the decline in average height with evidence of dietary deterioration caused by growth in population and food demand outstripping supply, especially of meat. It appears that a trough in average heights in the US was reached around the 1880s or 1890s and it was only around the turn of the 1900s that the clear secular increase in stature began, coinciding with advances in medical knowledge and hygiene (Steckel, 1995).

Heights in Europe have exhibited an upward trend from around 1850 to the present day, with some fluctuations caused by poor harvests. This trend has slowed in the Northern countries in the last half century (Cole 2002, Bozzoli et al. 2007). For example, Scandinavian heights have increased by about 3mm per decade while heights in parts of southern and eastern Europe have increased by as much as 30mm per decade, and by the 1980s average heights in Scandinavia and the Netherlands appeared to have reached a plateau.[5] By comparison, in the developing world rates of growth can still be high when the right conditions prevail.

(motivation- also Deaton PNAS says that India has the highest stunting amongst 57 LDCs in the WHO database and refers to the veg diet persistent effects) Turning now to India, data on height to measure welfare may be particularly valuable due to the prevalence of physical labour and malnutrition, the evidence of widespread son preference and the difficulties in obtaining income data at the level of the individual. Moradi (2006) found that in 1960 Indian women, with an average height of 151cm, were smaller than their sub-Saharan Africa equals (at 159.0cm). Using the WHO guides[6] in the 1990s 36% of Indian children under five years old were 'severely stunted', compared to 21% in sub-Saharan Africa (Borooah, 2004). Disparities by region and in rural areas as compared to urban areas have also been found to be noticeably acute in India. Concentrating on children aged 0-3 years old, Tarozzi and Mahajan (2007) have found that in urban areas child nutritional status generally improved substantially along with the rapid economic growth of the 1990s. However in rural areas, whilst there have been large improvements in weight-for-height, a short-term measure of nutritional status, the long-term measure, height-for-weight, improved much less. There was also a rise in gender inequality as measured by the anthropometric indices. For example, in rural areas of the north and eastern states of India, boys' nutritional status benefited much more than girls' and only in the southern states and in urban areas do there appear to be clear improvements for the health status of both boys and girls[7]. In rural areas and in the north there is even

[5] Cole suggests that the slowdown in northern Europe is to do with these populations reaching genetically determined maximum heights after about six generations of approximately optimal conditions.

[6] An individual is classified as 'not stunted' if they stand at a height closer than two standard deviations below the WHO norm for that age and sex, 'moderately stunted' if they are greater than two but less than 3 standard deviations below their norm and 'severely stunted' if they are greater than three standard deviations below the relevant threshold.

[7] The authors compose these groups of states as follows: the 'northern' states consist of Gujarat, Haryana, Jammu, Punjab, Rajasthan, Uttar Pradesh and New Delhi; 'eastern' states are Assam, Bihar and Orissa; and the 'southern' states are Kerala, Karnataka and Maharashtra.

evidence of a small decline in the average heights of girls. The authors highlight that these regional and urban-rural disparities coincide with traditional differences in son preference and gender bias across India. However they also point out that measures of gender inequality, such as sex-selective abortion, child mortality, access to health care, school attendance and labour force participation rates have generally become more *moderated* across the country, which rather runs against the rise in this measure of gender inequality (Tarozzi and Mahajan, 2007).

