Anthropometric Evidence of Indian Welfare and Inequality in the 20th Century

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India has two million gods, and worships them all. In religion all other countries are paupers; India is the only millionaire.

\- *Mark Twain*

Though “shining” democratic Indians can boast about many religions, castes, languages and tribes, they cannot ignore stagnating poverty and growing inequality between and within several groups. The aim of the thesis is to see beyond the typical welfare and inequality approaches. I dedicate my work to my family and millions of children- especially girls- whose future is impended by inequality and poverty.

Acknowledgements

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My last chapter on the simultaneous existence of malnutrition and obesity has improved tremendously over time. I presented this paper first in Bristol and later at several conferences. Suddenly, I was getting bored with the *good old results* and came up with the idea of applying quantile regressions for this chapter. I have benefited a lot from the comments, criticism and ideas of Stanley Ulijaszek, Wiji Arulampalam, and Barry Popkin. I also benefited from the comments I received from participants of the 3rd Economics and Human Biology conference and Population Association of America meeting (2006).

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Abbreviations

AIAS	All India Anthropometric Survey
CGM	Child Growth and Malnutrition world data
CV	Coefficient of Variation
DHS	Demographic Health Survey
GD	Gender Dimorphism
GDP	Gross Domestic Product
HAZ	Height for Age Z-score
NDP	Net Domestic Product
NFHS	National Family Health Survey
NNMB	National Nutrition Monitoring Bureau
OLS	Ordinary Least Square regression
QR	Quantile Regression
SADHS	South Africa Demographic Health Survey
SD	Standard Deviation
SLI	Standard of Living
WAZ	Weight for Age Z-score
WHO	World Health Organization
WHZ	Wight for Height Z-score

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Overweight in India

1. Introduction

1.1. Welfare and Inequality in India

The study of welfare and inequality in India is mainly focused on the post-1970, as data is not easily available. Since 1970, development economists have applied various indicators to investigate inequality and welfare (e.g. Gini coefficients, child mortality etc.); however, for a long-term study indicators like Gini coefficients are not good enough due to the aggregation of estimations and unavailability for all the Indian states even for the post-1970 years. Inequality is not a new phenomenon of the current Indian society. In contrast, it has a long history that is essential to explore when one wants to investigate the long-term reasons and consequences of inequality and overall economic development.

In addition, most of the Indian economic history is focused on the British colonial power with an either nationalistic or positive view concerning the benefits of colonization. Most researchers overlooked inequality and welfare especially for the first part of the 20th century causing a paucity of information about the same. Unfortunately, contemporary indicators of wellbeing are difficult to obtain for historical periods. Accordingly, I have to rely on anthropometric data (e.g. heights) besides "classic" time series of real wages. Collecting new data and applying sophisticated econometric methods allows testing several hypotheses regarding inequality and welfare in India.

1. What are the possible ways to assess the individual well-being?
2. How to aggregate the individual indicators of well-being into a measure?
3. How to assess the inequality in well-being?

4. What are the major determinants of welfare of a country?
5. What is the best way to capture the regional and gender welfare and inequality?

Researchers that follow the nationalistic view like Naoroji (1871), Dutt (1956) and Digby (1901) have emphasized the drain of wealth and burden of land taxation, whereas Griffiths (1952) highlights the positive impact of British colonialism on India. Most of the nationalistic bias has been stressed on the self-sufficiency of the early Indian village. Unfortunately these studies overlooked the inequality created by the Indian social structure between and within the different castes, ethnic groups, religions, and gender.

1.2. Measures of welfare and inequality in India

One of the commonly available data for recent and historical periods to quantify welfare is GDP. Maddison (2001, 1995) constructed GDP estimates for the period before 1950 (see Figure 1). According to his estimates, the Indian GDP has been growing mostly from 1970 onwards. Especially till the 1950's India's economy was stagnating, and the major economic expansion has started only after 1973. Nevertheless, China is growing much faster and the gap seems to widen over time.

Nevertheless, GDP does not give a detailed picture of welfare and inequality. GDP ignores everything that happens outside the realm of monetized exchange, regardless of its importance for well-being. Crucial economic activities in households and volunteer sectors are entirely not considered as economic value creation which is very important in the Indian context. In particular, childcare, elder care, other home-based tasks, and volunteer work in the community are not included as they are not paid for. Moreover, we cannot focus on regional inequality and related issues, as GDP estimates do not account for family labour, which is predominant in rural areas with an overwhelming importance of the agricultural sector.[1]

To analyse welfare, GDP data are combined with measures for inequality, as high GDP (even GDP per capita) does not imply a high level of well-being for all individuals and groups. The most common measure for inequality with regard to household income (or land) is the Gini coefficient. However, Gini coefficient estimations for India are available only for the post-1955 period.

An alternative indicator that can be used to fill the gap for the pre-1950 period is the real wage index of unskilled urban workers constructed by Williamson (2000). This indicator is regarded to be representative for the poorest section of the society, and the growth in this index can be seen as improvement in welfare. Nevertheless, this indicator does not include important groups of the workforce such as industrialists, housewives, and peasants practising subsistence agriculture.

Furthermore, there are some important limitations of Williamson’s estimates. His real wage estimates are based on urban wages only; hence, the rural urban divide in income (due to differences in labor productivity and importance of the agricultural sector) cannot be analyzed. To deflate nominal wages, Williamson (2000) used wheat and rice prices as proxy for the cost of living. Accordingly, important components of private consumtpion such as rents and protein-rich food does not enter the calculation of cost of living. A counter-check of Williamsons real wage estimates with other indicators like stature or life expectancy can yield crucial evidence.

[1] See Moradi and Baten (2005) for more discussion.

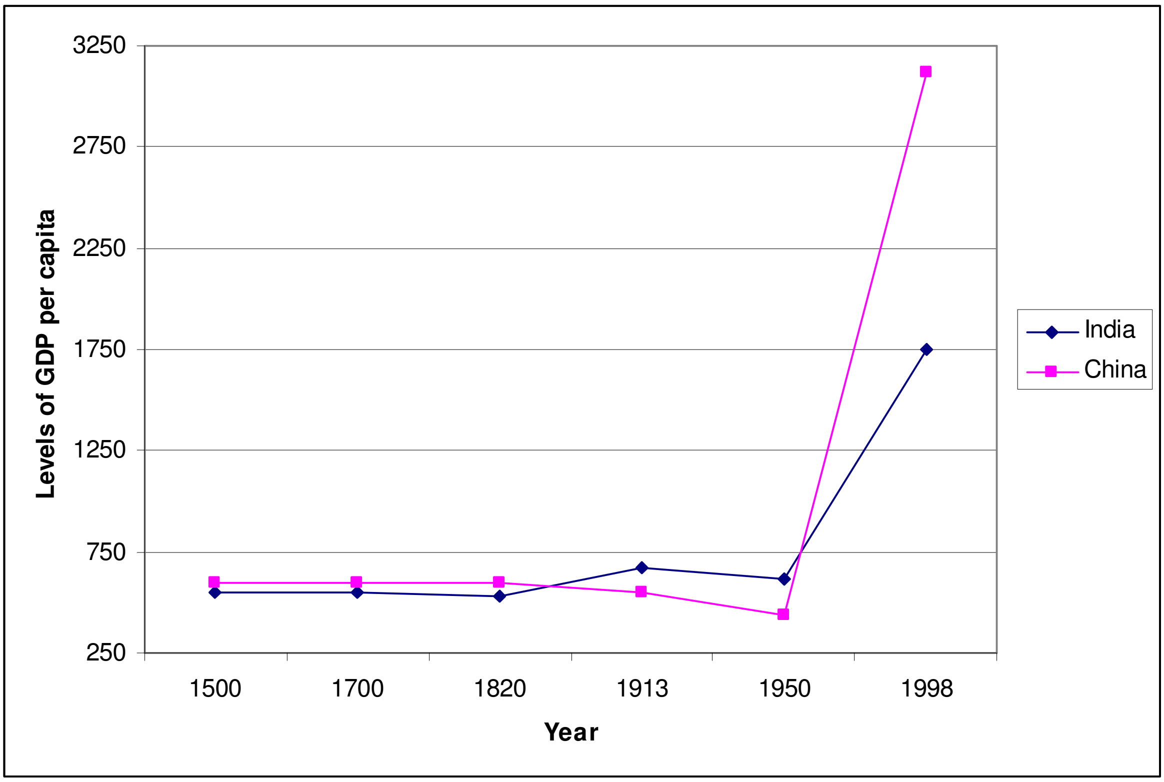

Figure 1: Levels of GDP per capita in India and China, 1500-1998 in 1990 international dollars

Source: Maddison 2001

An alternative measure for well-being is life expectancy at birth that can be used for Indians in the 20th century. Life expectancy is a statistical measure defined as the expected (mean) survival of human beings. This indicator can be based upon a number of criteria such as gender and geographic location. It is most often constructed to measure the life expectancy at birth, and the value is similar to the expected age at death. Figure 2 shows that life expectancy of males and females in India has been growing since the 1920's - but not before. This enhancement can be attributed to the improvements in public health (e.g. hygiene, access to water), nutrition and medicine.

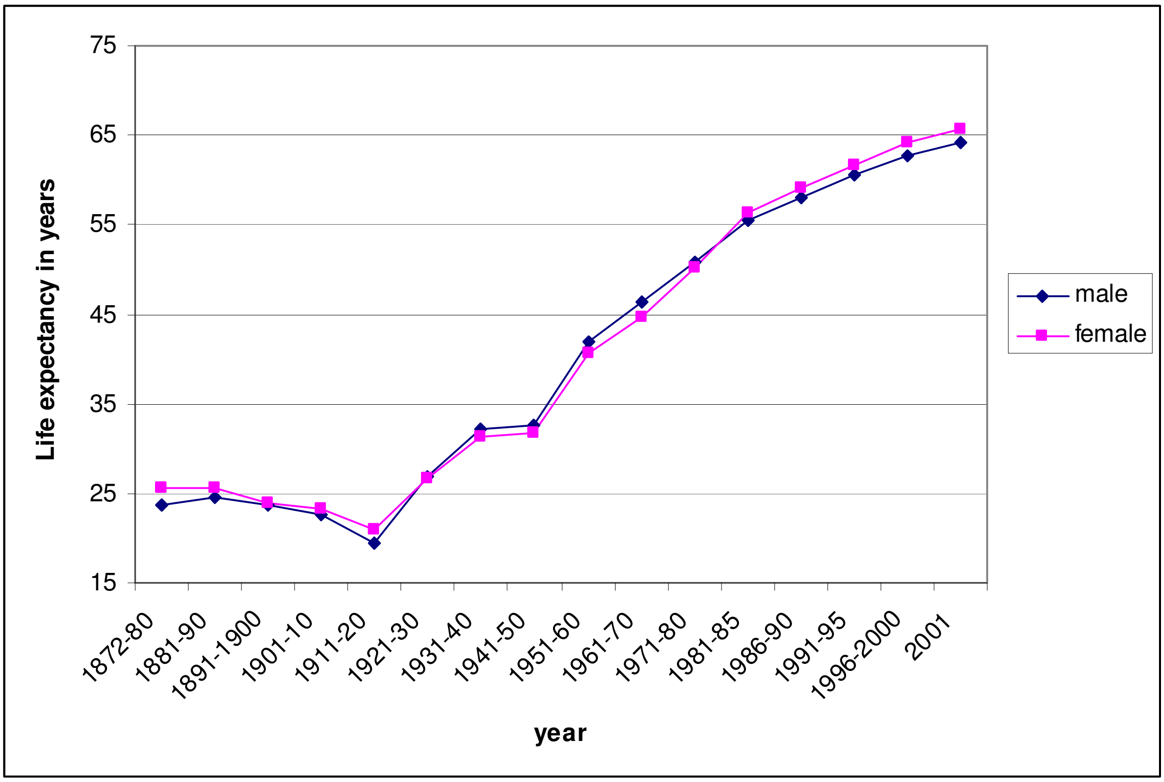

Figure 2: Life expectancy of males and females in India from 1872-2001
Source: Mostly from Mayer (1999) and various published sources

A most interesting observation can be drawn from the life expectancy of Indians in the last 100 years: life expectancy of males has surpassed females' life expectancy from 1930 to 1980, which indicates gender related discrimination. In theory, we could use life expectancy data for different regions, gender and social groups to uncover disparities driven by the discrimination of women and regional factors. However in practice, the use of this indicator is limited due to the unavailability of data by regions and groups.

To study the gender disparity in detail the commonly used indicator is sex ratio defined as the number of females per one thousand males. In most of the countries of the world, there are more females compared to males, as discrimination is not present. Moreover, females have higher biological survival rates. Astonishingly, we observe in India a continuous decline in sex ratios since 1901 proving the growing bias against females (see Figure 3). However, Mayer (1999) argued that discrimination and differencing values placed on women's labour made a relatively minor direct contribution to the trend in sex ratio. He further argued that one has to compare sex ratios with other indicators like education, labour force participation and mortality to obtain more insights.

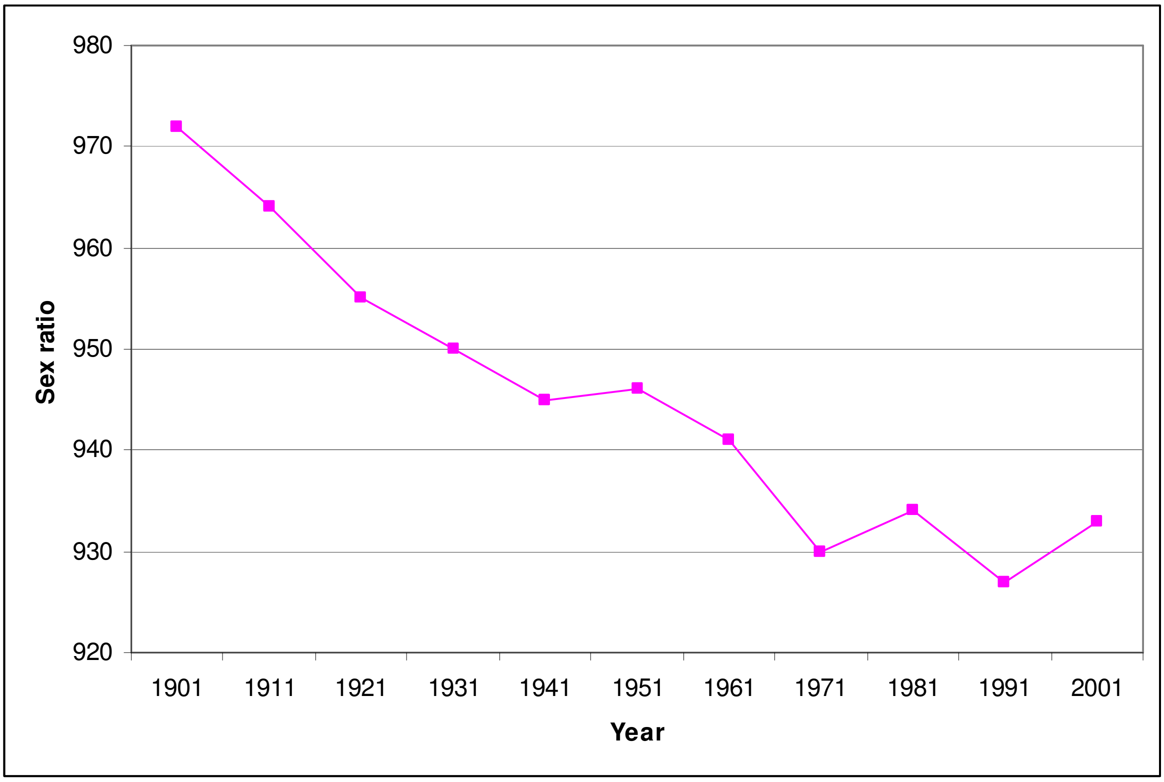

Figure 3: Sex-ratio in India from 1901-2001

Source: Census of India

Definition: Females per thousand males

Literacy is an important human capital indicator that can be regarded as welfare measure (e.g. the human development index considers literacy besides life expectancy and GDP as development indicators). Higher literacy increases labour productivity and is a necessity to achieve innovations and to preserve and use knowledge for future generations. Besides these economic aspects of literacy, having higher literacy is an essential achievement in itself.

An increase in the level of literacy indicates enhancing welfare; however, using a threshold approach (similar to a "poverty line" concept) could be an alternative to measure welfare and its improvement. Hence, educational poverty can also help us in investigating welfare and inequality. Indian data on education, particularly on literacy are available from decadal Census.[2] Using these data,[3] we can construct the crude literacy rate by taking the ratio of the number of literates to the total population. Figure 4 illustrates a steady increase of literacy levels in both males and females from 1901 to 2001. Nevertheless, individual or group-wise (religious, ethnic groups by regions) education data that can be used for in-depth study of levels and trends of welfare are not available.

Before focusing on more indicators of welfare it is essential to have a closer look at Indian demographic development. Though India occupies only 2.4% of the world's land, it has to support over 15% of the world's population. Population has increased

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[2] However, a person who can merely read but cannot write is not recorded as literate in census.

[3] As India has several languages the reading and writing ability in any language is taken into the category of literates.

continuously from 1921 to 2001 (Figure 5). Most of the major increase started from 1951 as the population rose 21.5 percent by 1961. Population thereafter increased by more than 20 percent every decade, though since 1971 growth slowed down (from an annualised rate of 2.24% to 1.96%).

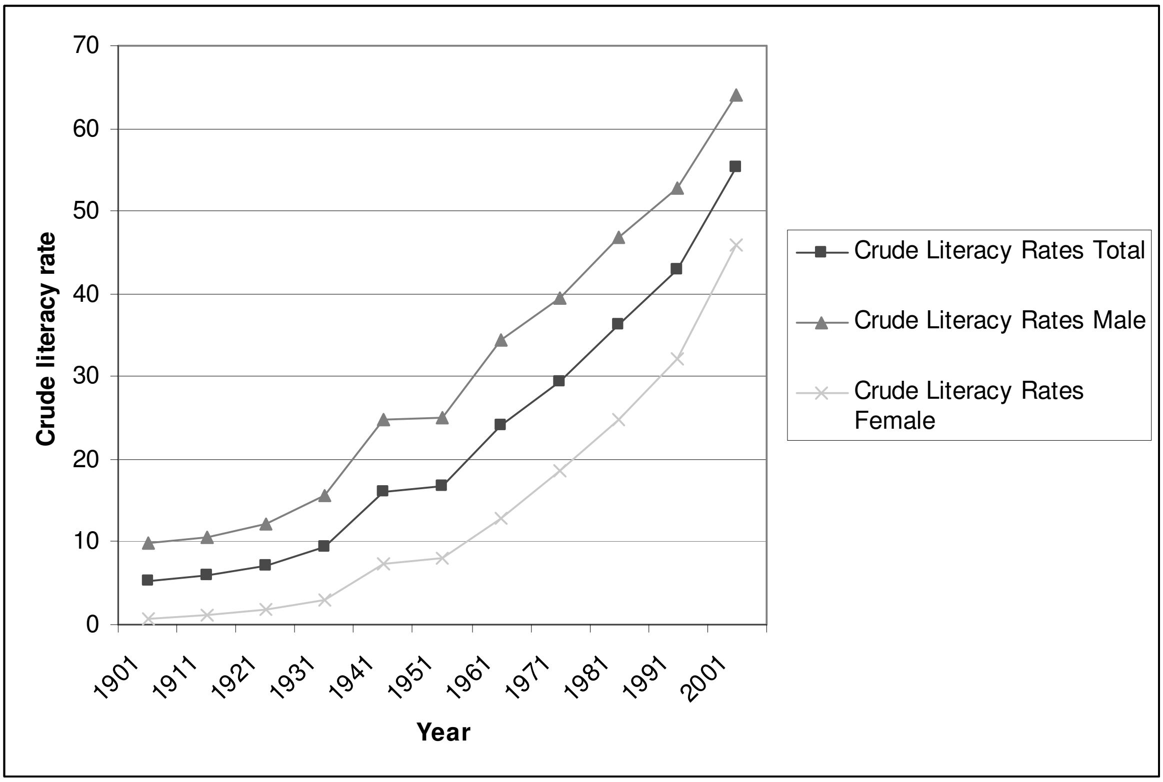

Figure 4: Crude Literacy Rates in India from 1901 to 2001

Source: Census of India

Interestingly, we observe that the rural population increased more compared to urban areas. Most of the population 'explosion' can be attributed to improvement in mortality and availability of food. Population increase was not homogenous and it depended heavily on regional factors, urbanization and the influence of religions and culture.

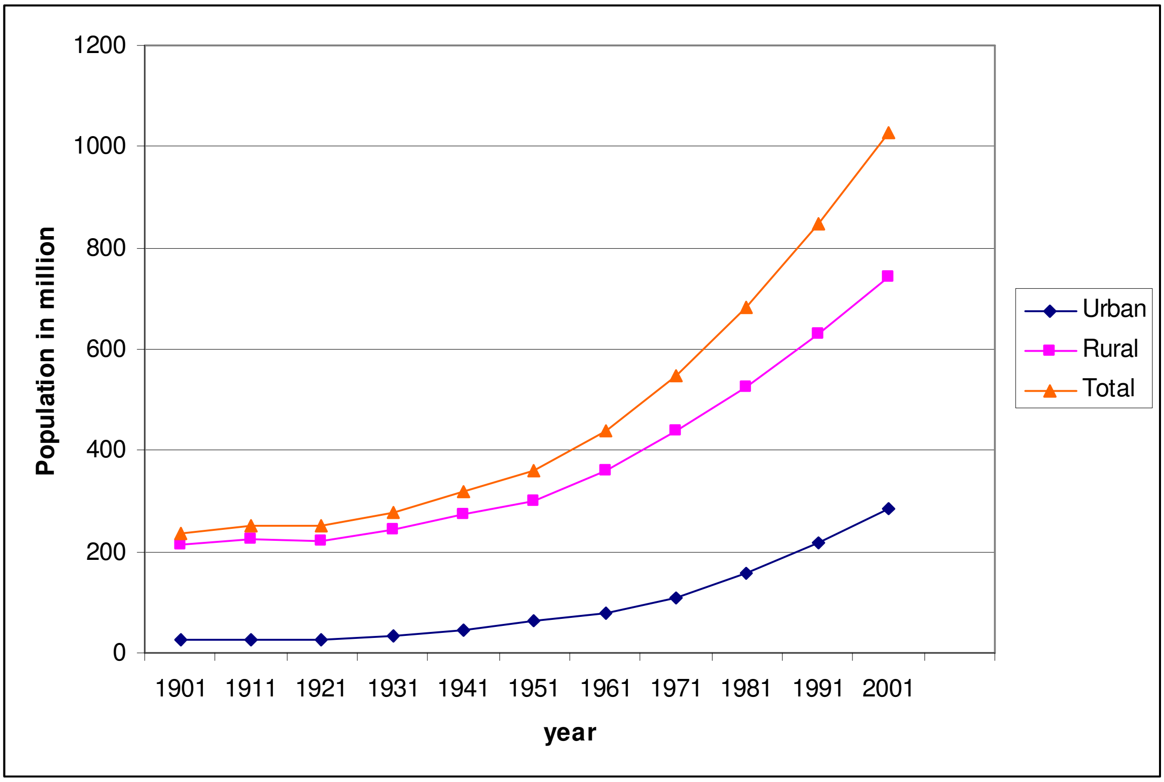

Figure 5: Indian population in 20th century (in millions)
Source: Census of India

Why is it important for the study of welfare? Based on the arguments above, it is evident that there is considerable disparity in education or demographic conditions by population groups. Hence, it is pertinent to study inequality within and between groups. Most of the indicators discussed above do not provide sufficient information before the 1970's, in particular on a disaggregated level, which is required for analysing specific groups

India is a heterogeneous country in terms of religion where nearly 83% of the population can be classified as Hindus. India is also the home for more than 120 million

Muslims, one of the world's largest Muslim populations. Moreover, the population includes Christians, Sikhs, Jains, Buddhists, and Parsis. Added to this, there is a complex caste system comprising of upper castes, middle castes, scheduled castes (previously treated as untouchables) and tribes. Persistent inequality among the caste groups exists, as upper castes have better access to resources and scheduled castes and tribes are lagging behind. Hence, we need to investigate divergence and convergence of welfare and inequality of these groups over time. To get a complete picture of welfare and inequality in India, we also need to take into consideration the socio-political system besides the economic system.

1.3. Complexity of welfare

To investigate welfare in general, we need to take into account various systems such as the economic, physical, social, and political. In seeking to measure the outputs of the physical system and their potential impact on human welfare, we can centre on indicators such as the total value of primary industry output per capita and population per square kilometre of arable land. At the same time petroleum rich countries score very high in terms of GDP per capita; however, this does not imply higher welfare due to high inequality and the lack of political and economic freedom.

For instance consider infant death rates that are affected by many aspects such as prenatal and post natal care, educational levels of parents, medical services, nutrition, access to safe drinking water, environmental sanitation, and some social factors have impact on infant death rates. Hence, infant mortality can act as a proxy of welfare due to the fact that it shows the impact of several economic and social factors. Also, living in rural or urban areas shows welfare indirectly. In a country like India with a great rural-urban disparity, living in rural areas means limited access to modern health facilities, infrastructure, educational institutions, and opportunities to work in non-agricultural sector. Moreover, one cannot neglect the political system that helps in managing the above mentioned social and physical resources efficiently. In addition, the political system can introduce policies for improvement of public health and education. The South Indian state Kerala is a best example, as the equality and welfare are improved by policies that focused on compulsory education and land redistribution (after 1957).

1.4. The use of anthropometric data

Komlos and Baten (1997) argued that it could be useful to supplement the conventional indicators of well-being, such as GDP per capita, by other welfare measures, especially anthropometric indicators. In particular, anthropometric indicators have been successfully implemented to analyse living standards in historical and pre-historical periods (Baten, 2000A, Koepke and Baten, 2005). Most of the anthropometric research is focused on Europe and the US. The aim of this thesis is to use anthropometric data along with GDP, environmental conditions (e.g. extent and variability of rainfalls) and other available indicators (e.g. caste or religious groups) to measure welfare and inequality of Indians in the 20th century.

Furthermore, the idea is to further extend the use of anthropometric data to quantify inequality. Deaton (2001) suggested that inequality should be considered as an important component of the standard of living. The coefficient of variation (CV) in heights can be used to measure inequality in height, which in turn represents a proxy for inequality in general

$$CV = \frac{\sigma}{\mu} \times 100$$

σ is standard deviation and μ is mean in heights. It is evident that standard deviation increases with the mean of anthropometric measures based on its construction (See appendix A for more details). In this case, the CV is the best way to express variation, especially when comparing different distributions of anthropometric indicators. A CV of 5% means that the standard deviation is equal to 5% of the mean.

The thesis "Anthropometric Evidence of Indian Welfare and Inequality in the 20th century" is organized as follows. The second part "The Development and Inequality of Heights in North, West and East India 1915-44" discusses the welfare of Indians during the last phase of colonialism. Welfare of Indians using stature from All India Anthropometric Survey was compared to GDP and real wage indicator to obtain a complete picture concerning the development of welfare. Moreover, caste and regional trends of welfare and inequality were investigated.

The third chapter "What Happened to the Welfare of Indians after Independence? A Study of Biological Welfare and Inequality From 1949-74" uses the National Family Health Survey-2 along with the available macroeconomic data to study the welfare of

Indians from 1950-1975. Moreover, inequality in caste and religion along with regional differences are explored by using data of 90,000 women.

The fourth chapter “Anthropometric Evidence of Gender Inequality in India” studies welfare differentials between males and females in India, especially from 1950-75. In the context of growing research and criticism regarding the use of calorie consumption, life expectancy, mortality and sex ratio data, gender inequality in stature could provide new insights. Accessibility of the state-wise stature data is relatively good especially for the pre-1975 period compared to other indicators for measuring gender inequality. Gustaffson and Lindenfors anthropometric data, Global Child Growth and Malnutrition database, National Nutrition Monitoring Bureau anthropometric data and South African DHS are the major data sources to analyse gender inequality and to uncover its determinants (including cultural).

The fifth chapter “Inquiry into the Simultaneous Existence of Malnutrition and Overweight in India” focuses on contemporary India. India is facing a double burden of overnutrition and undernutrition; hence, the combination of a high proportion of malnourished people and an increasing proportion of obesity needs further exploration. This paper focuses on the Body Mass Index of Indian women using National Family Health Survey to investigate the simultaneous existence of malnutrition, overweight and obesity.

In sum the aim of the thesis is to investigate welfare and inequality from 1900 to 2000. Regional, social and economic determinants were taken into consideration along with some methodological issues.