It appears that average height is quite a sensitive indicator of deprivation, and the effects of deprivation at key moments of the development process in particular can have persistent or long-term effects. Such key moments coincide with the times of most rapid growth in optimal conditions. That is, from birth to about five years old and again during adolescence. The velocity of growth is highest at the start of life and generally falls over the years to then rise again quite sharply for the adolescent growth spurt to about a half of what it was at the beginning (Tanner, 1978, ch. 1). Under conditions of malnutrition, which could be due to the deterioration of diet, or to the added toll exacted by illness, or to any other cause that affects net nutritional status, the first sign of an effect on height is a decrease in the velocity of growth. Growth is delayed whilst energy is diverted to immunological defences and can be raised again during a period of catch-up if conditions improve sufficiently. However, chronic malnutrition is more likely to lead to permanent stunting (Tanner, 1978, chs. 9-10). It is impossible to say how severe or long-lasting starvation and disease have to be to have permanent effects on height, but such effects will be more rapidly produced in young children and possibly in adolescents than at other times (Tanner, 1966). In a review focusing on epidemiological data from the developing world Kettle Khan et al (1994) assess the potential for catch-up following prolonged periods of under-nutrition. Although catch-up is possible through a delay in the maturation process and by prolonging the growth period this time is usually less than two years in developing countries. Therefore it is only enough to compensate for relatively limited periods of growth retardation. The authors find that improvements in environmental conditions are most effective at reversing stunting the earlier they come about.

Possibly of interest is the evidence of the growth experience of American slaves. By their age-height profile young slave children appeared to be severely stunted, yet they caught up this height to a considerable degree, mainly by a delay in the adolescent growth spurt and a continuation of the growth process into their late teens and early twenties. From the surviving records it appears that slave children suffered a very poor diet, illustrated by a postneonatal infant mortality rate as high as 162 per thousand. Improvements in their diet came about around the age of 10, when they entered the labour force and started to receive adequate food, including a meat ration, so that they were fit to work. However even after a prolonged growing period adult slaves remained smaller on average than a typical well-fed individual, with this remaining difference being principally the result of malnutrition in early childhood. (Steckel, 1986).

Further evidence on the long-run effects of severe temporary shocks to the childhood growth process is available in other parts of the world in a variety of instances. For example Banerjee et al (2007) document the effects of a major income shock experienced by wine-growing families caused by an insect infestation (Phylloxera) that destroyed 40% of French vineyards between 1863 and 1890. They report that the height at adulthood of children born to the affected families during the crisis was significantly diminished. Hoddinott and Kinsey (2001) use data from the time during and after droughts in Zimbabwe from 1993-1997 to demonstrate the long-term effects on child height caused by these shocks. They find that children aged between 12 and 24 months lose up to 2cm, although there was no evidence of children any older than this being permanently stunted. Children of poor families and girls were found to be particularly adversely affected. The temporary hardships of severe flooding in Bangladesh in both 1988 and 1998 provide similar stories. Foster (1995) highlights the impact of the floods in 1988 on long-term child growth through its effects on the availability of credit. He found that children in landless households, those that were least able to smooth their consumption over the period, were especially vulnerable. Del Ninno and Lundberg (2005) carry out an analogous study into the 1998 floods, showing that some households were able to smooth their consumption over the crisis with the help of small government transfers and borrowing. But the heights of children in the households worst affected by the floods and least able to smooth their consumption did not fully recover.

Sample selection issues

Much of the data used to infer information about the stature of populations in the eighteenth and nineteenth centuries is drawn from military records documenting the physical measurements of conscripts. This data may be biased for two reasons: Firstly, there tended to be explicit limits on the height range acceptable for military recruits, for example not to fall short of 5’6’’ and not to exceed 6’. On the other hand, it has also been noted that such ideals were not followed with any great discipline during times of war, when the priority would be to enlist as many fit men as possible. Secondly, those conscripts were usually taken from lower socio-economic groups than the average (Steegmann, 1998). It may also be noted however, that the trends in the stature of Americans from the nineteenth century have been corroborated from various sources other than military records, such as among free blacks in Maryland, among Amherst students and among several other groups (Komlos, 1998).

Bibliography

Banerjee, A., Duflo, E., Postel-Vinay, G. and Watts, T., ‘Long Run Health Impacts of Income Shocks: Wine and Phylloxera in 19th Century France’, NBER Working Paper No. W12895, February 2007.