Appendix A:

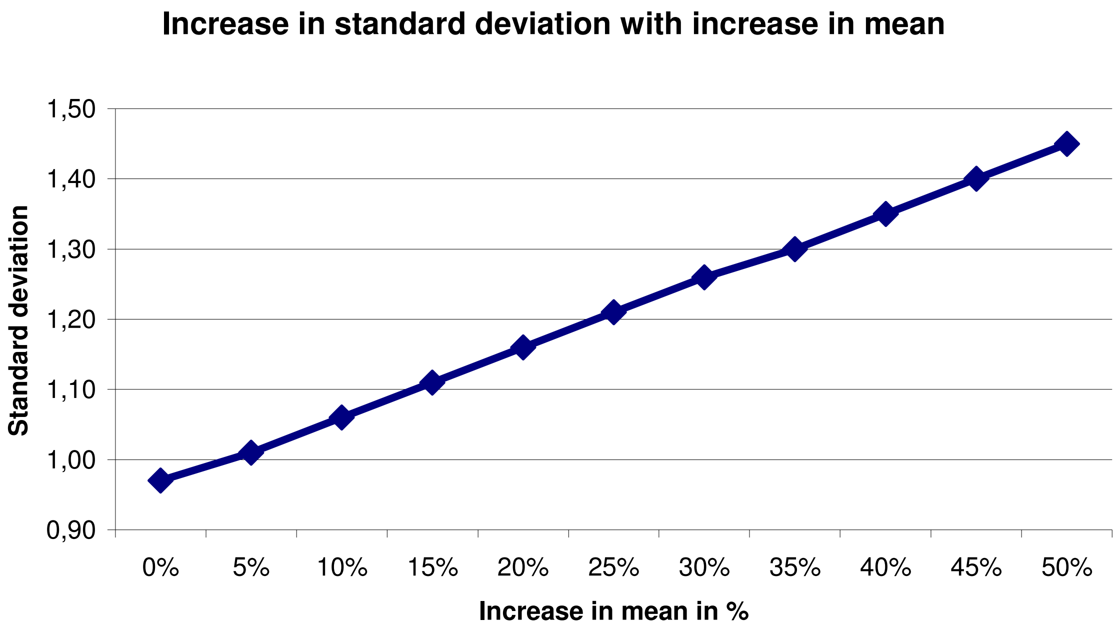

Figure A1: Representation of increase in standard deviation with increase in mean

The constant coefficient of variation stays the same when the mean increases, whereas standard deviation increases accordingly. Hence, using standard deviation to assess the variability of a distribution is misleading when comparing groups with different mean. This example is to illustrate in detail the advantage of coefficient of variation over standard deviation.

2. The Development and Inequality of Heights in North, West and East India 1915-44

This paper is based on joint project with Prof. Dr. Baten and the work is equally shared. Most of the research on Indian welfare from 1915-44 was published in Explorations in Economic History Journal in 2006.

2. The Development and Inequality of Heights in North, West and East India 1915-44

Abstract

In this study, we trace the development of height and its distribution in India during 1915-1944. Heights of North, West and East Indians grew very slowly. Though for this period it has been argued that income inequality declined, we reject our working hypothesis that height inequality declined parallel to income inequality. In fact height differences were low during the influenza/famine period of 1918-20, and the Great Depression period. With the growing openness of the late 1920s we observe a temporary rise in height inequality. The overall level of height inequality is lower than expected for Indian society that is influenced by a rigid caste-system.

Keywords: Stature; Heights; Biological Welfare; India; Great depression; Inequality; Influenza; Caste; Real wages

2.1. Introduction

The economic historiography of India has long been dominated by studies on the relations to the British colonial power.Though this remains an essential topic, the economic history of this South Asian giant opens many more important questions to be addressed. One such issue is the inequality of living conditions: Was inequality much higher than in other countries, given the peculiar caste system that stirs up debates until today (Deshpande, 2000)? How did inequality develop, both between social groups and between regions during this colonial period? Did the crucial events of the interwar period influence the history of Indian inequality?

We assessed those questions with anthropometric techniques, measuring inequality with (a) the height differential between social groups and regions, and (b) with the coefficient of height variation. We created the dataset of 26,154 observations that covers the large parts of North, West and East India and compared the results with our hypothesis based on the existing literature. For example, Williamson (2000) found that the inequality of purchasing power probably declined in the interwar years, as the real wages of unskilled workers rose, while average income fell. Ceteris paribus, we would expect that height inequality of the cohorts born in this period should also decline. However, Williamson formulated some important caveats about his estimates: his real wage estimates were based on urban wages only, and the cost of living is based on a mere wheat/rice price proxy that contains no information about other important components such as rents and protein-rich foods. A counter-checking of Williamsons real wage estimates with anthropometric evidence can yield crucial evidence.

Heights are mainly determined by nutritional intake and disease environment. While the inequality of food intake is strongly correlated with the social gaps of purchasing power, this is less the case for the latter factor, the disease environment. Especially in societies with a poorly, or modestly developed public health system, morbity crises also affected the middle and upper strata, especially those who were in frequent contact with other people (such as traders). We therefore assessed the height differences between social groups for - the most important event during this period - the influenza and famine period 1918-20.

This article is structured around the following four working hypotheses:

Hypothesis 1: Income inequality was declining significantly in the inter-war period, and this should be reflected in declining inequality of heights.

Hypothesis 2: During the influenza period, height inequality was particularly low as the disease also affected some middle and upper class groups, especially those with frequent contact with other people (such as traders). Large landowners lost some of their advantages based on purchasing power they enjoyed during other periods.

Hypothesis 3: The Indian caste system created particularly large inequality between social and economic groups.

Hypothesis 4: In terms of height development over time, declining average income and slightly increasing public health and medical knowledge outweighed each other; hence, heights were stagnant during this period. This hypothesis was constructed, but rejected for South India by Brennan, McDonald, and Shlomowitz (1994). The background of this hypothesis is given by the famous deviations between height and income development (for example, in the antebellum U.S., see Margo and Steckel 1983).

In the following, we first reviewed the quantitative literature on Indian inequality and height development, followed by a discussion regarding the main data sources of this study. Section 4 provides an overview of potential height determinants (real wages, GDP per capita, food production, disease and famine), which was compared with the empirically observed height development. Section 5 discusses social and caste differences in the cross-sectional view, and traces its changes over time. Section 6 discusses inequalities among regions. Our section 7 analyzes the overall inequality within the three regions (using the coefficient of height variation), and explores its potential determinants. The last section of this paper focuses on the influenza period to investigate the relation between disease environment and biological welfare.

2.1.1. Methods of anthropometric inequality assessments

The study of trends and inequalities of both income and height has attracted an enormous attention during the last decades. However, it is appalling to see the limitations imposed by the available datasets on inequality of purchasing power. Gini coefficients of income and wealth have been estimated very infrequently for the Less Developed Countries (LDCs) before the 1980s and this hinders long run perspective research that is particularly important in this field. One attempt to fill the gap was to compare the real wage index of unskilled urban workers (considered representative for the poorest part of the society) with an index of real GDP per capita (Williamson, 2000). Even though this method yielded interesting insights, it is important to complement it with additional techniques that take into account not only the wage earners, but also groups such as farm-hands, industrialists, housewives, and peasants practising subsistence agriculture.[4] In this context, various methods were proposed to make use of anthropometric measures such as human stature for extending the inequality database. Two methods based on height data were employed in this study. The first one is to use the height difference between occupational and social groups as an inequality measure, which was used successfully before by many anthropometric historians. Even though this measure depends on the availability and quality of (parental) occupational and other classifications that serve as income and education proxies, we employed this in our paper to study inequality. As height of adults is, to the largest part, determined in the first three years of life, their own occupation can only be used under the strong assumption of very low social mobility (not so unlikely in the Indian case).

Another measure that was recently explored is the coefficient of variation of height for both children and adults (Baten, 1999; 2000a, Pradhan et al., 2003; Baten and Fraunholz, 2003; Boix and Rosenbluth 2004; Moradi and Baten 2005). In the case of adult height, CVs can be organized by birth cohort to study changes over time. Moradi (2002) showed that the height variation over time is strongly correlated with Gini coefficients of purchasing power. These two measures of height inequality - height difference by occupation and social group, and coefficient of variation of height - were employed to describe the development of inequality in India during the early 20th century.

[4] The question is whether urban and rural labor markets were sufficiently integrated or not. One might argue that this indicator might be of less importance for our study which is dominated by the rural population (but also includes urban areas. Nevertheless, it gives us an understanding regarding urban poor.

2.2. Views of the literature: Indian inequality and theoretical expectations

Many scholars explored Indian inequality especially in the recent years. More comprehensive and recent studies of the early 20th century found heterogeneous results about trends of height and income inequality: Brennan, McDonald and Shlomowitz (2003) argued that inequality between major castes increased by observing height from the late 19th century to the 1960s. Williamson (2000) observed that until 1914 the urban real wage declined relative to GDP per capita (i.e., rising inequality), and after 1914 there was a decrease in inequality until the 1940s. We compared these studies with our results below, as trends in income inequality were different from height inequality.

Williamson's trends of the wage-to-GDP equality measure for India move in concordance with Bourguignon and Morrison's (2002) estimates of world inequality within and between countries. They found that inequality between all countries in the world rose over the last two centuries (in the "deglobalization" period 1914-45 perhaps slightly faster), whereas inequality within countries declined during 1914-45, but rose slightly before and after this. The reasons behind this development are not yet entirely clear, especially for the land scarce countries in Europe. If political ideas and movements were driving this development worldwide, then this would make our first working hypothesis more likely, because political ideas spread easily over country borders, and might have influenced the Indian development.

Which theoretical views on inequality determinants can be formulated from the existing literature? Globalization and economic integration can be important driving forces of inequality, if the initial land-labour and capital-labour ratios are quite different in the previously non-integrated economies. For example, in Punjab during the 1870s there was much more land per capita than in Britain. The economic integration of the 1870-1913 period (brought about by the transport revolution) led to strong increases in agricultural exports of Punjab and the non-agricultural products of Britain. *Ceteris paribus* and assuming perfect competition, this trade boom should have made British workers better off (relative to British land-owners), and Punjab landowners richer (relative to Punjabi workers). On the other hand, after the breakdown of the first globalization movement around 1914 the reverse tendency of an equality trend in Punjab and growing inequality in Britain were expected. There is some evidence for the first in both countries, but the second development did not take place in Britain, probably because of political counter forces.[5] We answer the question below whether this had the expected impact on Indian height inequality, differentiating between deglobalisation periods, and the slight recovery of globalisation in the late 1920s.

Baten and Fraunholz (2003) found that for seven Latin American countries during the period 1950-2000, height inequality was higher in periods of greater openness, whereas closed economies had lower inequality. Apart from the influence of globalization on inequality, there is a variety of other factors that influence widening or narrowing gaps between social groups. Among the other determinants, demographic variables such as the share of the mature population (aged 40-59) relative to the total population in the age groups 15-69 (working age) was featured prominently in the work of Higgins and Williamson (1999). Their reasoning was that an excess supply of younger

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[5] Whether all India can be considered a “land abundant” economy as Williamson (2000) did for Punjab and Burma (also Egypt) is a disputable issue.

workers who typically had lower wages competed the wages in their age-group down, so that inequality increased. This idea was emphasized in studies about the U.S. baby boom of the 1960s. They also considered Kuznets curve effects (growing inequality during the first phase of rapid income growth and decreasing in the second), structural change with lagging agricultural productivity, political and other factors. The implications of the first two of those factors for Indian inequality dynamics were probably small, because the age composition changed in the opposite direction (see below), and there was no rapid income growth phase.

The literature on height trends in India has mainly focused on the 19th and 20th century for which the Australian research team - Brennan, McDonald and Shlomowitz - provided a variety of rich anthropometric studies. As an example, we want to highlight their result that North Indian heights increased very slowly until the second half of the 19th century, but during the last decades they started to stagnate or decline. For the 20th century, trends of heights were less clear. There was no secular trend from the late 19th century to the 1960s (Brennan et al., 1994, 1997, 2000).

Earlier work by Ganguly (1979) hypothesized that during the first six decades of the 20th century, there was no significant height increase. Brennan et al. (1994) reported the following main working hypothesis of their project: There was no long term change in Indian stature under British rule, because income and disease environment before and after 1920 were offsetting each other, albeit in opposite directions. Before 1920, GDP per capita grew slightly, but the disease environment worsened. Just the opposite took place after 1920: GDP per capita declined, perhaps due to rapid population growth pressing on resources, whereas the disease environment in India improved, caused by improving knowledge about public health. Klein (1989; 1900) explains similar phenomena, but stresses other determinants. He argues that the population that had survived the influenza pandemic after 1918 had greater immunological resistance, because the more vulnerable groups had died.

For South India, Brennan et al. (1994) reject their working hypothesis. They arrive at the result that before 1920, it was mainly climatic volatility on the dry plains (along with inappropriate legislation against draft animal grazing), and inequality in the irrigated areas that kept heights stagnant. The GDP growth before 1920 might have come with a more unequal distribution of income, as Kumar (1965) argues for declining real wage rates before 1900 in South India. This was intensively debated in the literature. But even an optimist would accept that at best there was a stagnation of real wages, and some increase after 1900 (Morris 1966).

In the four decades after 1920, Brennan et al. (1994) find only modest improvements in the disease environment, whereas the lower food production per capita was partly offset by unusually cheap rice imports from Southeast Asia. If those developments were main driving forces, we would expect improving living standards for market-dependent workers, and stagnant or declining welfare for rural independent producers.

While the development over time was modest, cross-sectional differences were remarkable. Brennan et al. (1995) found important interstate differences in height. Intercaste differences in stature were also observed in all their studies for the early 20th century (Brennan et al., 1995, 1997, 2000, 2003). Sahn (2003) explored health inequality in late 20th century India using height of pre-school age children with a special emphasis on spatial analysis. He found that inequality was low in Kerala state when compared to other states of India and health of children in Kerala was relatively equally distributed.

We extended all these previous contributions by considering the short-term variation of height, the development over time for each region, caste group, and occupation. Moreover, we also measured intra-group variation over time, and considered determinants of inequality such as integration into the world market, and the impact of the influenza pandemic.

2.3. Data

The anthropometric data used in this paper were taken from the All India Anthropometric Survey (AIAS) that was done in 1960s. The anthropometric survey of the "North Zone" was initiated in December 1962. It covered the states of Assam, Bihar, Orissa, Maharashtra, Gujarat, Rajasthan (only two districts), Jammu and Kashmir, Himachal Pradesh, Punjab, Haryana, Madhya Pradesh and Uttar Pradesh (for the location of states, see Figure 1). The survey was carried out in different phases between the years 1963 and 1971 (mostly in the mid-1960s). Many of the state surveys were taken in one year so that we could calculate the year of birth using the age information.