Borooah, V., ‘The Height-for-age of Indian children’, *Economics and Human Biology,* vol. 3, issue 1, 2005, pp45-65.

Cole, T., ‘The secular trend in human physical growth: a biological view’, *Economics and Human Biology,* vol. 1, issue 2, June 2003, pp161-168.

del Ninno, C. and Lundberg, M., ‘Treading Water: The long-term impact of the 1998 flood on nutrition in Bangladesh’, *Economics and Human Biology,* vol. 3, issue 1, March 2005, pp67-96.

Duflo, E., ‘Grandmothers and Granddaughters: Old Age Pensions and Intrahousehold Allocation in South Africa’, *The World Bank Economic Review,* vol. 17, no. 1, June 2003, pp1-25.

Floud, R., ‘The Heights of Europeans Since 1750: A New Source for European Economic History’, published in Komlos, J., eds., *Stature, Living Standards and Economic Development* (Chicago, 1994), pp9-24.

Floud, R., Wachter, K. and Gregory, A., Height, health and history: Nutritional status in the United Kingdom, 1750-1980, Cambridge, Cambridge University Press, 1990.

Foster, A., 'Prices, Credit Markets and Child Growth in Low-Income Rural Areas', *The Economic Journal,* vol. 105, May 1995, pp551-570.

Hoddinott, J. and Kinsey, B., 'Child growth in the time of the drought', *Oxford Bulletin of Economics and Statistics,* vol. 63, no. 4, 2001, pp409-436.

Kettle Khan, L., Martorell, R. and Schroeder, D., 'Reversibility of stunting: Epidemiological findings in children from developing countries', *European Journal of Clinical Nutrition,* vol. 48, no. 1, 1994, pps45-s57.

Komlos, J., 'The Height and Weight of West Point Cadets: Dietary Change in Antebellum America', *Journal of Economic History,* vol. 47, no. 4, December 1987, pp897-927.

Komlos, J., 'Height and Social Status in Eighteenth Century Germany', *Journal of Interdisciplinary History,* vol. 20, no. 4, Spring 1990, pp607-621.

Komlos, J., 'Anomalies in Economic History: Towards a Resolution of the ''Antebellum Puzzle'', in Komlos, J. and Cuff, T. (eds.), *Classics in Anthropometric History,* pp590-607, St. Katherinen, Scripta Mercaturae Verlag, 1998.

Micklewright, J. and Ismail, S., 'What can child Anthropometry reveal about living standards and public policy? An illustration from Central Asia', *Review of Income and Wealth,* Series 47, no. 1, March 2001, pp65-80.

Miranov, B., 'Birth weight and physical stature in St. Petersburg: Living standards of women in Russia, 1980-2005', *Economics and Human Biology,* vol. 5, issue 1, pp123-143.

Moradi, A., 'Nutritional status and economic development in sub-Saharan Africa, 1950-1980', Global Poverty Research Group Ref: GPRG-WPS-046, available online at: http://www.economics.ox.ac.uk/Research/workpapers.asp

Morris, D., Measuring the Condition of the World's Poor: The Physical Quality of Life Index, Pergammon Press, New York, 1979.

Shammas, C., 'A New Look at Long-Term Trends in Wealth Inequality in the United States', *The American Historical Review,* vol. 98, no. 2, April 1993, pp412-431.

Silvertoinen, K., 'Determinants of Variation in Adult Body Height', *Journal of Biosocial Science,* vol. 35, 2003, pp263-285.

Steckel, R., 'A Peculiar Population: The Nutrition, Health, and Mortality of American Slaves from Childhood to Maturity', *The Journal of Economic History,* vol. 46, no. 3, September 1986, pp721-741.

Steckel, R., 'Stature and the Standard of Living', *Journal of Economic Literature,* vol. 33, no. 4, December 1995, pp1903-1940.