We analyzed the data by birth cohorts in the following. In those surveys that lasted for two or three years, we took the middle year to minimize the measurement error. Though we assume that measurement error is uncorrelated with our explanatory variable, we need to keep in mind that individual year events might turn out insignificant as the birth year cannot be exactly ascertained. From the 12 Northern states of India we had access only to 10 states (Madhya Pradesh and Rajasthan were unavailable), and after removing extreme ages and heights (<120 cm, >200 cm), we obtained a database of 26,154 cases. The frequency distribution of the sample is approximately normal, as our kernel density estimates showed (Figure 2). Tests for normal distribution also indicated that there was no normality problem with our data (not shown).

How were the surveys conducted? It seems as if the research teams measured randomly 50 individuals in general for each group in each district. A "group" consists of, as per the definition, a caste, tribe, or religious group (such as Jains, Sikhs and Muslims) in a district. Males from both urban and rural areas were selected in the sample and rural men were probably overrepresented in the sample. The measurements neither took place in special places (such as in schools), nor in social gatherings, which helped in avoiding bias. The subjects were not chosen on the basis of their bodily structure and proportion (as, for example, Risley [1891] did). The authors concluded that "the sample were free from any selection bias," although this sentence might just be relatively realistic.

The principle was that if a "group" had a substantial representation in a district, 50 individuals were selected. Groups that have small shares but lived in all districts (such as Muslims in Orissa) were somewhat over sampled. Very large groups (such as the Keota or Nulia in case of Orissa) were sampled with N=100. Brahmins and Kshatriyas were also over sampled due to the fact that they are present in all regions of India. In the following estimates, we weighted their impact on the overall mean by assigning them population weights. The authors of the AIAS survey selected males aged 18-70, but very few were in the age group 55-70. We restricted the height data to the ages 20-49 in order to avoid potential shrinking biases. More information related to shrinking is added in appendix D. Late adolescence growth beyond age 20 was tested with regression techniques that turned out to be insignificant.

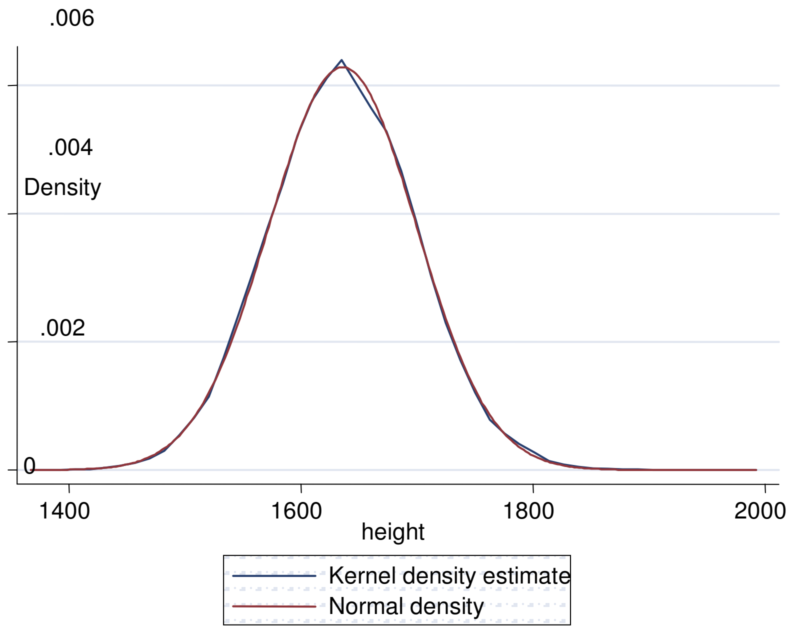

Figure 2: Test of normal distribution of the sample

This data set contains as many as 101 population groups from 134 districts. Each caste group had a typical occupation that was described in the survey documentation. We employed this "typical occupation" as an explanatory variable, aside with the caste status. Nevertheless, we need to keep in mind that not all caste members performed the “typical” occupation of their caste in a specific region. In a few cases there were remarks about changes in the dominant occupation of a caste over time.

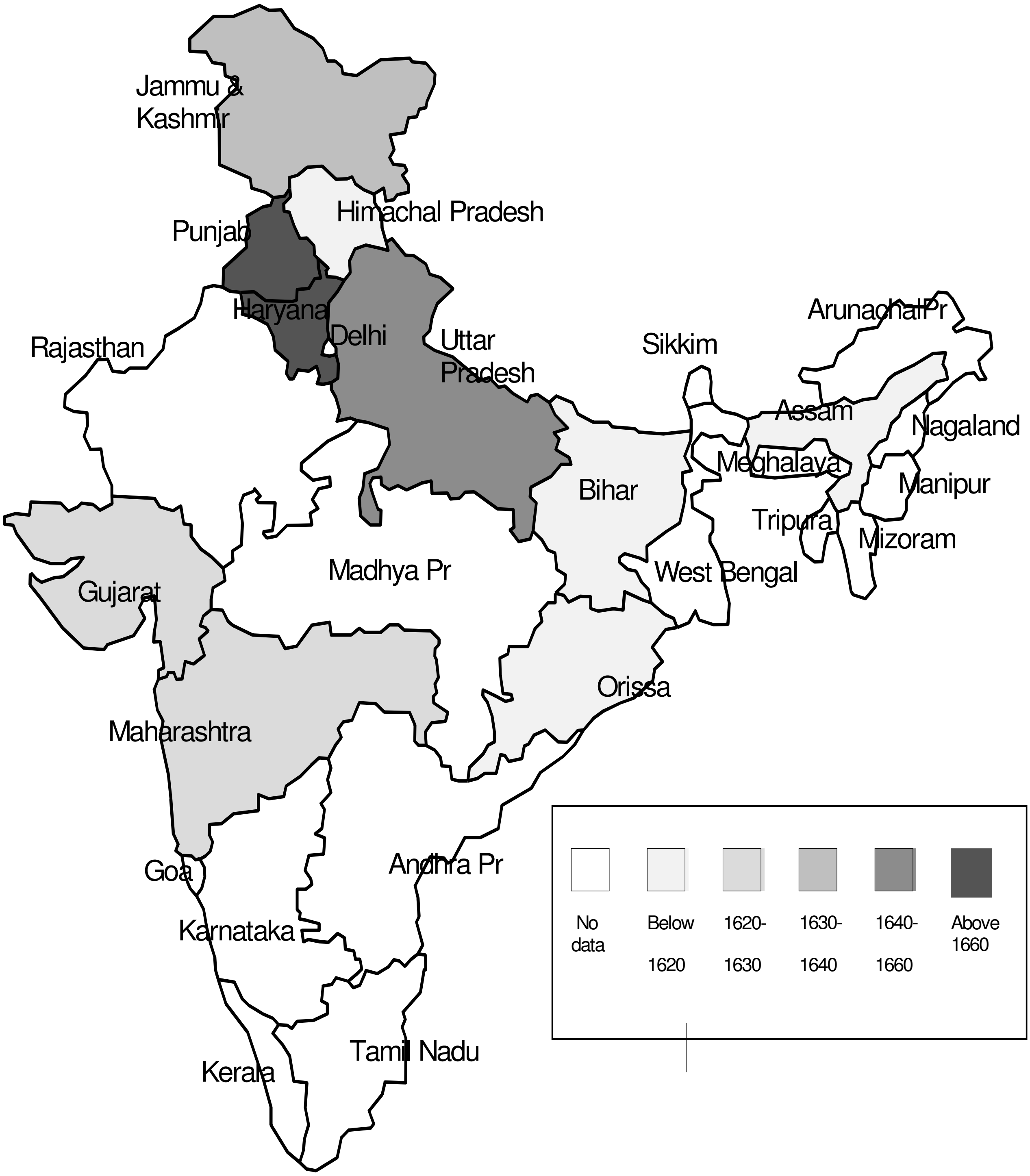

Figure 1: Map of Indian States with mean height level

Source: State coefficients from Table 4

But in general, the early 20th century can be characterized by widespread immobility among castes and their typical occupations (see appendix B). However, the exact quantitative extent of social mobility between castes in the first decades of the 20th century is a desideratum of Indian economic history. More focus on this topic can be found in later sections.

Table 1: Composition of the sample by state

State	**Number**
Assam	1468
Bihar	3683
Gujarat	3296
Haryana	500
Himachal Pradesh	773
Jammu and Kashmir	559
Maharashtra	5607
Orissa	3789
Punjab	1013
Uttar Pradesh	5498
Total	26186

The regional composition by state fits well to the expectations (Table 1). Large states such as Maharashtra and Uttar Pradesh account for many cases in our sample and the sample gets tiny for small states. Over time, the geographical composition is relatively stable (Table 2). Among the "Northern" states (Jammu and Kashmir, Punjab, Haryana, Himachal Pradesh, Uttar Pradesh), some surveys were taken relatively late, so that the earliest five year birth cohort contains only about 500 cases even though it is almost as well-documented as the West (Maharashtra, Gujarat) for the later birth cohorts.

Table 2: Composition by birth cohort and large region

	1915-19	1920-24	1925-29	1930-34	1935-39	1940-44
East	668	1305	1370	1681	2143	1773
North	490	886	1489	1530	2043	1905
West	745	1074	1257	1817	2068	1910

Table 3: Composition by occupational groups

Occupation	**Frequency**
Agriculturist	3163
Agriculture labor	1695
Land holder	2948
Professional	4157
Cultivator	2253
Fisher	602
Menial	1319
Pastoral	1613
Potter	1299
Trade	902
Writer	628
Weaver and leatherworker	2010
Skilled crafts	1420
Mixed	2145
Total	26154

In general the distribution is relatively even, which implies that sufficient height measurements are available after 1915 for all regions. As most measurements were taken in the mid-1960s, the size of the birth cohorts closely reflect the age structure: Those born 1915-19 were mostly aged 45-49, those born 1940-44 mostly aged 20-24. Hence the slow increase in birth cohort size until 1935-39 describes an age pyramid as it is typical of LDCs during the 1960s (many young adults, fewer older ones). Only the age group 20-24 (born 1940-44) is smaller, perhaps due to the Bengal famine. This is supported by the fact that this phenomenon has concentrated on East India, where the famine was the most severe. Hence, the age composition of the sample does not show indications for substantial bias.

The composition of “typical occupations” in the sample covers a wide range of relevant Indian occupations of the study period (Table 3). One particular source of concern here is the large number of professionals (mostly Brahmins). We had to weigh the following estimations accordingly with population weights to remove this source of bias.

In order to address questions of survivor bias, the social structure by birth cohort needs to be assessed. If selectively higher mortality of poorer population segments is significant, we would expect an under-representation of poorer strata at the beginning of the period, and the opposite at the end. We consider the share of caste hierarchy and religious groups that falls into each birth quinquennial (Figure 3).

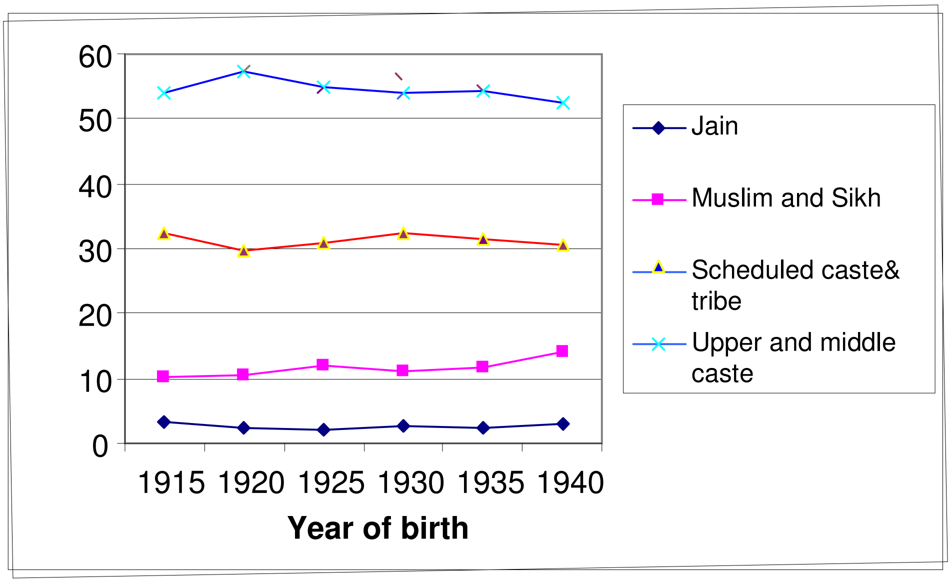

Figure 3: Composition by religious and caste groups of high and low status over time

We distinguish groups with above-average social status (such as Jains, and middle/upper Hindu castes) from those below average (the Scheduled Castes and Tribes). In between, there were Muslims and Sikhs with mixed social status. We find that the share of all the caste and religious groups stayed constant over time. If mortality would have caused a very strong selectivity, we should have observed a higher share of jains and upper/middle hindu castes in the first cohort, and a lower share of Scheduled Castes and Tribes. As this is not the case, we conclude that selective mortality had only a modest importance on the overall shares of survivors. Moreover, the share of these status groups in our sample is more or less representative in terms of their share in the total population (except Brahmins, as noted above).

2.4. Developments in Indian GDP, real wages, and heights

Before describing the development of Indian heights, we consider the question: which development over time would we expect, based on income and production data, if height and income would be perfectly correlated? It is clear that Indian national income during the early 20th century was extremely low and stagnant, even if it grew modestly during the "first era of globalization" 1870-1913 (but very little in comparison with the West). Maddison's (1995) estimates of GDP per capita were very pessimistic, not only in terms of level, but also regarding the development over time (Figure 4).

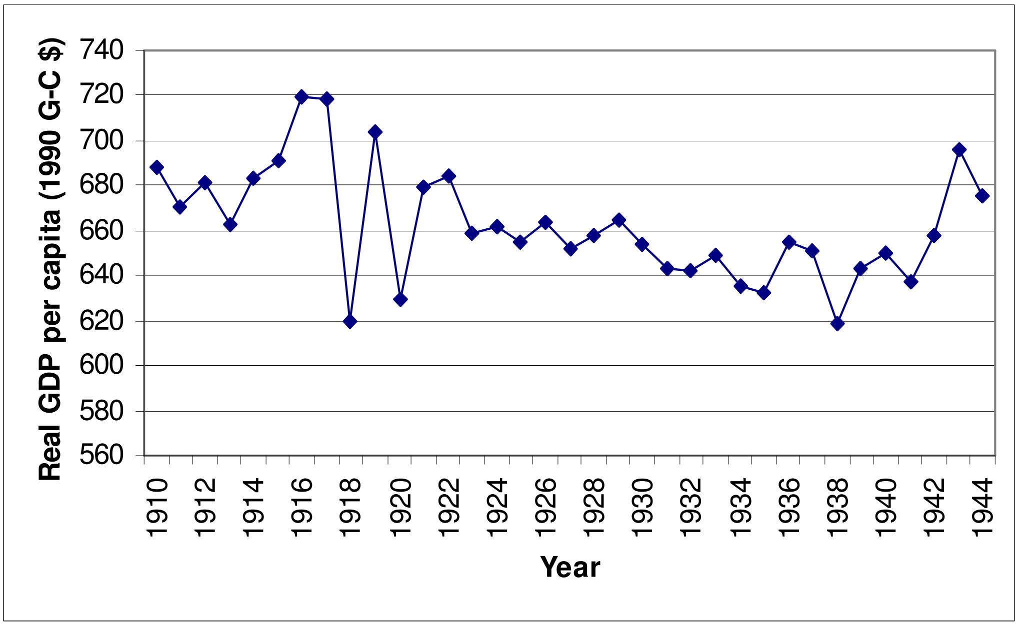

Figure 4: Real GDP per capita in India from 1910-1944 (in 1990 Geary-Khamis $)

Source: "Maddison 1995, p. 204-5".