Steegmann, A., '18th Century British Military Stature: Growth Cessation, Selective Recruiting, Secular Trends, Nutrition at Birth, Cold and Occupation', in Komlos, J. and Cuff, T. (eds.), *Classics in Anthropometric History,* pp160-178, St. Catherinen, Scripta Mercaturae Verlag, 1998.

Strauss, J. and Thomas, D., 'Health, Nutrition, and Economic Development', *Journal of Economic Literature,* vol. 36, no. 2, June 1998, pp766-817.

Strauss, J. and Thomas, D., 'Health Over the Life Course', BREAD Working Paper No. 154, July 2007.

Tanner, J., 'Growth and Physique in Different Populations of Mankind', in Baker, P. and Weiner, J. (eds.), *The biology of human adaptability,* Oxford, Oxford University Press, 1966, pp45-66.

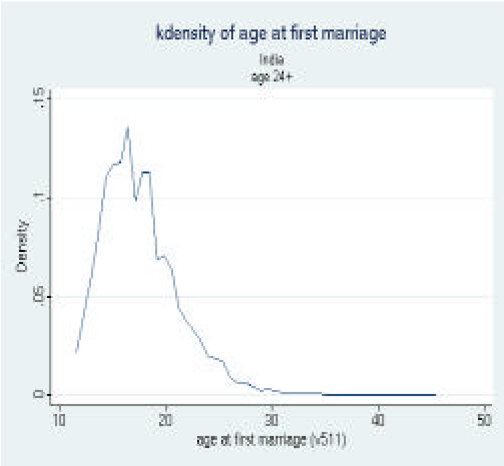
Tanner, J., Foetus into man: Physical growth from conception to maturity, London, Open Books, 1978.

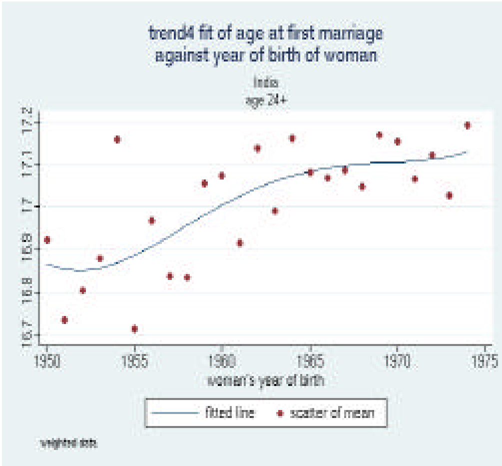
Tarozzi, A. and Mahajan, A., ‘Child Nutrition in India in the Nineties’, *Economic Development and Cultural Change*, vol. 55, no. 3, 2007, pp441-486.

World Health Organisation, Physical status: the use and interpretation of anthropometry. Report of a WHO Expert Committee. Technical Report Series No. 854, Geneva, 1995.

Deaton, 2007?

acemoglu paper cited in incomeshocks explains that epidemiolo transition
is dated in the 1940s. relevant to my period starting in 1950.





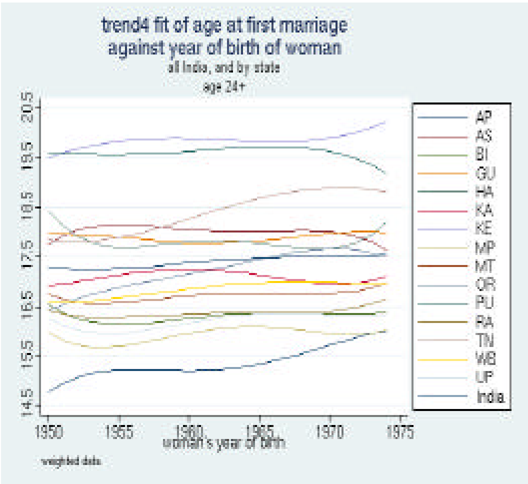
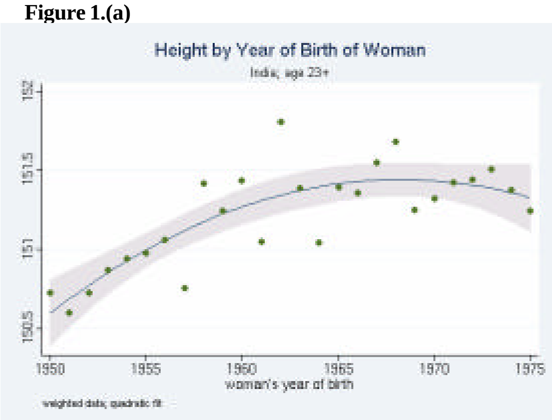


Figure 1.(a)

Figure 1.(b)



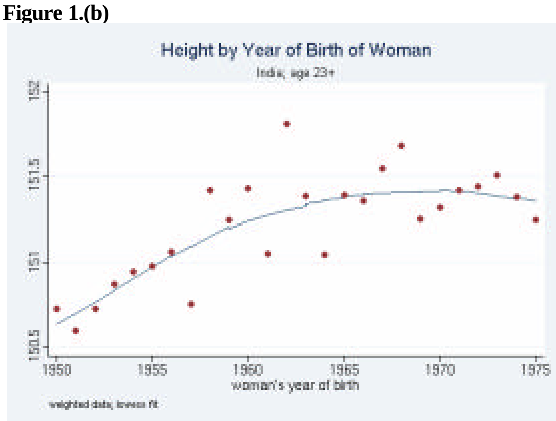


Figure 1.(c)

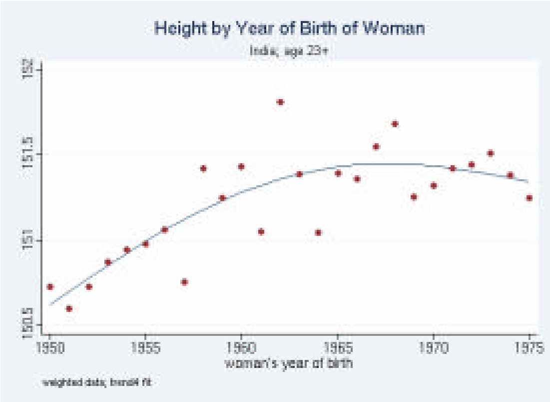
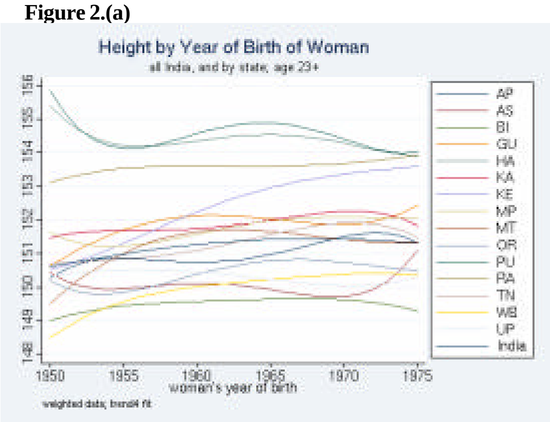


Figure 2.(a)

Figure 2.(b)