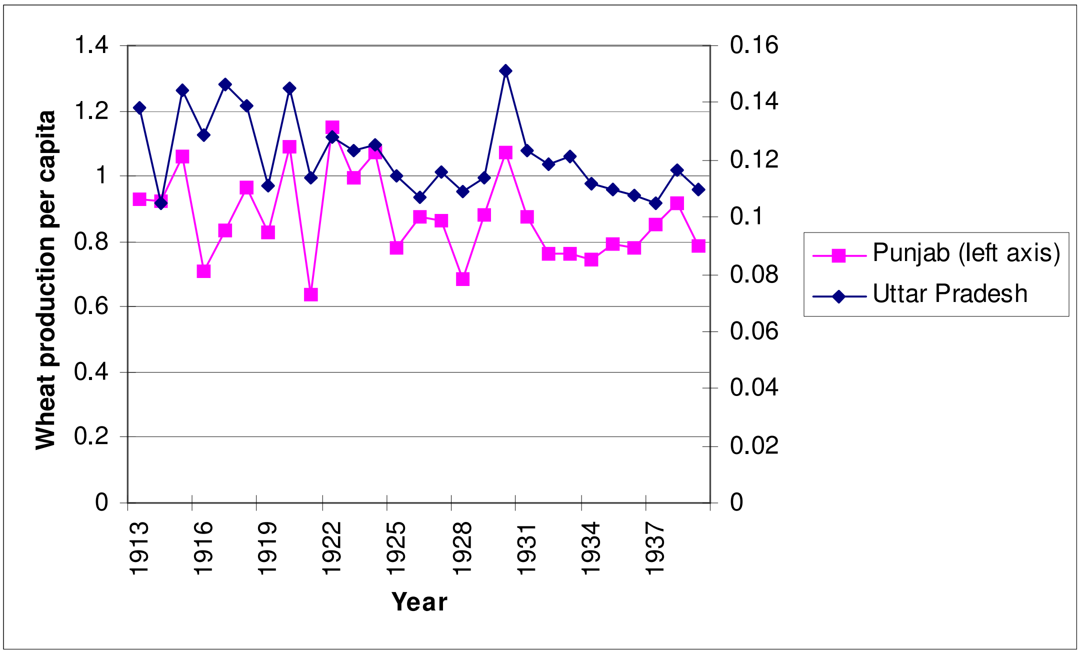

Figure 5: Two-Axis-diagram: Estimates of wheat production per capita in Punjab (left y-axis) and Uttar Pradesh (right y-axis).

Source: "Narain 1965, pp. 216 and 223".

Wheat production per capita is measured by 1000 pounds per capita and year.

Except for the World Wars (!) Indian real national income declined from about 680 $ (in 1990 Geary-Khamis $) to a meager level of some 640 $ after the Great Depression. Even though those inter-war years were not a successful period for many countries around the globe, India was particularly unsuccessful during those last decades of British reign (afterwards, Indian GDP growth continued to be slow relative to many other nations, until the early 1990s).

Scattered agricultural production data moved with a similar pessimistic trend, which is not astonishing given the dominance of the agricultural sector in the Indian economy. We constructed per capita wheat production series in two of the major wheat-growing states, Uttar Pradesh and Punjab (Figure 5, data from Narain 1965). Those series were built with fairly good data about the area sown with wheat (this causes most of the variation), somewhat weaker land productivity data, and interpolated population data (between the censuses that were taken every decade). We can see that wheat production did not grow as fast as population did in Uttar Pradesh (population: +7% in the 1920s and +14% in the 1930s).

The per capita level was much lower in Uttar Pradesh (right x-axis in this two-axis diagram) then in Pubjab (left x-axis). The years of WWI saw some relatively successful harvests on large areas, but during the famine period of 1918-20 first the volatility increased, and then the levels started to fall (on a per capita basis) during the 1920s. Except for a production peak in 1930, the levels of 1913 and 1914-17 were not reached again during the 1920s and 1930s. Punjab had a population that was six times smaller than Uttar Pradesh due to which its greater stability (on a higher level) did not influence the general Indian development with the same weight. In this state, wheat production per capita in 1922-24 was slightly higher than the pre-war and WWI levels. Later it declined some 15-20% (except, again, in 1930).

Overall, income and agricultural production trends (in the North) would lead us to expect a height stagnation or slight decline in India, if the medical and hygienic progress during the early 20th century can be assumed to act as a counter-balancing force, as it probably did to a certain extent. Hence, hypothesis (4), the one on height stagnation, would be confirmed. However, another series of income estimates offered a different view: The real wage estimates of urban unskilled workers performed by Williamson (2000) were much more optimistic (Figure 6). Especially the Western metropolis of Bombay and Ahmedabad experienced an increase of 60% and more between the 1910s and 1920s. Real wages have doubled there between WWI and the 1930s, even when the astonishingly low food prices of the early 1930s were dismissed as a temporary phenomenon.

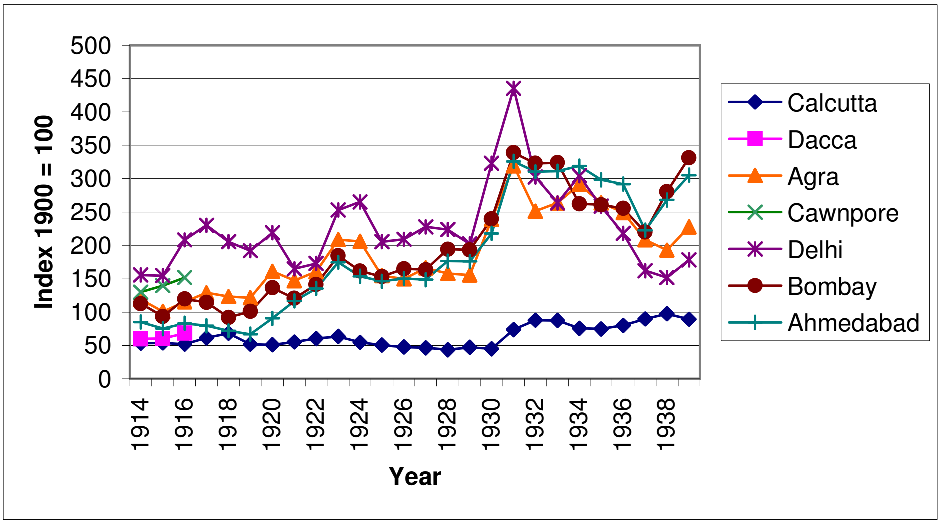

Figure 6: “Real” (wheat/rice) wages of urban unskilled workers in Indian cities.

(Source: Williamson 2000)

Real wages in Calcutta, the largest city of India and the giant of the East, increased modestly only after the 1930s (perhaps partly because they had grown exceptionally before 1900, the year on which the index is based). In spite of high wages during WWI, Delhi participated in the later wage boom. We should however note that those “real” wage estimates are only based on wheat and rice prices (and nominal wages). It is likely that other (untradable or less transportable) cost-of-living components, such as rents, milk and other protein-rich food, became much more expensive in booming cities like Calcutta (+138% inhabitants in the 1930s), Bombay (+46%) and the others. If we nonetheless trust the general tendency of those real wage estimates, we would expect a more favourable height development. This would lead to rejection of hypothesis (4) of height stagnation, because it is unlikely that the disease environment worsened during this period where there was definitely modest progress in medical technology. Williamson assumed that this wage series meant not only gains for urban unskilled workers but also served as an indicator (assuming sufficient labour mobility) for a general decline of Indian inequality.

Does the development of purchasing power and biological components such as longevity, health and quality of nutrition always correlate? In fact, some important deviations were found, especially during the early phases of Modern Economic Growth in the 19th century. The highest deviation occurred during rapid economic growth in the Antebellum US, as Margo and Steckel found (1983) [for an overview, see Komlos (1996) and Steckel and Floud (1997)].

How did Indian heights develop in the interwar period and the Second World War? Our strategy to assess this development is based on a multiple regression with control for regional composition (using state dummies), caste and religion, to interpret the birth year dummy variable coefficients (Table 4). Height of Indian men during this period increased in an extremely slow pace. In Figure 7 the coefficients of our annual dummy variables are shown. We adjusted the height development by adding the year dummy coefficients to the constant that is adjusted with the state dummy coefficients, population share of these states, and the caste shares (see Table 3, Figure 1).

We weighted the state coefficients by the population weight of each state (and not with the sample weight), so that the level of height is more or less representative of the ten Northern, Eastern and Western states of our sample. We found that the male height level around 1915 was 163.5 cm, which fitted together with Brennan et al.'s (2003) estimates of 162.8 cm (lower castes) to 164.0 cm (higher castes) for indentured workers of Uttar Pradesh measured during 1870-1900. Neither the pessimistic development of declining GDP *per capita* nor the optimistic views based on urban real wages corresponded exactly with our results. The anthropometric evidence takes the middle position between the optimistic and the pessimistic view, perhaps a bit closer to the pessimistic one. The real wage series does not correspond with the height developments due to the possible reason that the deflator was only grain price. In addition, the real wage refers to cities only, whereas heights are both urban and rural, with a strong representation of rural. One considerable aspect of the low grain prices during the 1930s might be a shift from protein to starches that might have slowed down height increase.[6] A slight increase in average height after about 1932 matches up well with the potentially strong increase in urban unskilled real wages.

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[6] Thanks to Sevket Pamuk for this suggestion.

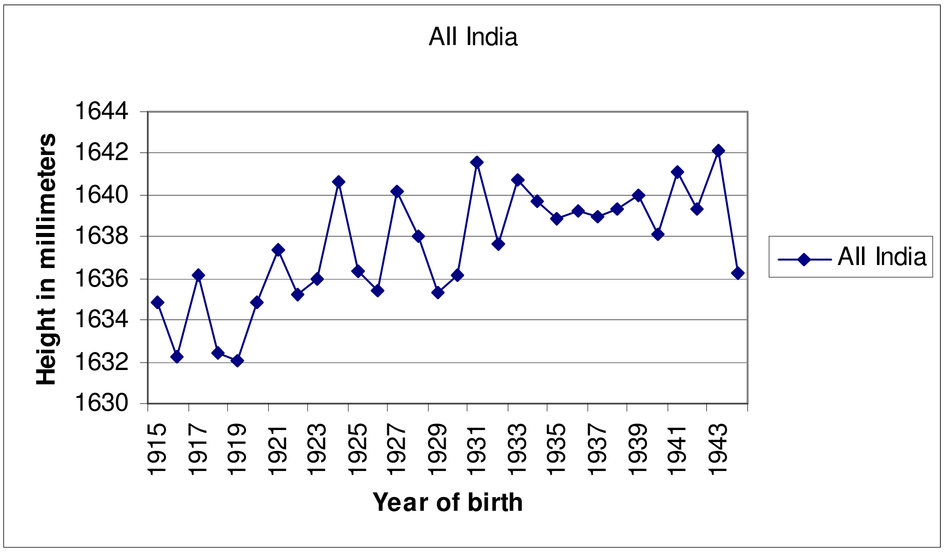


Figure 7: Height in India, 1910-1944: Adjusted annual average heights.

Note: We adjusted for regional composition (using population, not sample weights), and for cate status composition to avoid biases (for example, because of Brahmin overrepresentation).

After the crisis years of 1918-20 that meant a decline of height, stature of Indian men started a slow and volatile growth during the 1920s, reaching a first peak in the year after the production peak of 1930 and exceptionally low grain prices. In the high-income years of WWII, heights reached their maximum around 164.0 to 164.3 cm. In 1944, the year after the Bengal famine, heights fell back to 163.6 cm, even though Bengal and Calcutta were not included in our sample. In sum we can say that Indian heights increased, but very modestly (around 0.7 cm), and at a very low level. The fact that we often find a height effect in the year after an event might either be explained by birth year measurement error (see above) or by the fact that maternal nutrition during pregnancy impacted strongly (particularly strong gender discrimination).

Table 4: Regression of height on state, caste, religion and individual year dummies.

Variable	Coefficient	P-values
Assam	-32.8	0.00
Bihar	-29.5	0.00
Gujarat	-21.3	0.00
Haryana	14.0	0.00
Himachal	-31.6	0.00
Jammu	-22.9	0.00
Maharastra	-23.7	0.00
Orissa	-32.8	0.00
Punjab	14.4	0.00
Rounding 10	-1.9	0.20
Rounding 5	1.5	0.25
Near rounding 10	-0.6	0.70
Near rounding 5	1.6	0.19
Birth year		
1915	-7.3	0.19
1916	-9.9	0.01
1917	-6.0	0.13
1918	-9.7	0.01
1919	-10.1	0.00
1920	-7.3	0.03
1921	-4.8	0.14
1922	-7.0	0.02
1923	-6.2	0.05
1924	-1.5	0.61
1925	-5.8	0.05
1926	-6.8	0.02
1927	-2.0	0.49
1928	-4.2	0.17
1929	-6.8	0.01
1930	-6.0	0.04
1931	-0.6	0.82
1932	-4.5	0.08
1933	-1.4	0.61
1934	-2.4	0.38
1935	-3.3	0.23
1936	-3.0	0.25
1937	-3.2	0.21
1938	-2.9	0.26
1939	-2.2	0.38
1940	-4.1	0.13
1941	-1.1	0.67
1942	-2.8	0.27

1944	-5.9	0.03
Upper Caste	29.8	0.00
Middle Caste	8.6	0.00
Scheduled Caste	2.4	0.09
Sikh	44.6	0.00
Jain	20.2	0.00
Muslim	25.2	0.00
Constant	1642.8	0.00
Adjusted R^2	0.10	
N	26154	

Notes: Height was measured in millimeters. In the right column, p-values are given. The constant refers to Scheduled Tribe men measured in Uttar Pradesh, born in 1943, whose age is not on round or next-to-round numbers.

An international comparison confirms this view of almost stagnant Indian heights (Figure 8). Chinese heights were on a higher level, even if the sample selection of Chinese male heights - based on records of railway workers – is not entirely clear (Morgan 1998). Only during the late 1920s, when warlordism and civil war had affected the Chinese economy already several years, the two Asian giants had similar stature. Men in Russia were taller where consumption of milk and other protein-rich food is traditionally higher. Due to the agricultural structure they were not brought down to Indian levels during the early 20th century, not even by the brutal Stalinistic agricultural policy. Sweden in contrast had the highest level of height (determined by its agricultural production and consumption structure). Those levels are less interesting compared with the changes of stature. Swedish heights increased during this period by 3.4 cm between the birth years 1910 and 1941, when Indian males only grew 0.8 cm. Sweden is not an exceptional case: Norwegians grew 4.3 cm (1910-40), French 2.9 cm (1910-40), Germans 3.6 cm (1916-39), and Italian, Dutch, Swiss and Belgian heights increased at a similar pace.

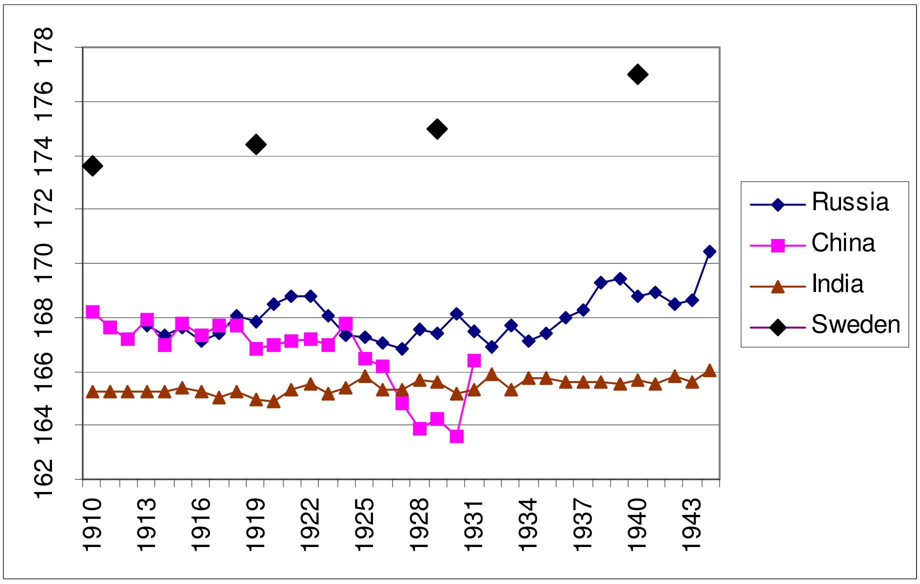


Figure 8: Height development in India, China, Central Russia and Sweden 1910-1944

Sources: Sweden: Floud (1994). India: see text. Soviet Union: Wheatcroft (1999), but adjusted according to Mironov's (1999) comments – plus 0.7 cm before 1925 because of the selective WWII mortality of soldiers cohorts (who had above-average height), Plus 0.27 cm in 1913 because this cohort contained many adults above 50 and then this premium linearly declining until 1930. China: Morgan (1998).

Summing up, Indian heights grew only modestly during this period. In international comparison, no convergence was observable. We rather find a strong divergence compared with European countries of the same period. Therefore, we can confirm the first part of hypothesis 4 posed in the introduction: height did not change very much during this period.

Four caveats of our time series estimates need to be mentioned. We also report the degree to which we could control them.

1. Selective mortality problems of cohort studies: Shorter people had a higher risk of dying at younger ages compared to the older ages (Waaler, 1984). Those that survived might have been from a slightly taller selection, although many direct comparisons did not yet gain conclusive results. In our case, the influenza and famine period of 1918-20 and the Bengal famine 1943 are events that might have caused special selective mortality. But our discussion of survivors by caste and religion did not yield strong evidence of selective mortality (see Figure 3).

2. The influence of environmental conditions during the years after infancy and early childhood is also important, especially for short-term deviations from the growth path. But we rely on the study of Baten (2000b) that found the effect of environmental conditions during the first three years to be so overwhelmingly strong that the later influence on growth had only a very modest impact on the adult final height.

3. Age heaping: Especially people from less educated social strata did not know their exact age and they tended to round their age to the nearest number, generally a number that ended with zero or five. Those who were not able to report their exact age are considered to be less educated and of lower social status (and also perhaps lower height). Therefore, age heaping had the consequence that average height might be lower on round years and there might be less cases documenting height in the numbers that do not end with five or zero. We adjusted age heaping by assigning dummy variables to the

"preferred" round and the neglected ages. The age heaping effect on ages ending with zero was strong enough to decrease the heights significantly (Table 4).

4. We could not control for migration, and this leads us to avoid all comparisons between urban and rural welfare, or between individual states. However, migration across the borders of our three large regions (North, East, and West) was relatively limited. Somebody born in rural Maharashtra (West) might have preferred to migrate to Mumbai instead of migrating to Delhi (North) or Madras (South). We would therefore argue that an interpretation of height developments of these three regions is legitimate.

2.5. Did the caste system create abnormally large inequality? How did social inequality develop?

We will now shift to study the differences in anthropometric development among different Indian social groups and to various regions. We have tested whether the egalitarian trend suggested by the unskilled real wage vs. GDP/c. data can be confirmed by height data (hypothesis 1). We also considered whether the more open period during the late 1920s increased height inequality. We also attempted to understand whether the Great Depression and influenza epidemic decreased social differences.

Before we discuss height differences by caste, it is revealing to have a general view on the caste system in India. From a religious point of view Indian society during pre-independence time was mainly divided into two categories viz., the Hindu and Muslim society, whereas Sikhs, Jains and others were smaller religious groups. The division of Hindu society can be explained in terms of the so-called Varna system from the Brahmin point of view, the Brahmin on the top, followed by Kshatriya, and the Vaishya. Sudras were at the bottom of this social hierarchy. In a village different castes lived separately from one another and the so-called untouchables suffered greatest disabilities. There was a restriction on occupational mobility and caste mobility. Every Hindu was born in a caste and could not leave it unless he or she was made an outcaste or decided to become a Sanyasi (Yogi) who completely abstracts from all worldly objects to acquire superhuman faculties.

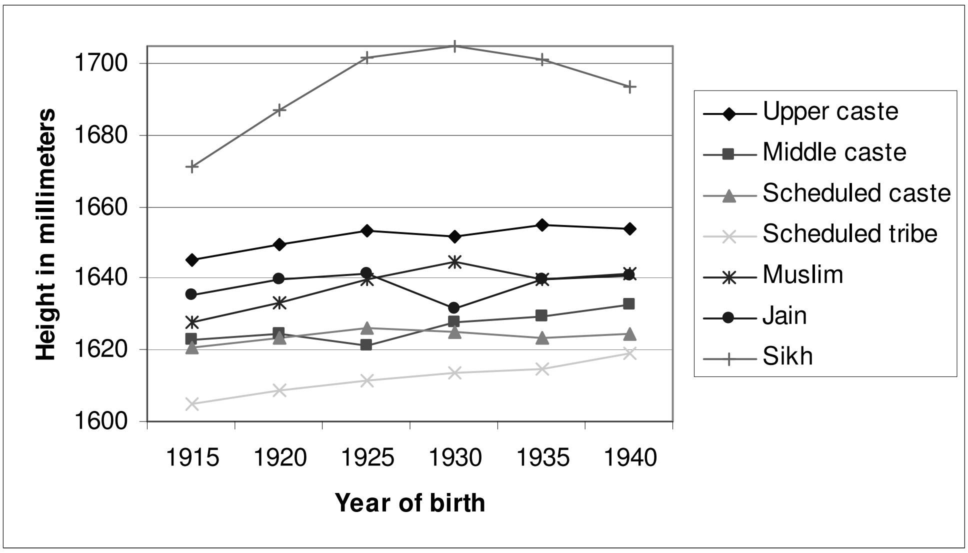


Figure 9: Height development of various caste and religious groups

Caste was characterized by endogamy and caste status was fixed for all the castes. There was a network of socio-economic relationships often termed as Jajmani system that does not exist now, but was still influential during the early 20th century. Anthropologists and sociologists in general define it as the reciprocal social and economic arrangement between families of different castes within a village community of India, by which one family exclusively performs certain services for the other. These relations continued from one generation to another, and payment was normally made in the form of grain, clothing, and money. It added to low occupational mobility of the castes and did not create incentives for productivity and quality improvement (Desai, 1968).

The Brahmin was a temple priest, teacher, doctor and cook of a rich landlord. Rajputs were cultivators, landowners or so-called Zamindars (i.e., the feudal lord of the village). Sometimes they worked in the army or police. Vaishyas' were generally involved in trade and business. Other social groups were oil processors (Teli) and carpenters who repaired ploughs, agricultural implements and made furniture for every village. Blacksmiths made iron instruments and utensils and some castes performed occupations like leatherwork, washing, pottery, barbering and scavenging. There were also castes for those who made sweets and liquor. There were pastoral castes, flower and vegetable growing castes, entertaining castes, a fishery caste, an accountant caste, a prostitute caste, a watchmen caste, and other groups. Summing up, Indian caste system created hierarchy in the society where certain castes enjoyed privileges and the remaining castes were discriminated.

From all those factors, we would expect that height differences between social groups were abnormally large in India, which refers to our initial working hypothesis (3). But there were also other factors that might have reduced this inequality: For example, the Dravid movement (1920), Justice movement (1916), self-respect movement (1926) and few other similar movements played a significant role as anti-Brahmin and anti caste movements. Along with these movements modern education, industrialization, means of communication, new legal machinery provided by the British government (like punishing criminals of all castes in equal way), legalization of inter-caste marriages and abolition of untouchability might have contributed to changes in the caste system in British India. Later on, independent India guaranteed right of equality and abolished untouchability in a constitutional way. These factors might lead to the rejection of hypothesis (3).

This study classified the castes of the total sample into seven major categories: High, middle, and low castes, tribes, Muslims, Sikhs and Jains. People from 'high castes' had access to land and education. Middle castes included artisans, fishermen, and oil pressing specialists, agricultural labourers and many others. Low caste people were those who were assigned various menial jobs and ritually polluting jobs like cleaning, leather working, butchering, and serving. Low caste people were so-called 'Untouchables' and currently they are referred as "Scheduled Castes" (as they are now under governmental protection for rights). High caste people belong to the "twice born" group that distinguishes them from the other caste groups. The typical characteristics of tribes were simplicity of technology, geographical isolation, distinct culture, shyness to contact with the rest of the society and economic backwardness. In summary, high caste people were the ones that belonged mostly to priestly, warrior and trading caste. The castes that were neither lowest castes (Scheduled Caste and Tribe) nor upper castes were classified as middle caste.

We will now shift our focus to the discussion regarding height differences in a cross-sectional perspective before tracing the development of inter-group differences over time. Men belonging to the Sikh religion were the tallest and they were followed by the men belonging to upper caste (Table 4, Figure 9). Jains and Muslims were shorter than Sikhs and Upper caste men, but they were taller then other Hindu groups. Within the Hindu religion, upper caste men were taller than the middle and low caste men. Scheduled Tribe and Scheduled Caste men were in the most disadvantageous position in terms of stature. From this we can conclude that social hierarchy played an important role in determining height of individuals. Higher caste people who were taller had better access to food, health and education compared to the lower castes. In contrast, the religious groups of Sikhs and Jains had a relatively egalitarian society with no caste hierarchy. In addition, most of the Sikh men were residing in Punjab and Haryana where agricultural productivity and protein supply was high. Jains were mostly in trade occupation that yielded high incomes that reflected in their height.

However, the remarkable social height differences were not confined to India only. Everywhere in the world, higher income groups had a tendency to be taller. The interesting question is rather: Did the Indian caste system with its low occupational mobility lead to abnormally large height differences? Comparing our differentials with the literature on other countries, the answer is negative. Height differences elsewhere had a similar range, and sometimes even larger. For example, in the late 19th century U.S. farmers were the tallest group, whereas laborers were the shortest, with a difference of about 3.1 cm (Haines 2004). Height differences in Argentina were about 2.5 cm between unskilled workers and students/teachers/professors (Salvatore 2004).

In 1875, Belgian students were even 5.3 cm taller than woolworkers, who were the shortest group there (Alter, Neven, and Oris 2004). In this case, some of the 20-year-old Belgian recruits might not yet have reached their final adult height. Therefore this difference might translate into slightly lower adult height differences, because both growth velocity and final height differential are both affected by worse net nutritional status of the poorer groups. The growth velocity part of the differential might later disappear due to catch-up growth**.** This explains also the truly enormous height differential between English schoolboys, which were far more than 10 cm around 1800 (Floud, Gregory, and Wachter 1990). To sum up, caste inequality was definitely important in India for the period 1915-1944, but in international comparison it was not as abnormally large as we would have expected, hence we falsify hypothesis (3). Religious rules might have played a role here that constrained the protein (especially beef) consumption of Indian upper classes, whereas the lowest classes were not hindered by those rules.

In our next step, we focus on the typical occupations of the groups, which is a refinement to the classification we used before. Now we consider 14 typical occupations of population groups. Interestingly, pastoral men were taller in many states despite of their typically low caste status (Table 5). For example, the tallest men in the state of Himachal Pradesh were the men belonging to the Scheduled Tribe group of the Gujjars (Figure 10). Brahmins and Rajputs were shorter than this Scheduled Tribe that might have had good access to protein (given their pastoral occupation).

Table 5: Determinants of height: typical occupations

Variable	Coefficient	P-values
Agriculturist	15.9	0.00
Agriculture labor	4.6	0.03
Land holder	27.0	0.00
Professional	36.0	0.00
Cultivator	20.1	0.00
Fisher	12.8	0.00
Menial	2.7	0.24
Pastoral	35.2	0.00
Potter	5.0	0.03
Trade	29.4	0.00
Writer	31.7	0.00
Skilled crafts	12.8	0.00
Mixed occupation	24.4	0.00
Constant	1639.7	
Adjusted R^2	0.11	
N	26154	

Notes: Height was measured in millimetres. In the right column, p-values are given. The constant refers to weavers and leatherworkers born in 1943. The regression also controls for year of birth and age heaping though not reported here.

On average in all states, and controlling for regional composition, landholders, professionals, pastorals, writers, and traders were relatively tall (Table 5). A middle group consisted of skilled craftsmen, cultivators, agriculturists, fishermen, mixed occupations. They were doing relatively better than agricultural labourers, men doing menial jobs, potters, and weavers and leather workers.