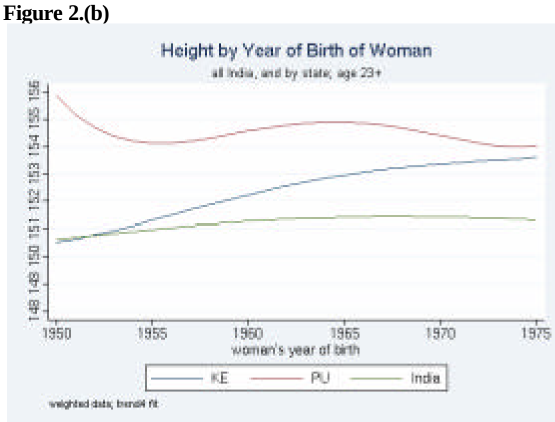
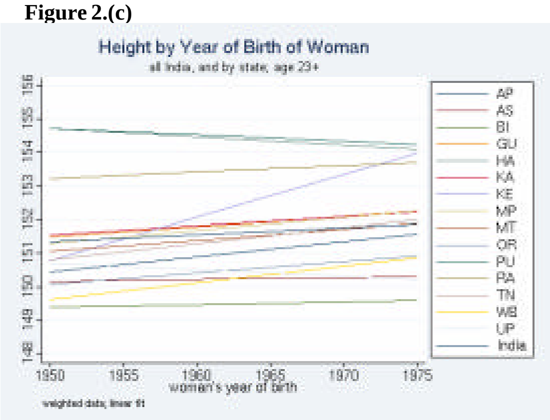


Figure 2.(c)

Figure 2.(d)



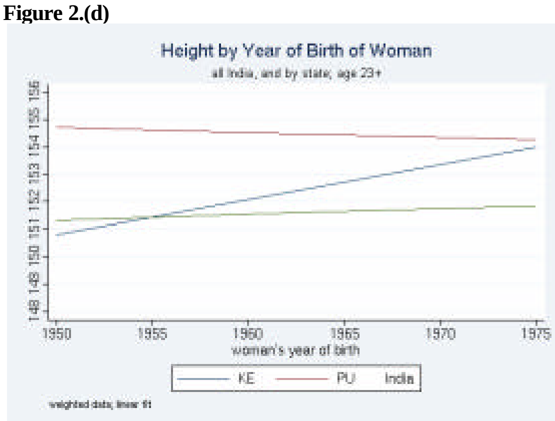
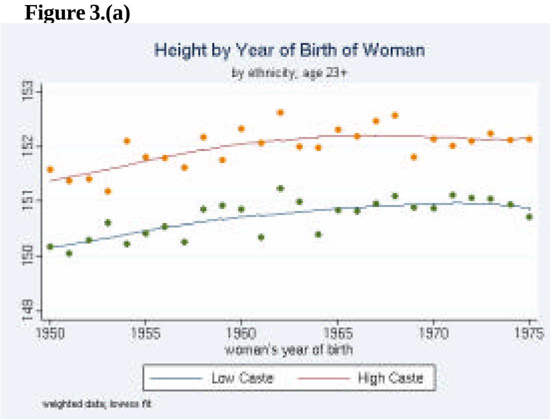


Figure 3.(a)

Figure 3.(b)



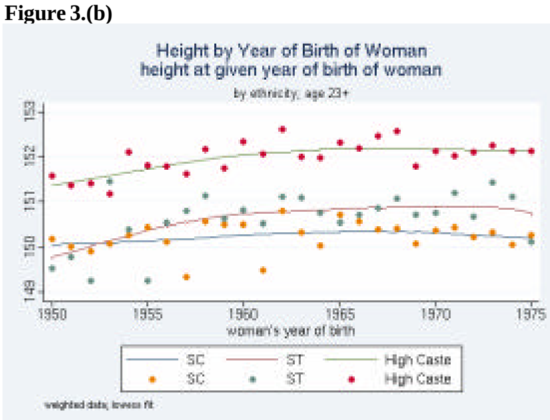
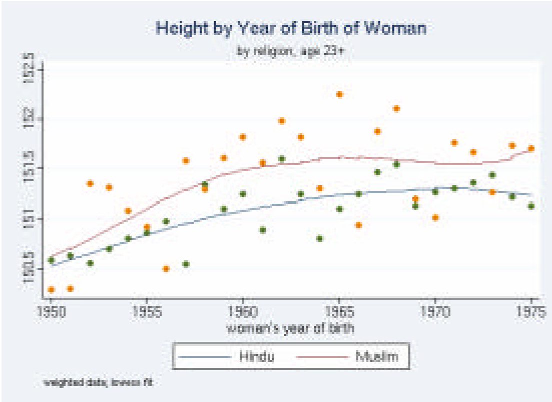