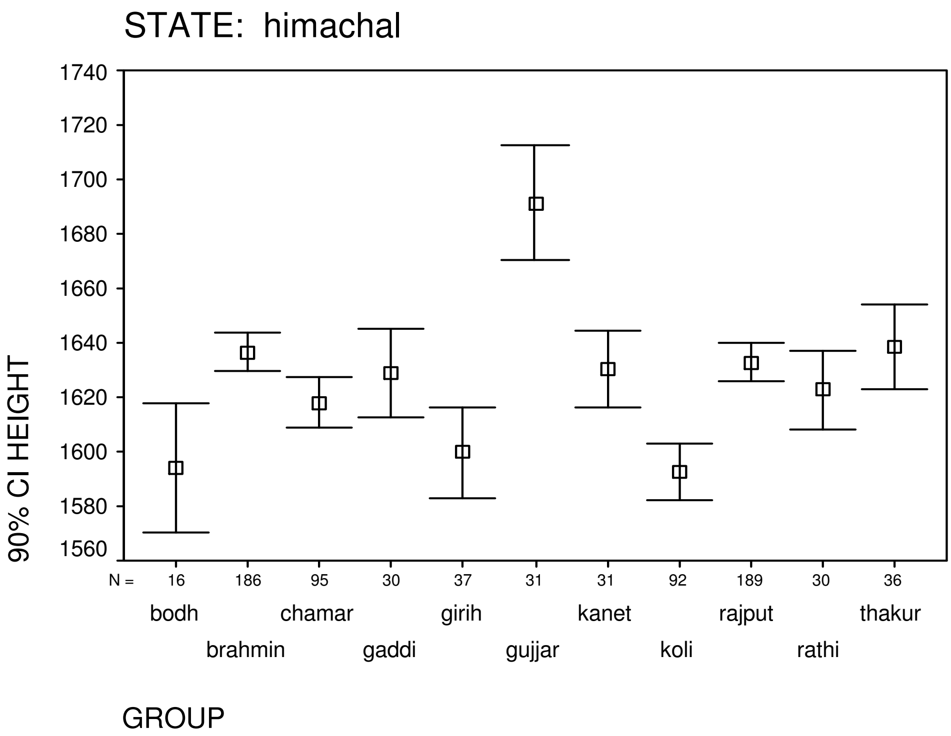


Figure 10: Height among various caste groups in Himachal Pradesh

How did height of the seven religious and caste groups' change during the period 1915 to 1944 (Figure 9)? In short, the differences did not change very much, except for the Sikhs. This relatively well-educated religious group might have benefited from the "open period" during the late 1920s, and from the very low grain prices during the early 1930s; the two advantages that were lost in the following period. However, we would not over-emphasize this result as our sample size for Sikhs is relatively small. Other groups moved very similar to the general development. Slight increase in the height of upper caste men and Muslims can be observed, whereas Jains and Scheduled Caste men gained no real increase in height. The biological welfare of Scheduled Tribe groups converged somewhat. Overall, among men belonging to Hindu caste height disparities did not decrease much from the period 1915 to 1944. Our working hypothesis (1) of an egalitarian development must be rejected for caste groups, although we will consider below whether this was also true for the development between occupational groups, and within groups.

Panel A

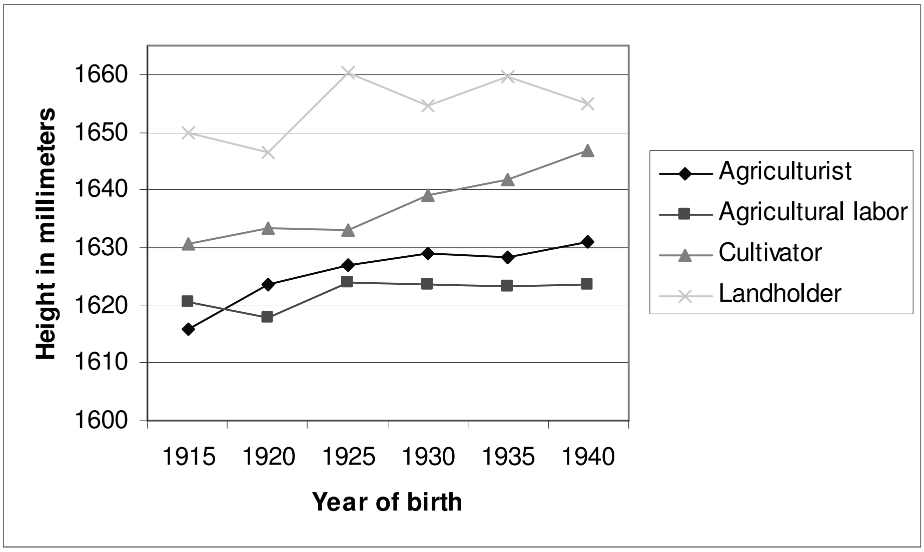


Figure 11A: Height development of various occupational groups

Finally, we consider the development of the 14 typical occupations over time (Figure 11). In general, the movement of those time series is quite similar. Fishermen had a high volatility (probably due to relatively small sample size). Interestingsly, traders might have benefited most from the "open" period of the late 1920s, but their heights fell dramatically during the Great Depression. Poor and less market-integrated groups (cultivators, perhaps fishermen) did relatively better during this economic downturn. In sum, this component of inequality between occupational groups again confirmed that between-group differences did not change much, except perhaps modestly for the early 1930s.

Panel B

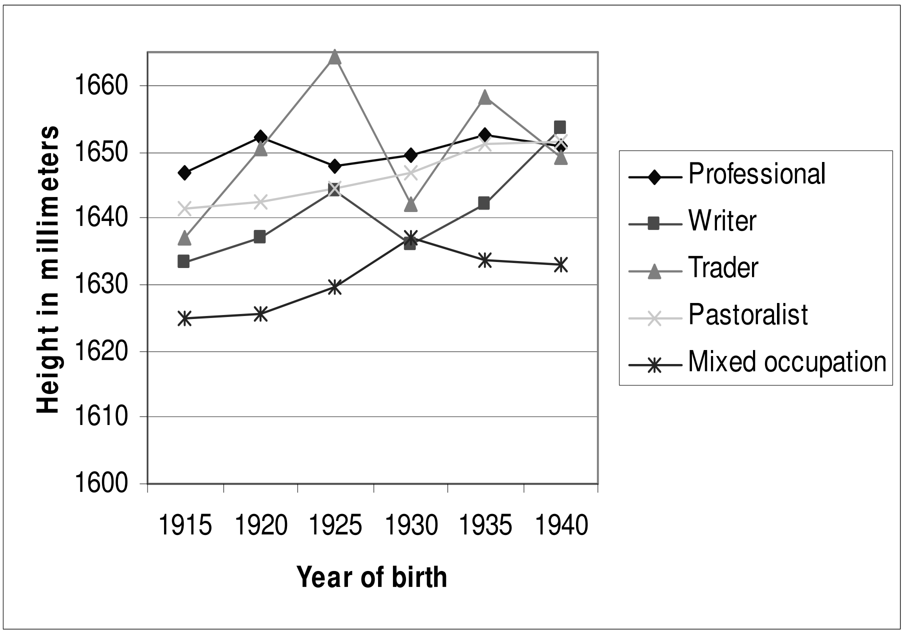


Figure 11B: Height development of various occupational groups

Panel C

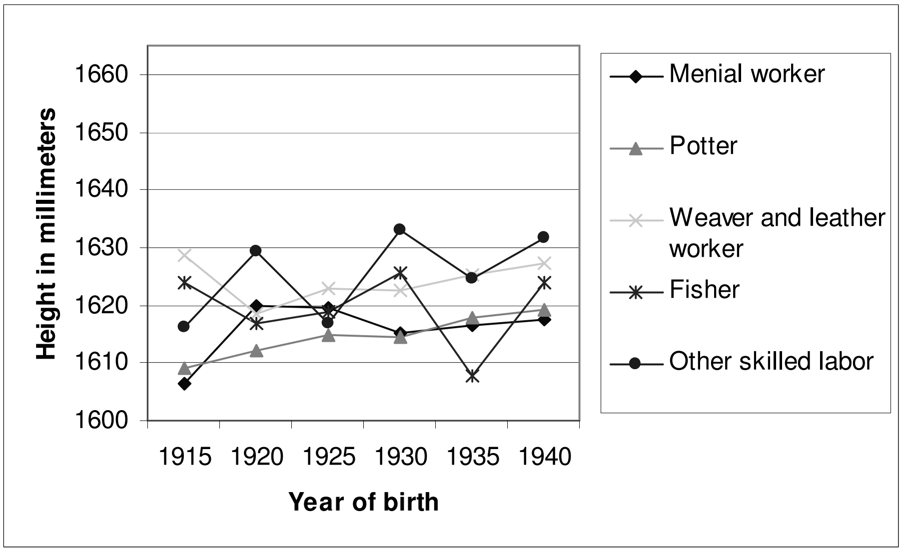


Figure 11C: Height development of various occupational groups

2.6. Height differential by region

Regional differences are often an important element in overall inequality, as it is certainly the case in today's China. Within our sample, they were clearly noticeable. Men from the Northern region were the tallest over the period 1915-44 (Figure 12). Eastern men were the shortest and they experienced only a very slight increase (about half a centimetre) over the time period. Northern male heights remained most of the time between 166 and 167 cm, except for the crisis period around 1920. The North and the West did not show much upward trend in height. The disparity between East and North/West declined slightly. In sum, we find that regional inequality did only decline very modestly during this period, as East Indians converged to a limited extent from below. Hence, this is partial evidence favouring our first working hypothesis.

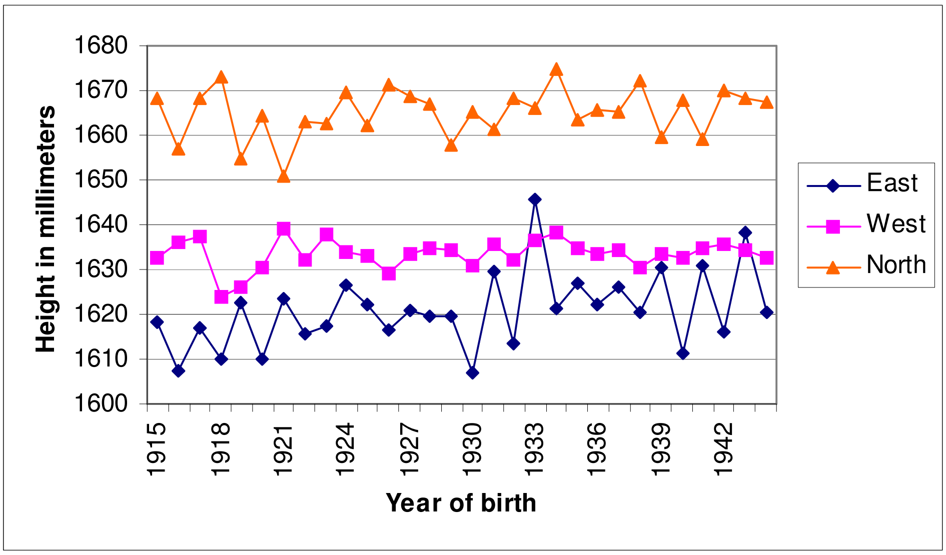


Figure 12: Regional height development in India, 1910-1944: Adjusted annual average heights

It is also interesting that the most urbanized West suffered the most from the 1918-20 influenza and famine crisis. The variability of Western heights decreased – as one can expect during the 20th century market integration process – whereas the variability of Eastern heights increased over time. This is not caused by small sample size. It might be a hint that food markets in the East with its rapidly growing population did not develop fast enough. This observation could be helpful in subsequent studies on the Bengal famine.

2.7. CV of height inequality

The overall height inequality can be assessed with the coefficient of variation of height (Baten, 1999; Baten, 2000; Pradhan, Sahn, and Younger, 2001). After we found above that height differences between groups and regions did change only modestly, this measure of overall inequality might have determined mainly by intra-group and intra-regional inequality. The height inequality coefficients had no clear trend in the three Indian major regions for the period as whole (Figure 13). But we found that 1915-29 was a period of increasing inequality for all the three regions. The Northern region experienced highest increase during this period and had decreasing inequality till 1944. The Eastern region experienced their highest peak slightly later, in 1935-39. In contrast, the early 1930s with their particular low food prices were a period of falling inequalities for west and north, and stable values in the East.

What could explain this development? The influence of openness on inequality could be one point. Baten and Fraunholz (2004) have argued that openness increased height inequality in another less-developed region of the world, in Latin America 1950-79. Firstly, there were growing height differences between the well-educated and the uneducated during the more “open” periods. Secondly, foreign investment was more dynamic in high-income metropolitan regions (thus, capital and labour markets worked imperfectly). O’Rourke and Williamson (1999) found that especially in land-rich countries (that included India) income inequality increased during globalisation. While the whole period of 1914-45 was characterized worldwide by deglobalisation tendencies, during the 1920s some recovery of international integration took place. In the late 1920s India’s trade shares ([Import + Export] divided by GDP) reached their highest values during this whole period (Mitchell, 1998). In contrast, the decrease of international integration during WWI and the Great Depression might have had the opposite effect of reducing height inequality. Apart from the openness, the particularly low food prices during the early 1930s could have also decreased inequality.

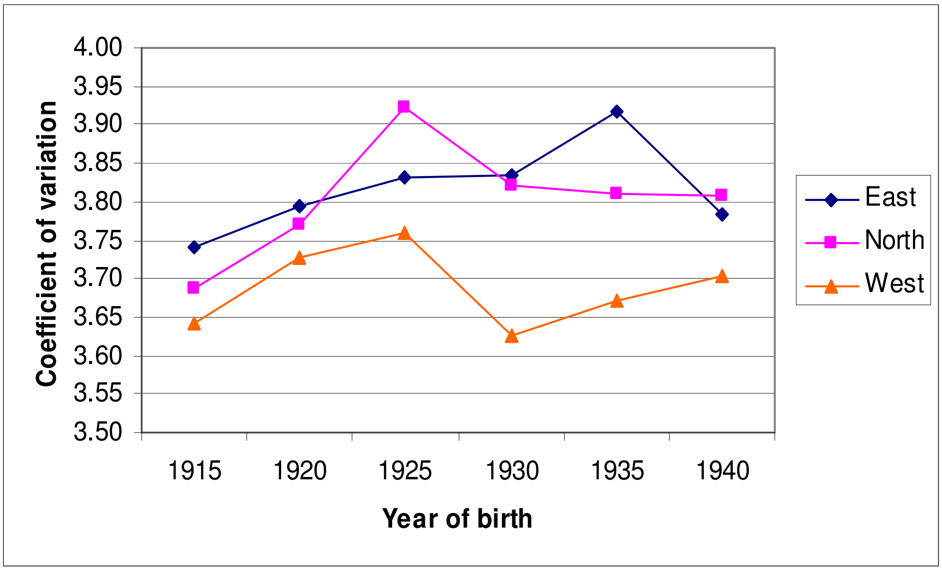


Figure 13: Height CV by regions

What about other determinants of inequality? The demographic theory that the share of mature people in the labour force was not likely explanation here, as India experienced a decline in the share of mature people between 1911, 1921 and 1931 that would lead us to expect a constant increase in inequality. Kuznet's inverse U theory of growing inequality during the first phase of rapid economic growth does not apply because there was no rapid growth. In sum, we reject our working hypothesis (1) of a continuous equality trend during the interwar period. We would rather argue that there were two periods of low inequality, the late 1910s, and the early 1930s, and an increasing inequality during the 1920s.