Figure 4.(a)

Figure 4.(b)



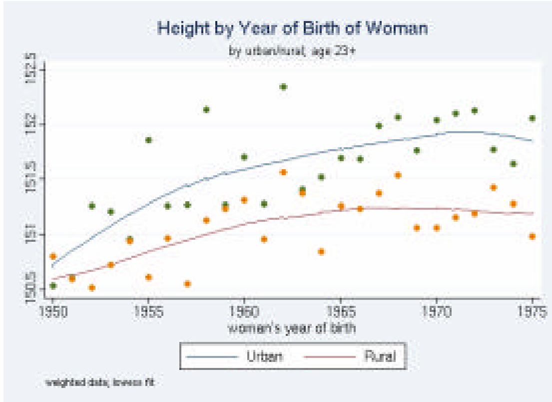


Figure 5

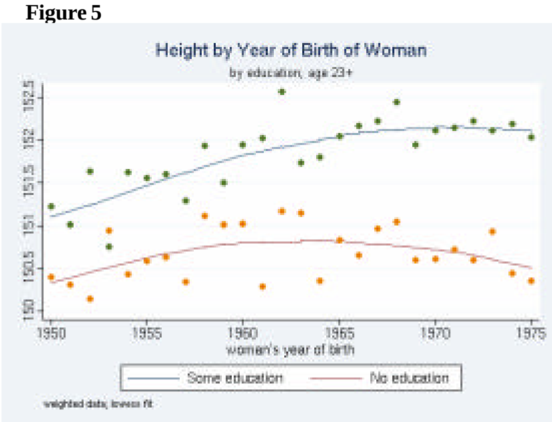


Figure 6

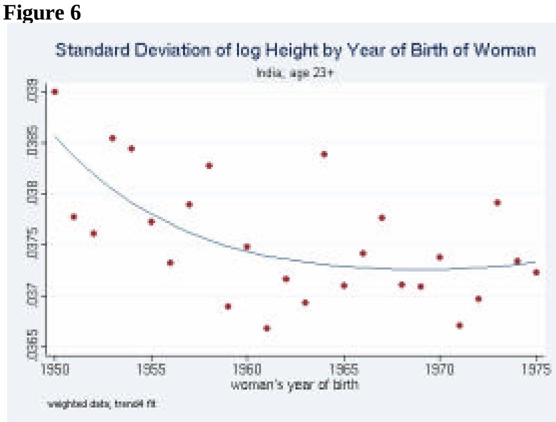
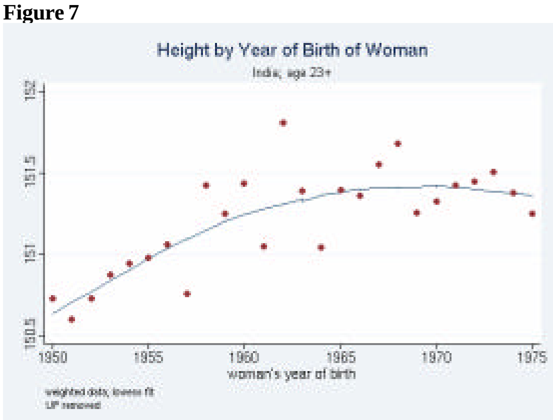


Figure 7



ht_miss correlations: (redo with UP excluded and with significance values attd as *)

agefirstma	-0.040	educf1	0.078	educm1	0.062
rural	0.005	educf2	0.067	educm2	0.130
highcaste	0.336	educf3	-0.107	educm3	-0.058
muslim	-0.011	educf4	0.049	educm4	0.049
hindu	0.002	educf56	-0.185	educm56	-0.200
otherrel	0.008				