2.8. Height inequalities during the influenza period

Influenza is caused by a virus, a member of the family orthomyxoviridae. The 1918 influenza epidemic was truly global, leaving no continent untouched. The epidemic began in 1918 and ended by 1921 in New Caledonia (Crosby, 1989). The influenza had severe impact during 1918 and resulted in more than 20-40 million deaths worldwide (Lamb and Takeda, 2001) and there is still discussion about the exact number of deaths even today (Davis, 1951; Noymer and Garenne, 2000).

The influenza pandemic of 1918-19 was the most deadly in India, where it killed 6.2 percent of 1918 population of the British India according to the estimates of Kingsley Davis (1951). Theodore Schultz estimated the death rate for the working population in agriculture was higher than 8.3 % (1967). Based on the disease epidemic in the past we can investigate more about who are affected the most. Heights are used as an index of nutrition in this paper so that we can quantify the nutritional stress of children that were born during this epidemic time. Based on the “synergism” concept we would expect that biological welfare measured by heights developed worse for the lower income groups when suffered from malnutrition. Scrimshaw, Gordon and Taylor (1953) argued that malnutrition progressively enhances infection in an individual, and the infection in turn causes further malnutrition. Based on this synergism, Taylor (1983) believes that the behavior of most diseases is shaped by the nutritional state of the affected host. The main argument is that an ill person cannot eat well in spite of higher metabolic needs and poorly nourished individuals rapidly spend lot of their energy in fighting the infection. This synergism is reflected in the higher deaths and illness in the less developed countries.

We focus on its effects on the various income and social strata asking the question: were the poor more affected? We use anthropometric methods that employ human stature as a proxy for the biological standard of living (Baten and Komlos, 1998). To find out whether influenza did hit the poorer population relatively harder or not, we took height deviations of occupational groups from mean height for the pre-influenza pandemic and famine period (1915-17), influenza pandemic and famine period (1918-20) and post-influenza pandemic and famine period (1921-24). This allowed us to study the impact of influenza and famine on different occupational groups.

We find actually the height differences significantly during the pandemic: Among Indians born before 1918, castes with typically high income occupations were much taller, as they were after 1920 again. In contrast, among those born during the peak of the pandemic social differences were smaller, indicating an egalitarian effect. The influenza did not care whether someone was well-off or poor thereby affected all groups disregarding the social inequalities.

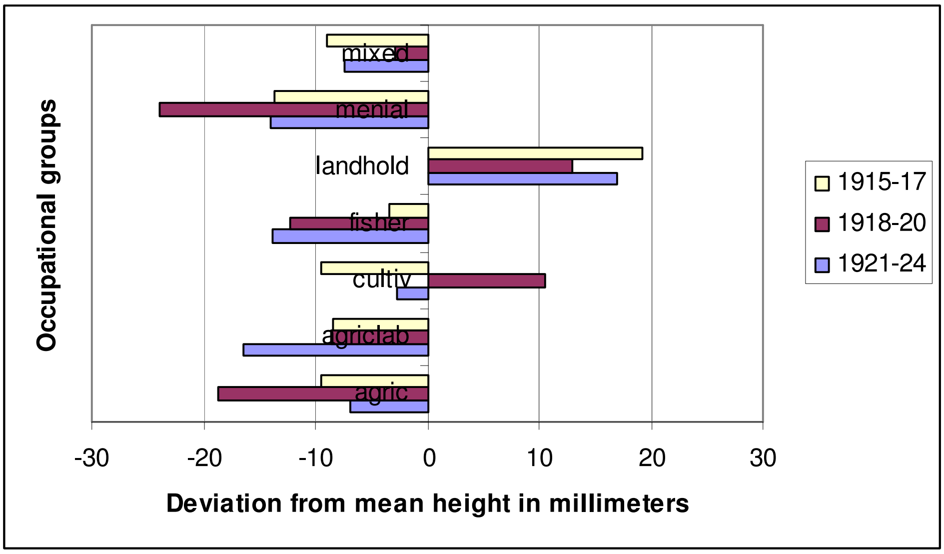
We actually find that during the influenza and famine period of 1918-20, health inequality declined in India. Landlords and traders that belonged to high income groups had a relatively more pronounced height decline compared the middle and lower income groups (Figure 1). Some lower income groups, such as weavers, leather workers, and potters even converged in the influenza period in relative terms. But there were also exceptions: Menial workers from the lowest casts did even worse during the disease, as they were in frequent contact with infectious material. On the other side the heights of children born to the highest castes (Brahmins and similar groups) that had typically professional occupations, did not decline in height. What could have lead to the lower height inequality during the influenza and famine period? Three hypotheses were mentioned in the literature.

(A) During a major wave of epidemic disease, the infection is less determined by income, especially if the health system is less developed. Compared with food consumption, which is directly determined by income, social differences of height might decline (compare McKeown's [1976] arguments about disease).

(B) The Indian religious constraints about food consumption kept the upper Hindu castes, especially the Brahmins, from going to soup-kitchens and other food distribution institutions, because they would have felt polluted. Higher castes aimed at never sharing cooking, eating and drinking vessels with other castes. Apart from this, Brahmins never accepted food and water from any other castes other than their own. Moreover they never ate with persons of other castes during ceremonies such as marriage or food distribution programs. Religious taboos could have played a role here.

(C) The closing of the economy during WWI and the decline in world trade continued, and created less additional income for the well-educated groups (such as traders, Sikhs etc), and for the inhabitants of vibrant metropolitan cities, so that their income advantage over the uneducated and over those living in economically depressed regions vanished. To a certain extent, this might have been reflected in heights (Baten and Fraunholz 2004).

Panel A



In fact, disaggregating by typical occupations, we find that traders and landholders, who did well under other circumstances, did badly during the influenza and famine crisis (Figure 14). In contrast, the professionals (mostly Brahmins) kept almost entirely their high biological standard of living. Among the lower and middle height groups, the development was heterogeneous. Menial workers and agriculturists who were already below mean height in other periods were hit hard during influenza period. Weavers and leather-workers, mixed occupational men, potters and cultivators who did not fare well under normal situation were doing better during the famine and influenza epidemic. Pastoralists who were already doing well also kept their anthopometric values during the influenza and famine period. In general, the influenza pandemic had egalitarian effects, as landholders and traders (rich and educated) were among the suffering strata. At the same time menial workers were severely affected by their contact with diseased people due to their cleaning and scavenging occupation.

Panel B

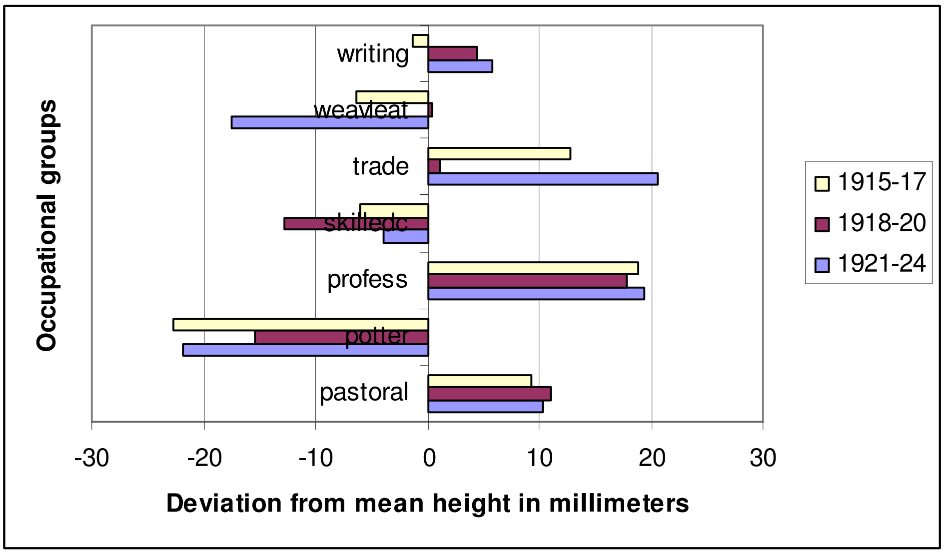


Figure 14: Height deviation of occupational groups from mean with special focus on influenza/famine period (1918-20)

Note: Definition of the occupational abbreviations in appendix C.

Which conclusion can we draw about our hypotheses? Factor A, the egalitarian spreading of disease was definitely true given that so many high-income Indians were also affected with low and middle income people. Brahmins might have used their education to isolate themselves sufficiently to decrease their infection. Though traders had a good education it was of a more commercial character compared to health and hygiene. The second hypothesis (religious constraints not allowing sharing food aid) is somewhat less supported in our cross-section, because we would have expected the detrimental effects on Brahmins to be strongest, but their anthropometric values only declined modestly. In contrast, traders in early 20th century India might have been less "irrational" about not accepting food aid because of religious rules when their children were hungry. But we find a strong height decline in the traders groups in the core years of the crisis. Hypothesis C (egalitarian effects of closing) certainly has some explanatory power, as our intertemporal comparison above has suggested. But this cannot be the whole story, as the egalitarian effect did not affect the cohorts born 1915-17. In sum, we would argue that the egalitarian effects of the influenza pandemic (Hypothesis A) were the driving force for the low inequality of the 1918-20 periods.

A comparison can be drawn with the second major equality episode, the early 1930s. Around the world, this was the period of the Great Depression, although in India the effects might have been slightly less pronounced. Again, we took the deviation of height of various occupational groups from mean for the period 1926-29 (pre-depression period), 1930-33 (great depression period), and 1934-37 (post-depression period). We found that landholders and traders were particularly affected during the 1930-33 period (Figure 15A and 15B). Traders had the maximum decline of their anthropometric values during this Great Depression period. Contrastingly, most other occupational groups showed only little change, some even small improvements during this period. We can conclude that the occupations that were related to the world market directly suffered most from the Great Depression in relative terms, and this might have contributed to the egalitarian effects of this second major crisis.

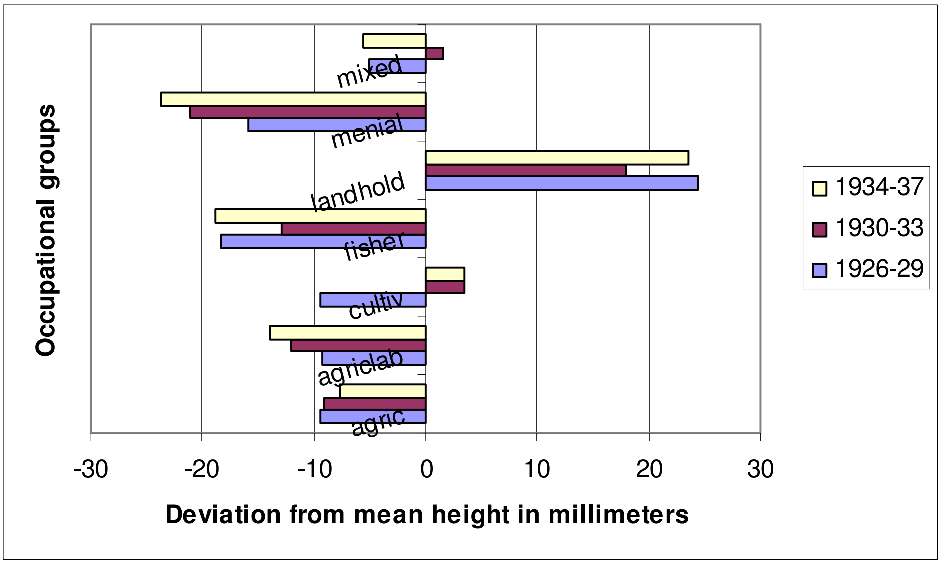


Figure 15a: Height deviation of occupational groups from mean during great depression

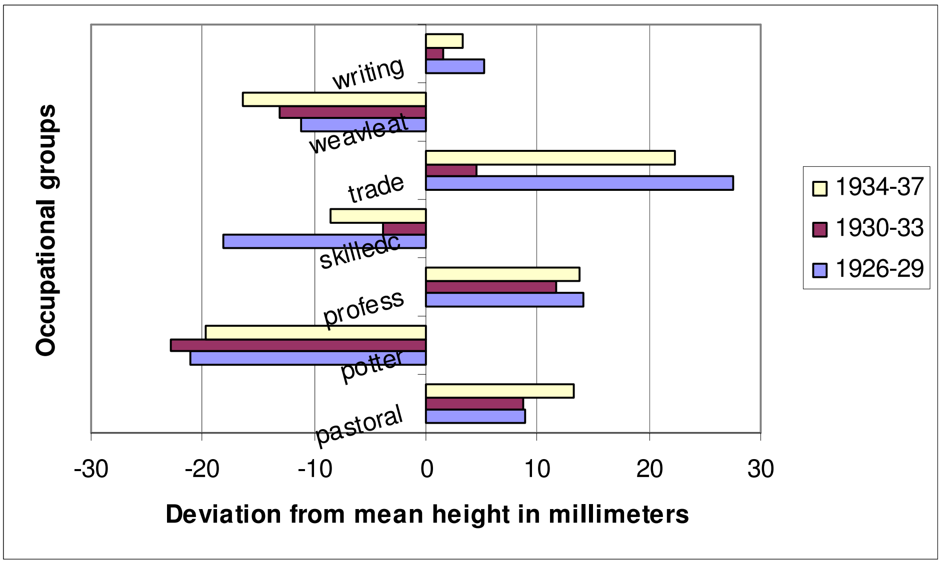


Figure 15b: Height deviation of occupational groups from mean during great depression

Note: Definition of the occupational abbreviations in appendix B.

2.9. Conclusion

We structured this study around a set of four interrelated hypotheses about Indian height inequality and height development during the period 1915-1944. We obtained the following results.

Hypothesis (1): In sum, we reject our working hypothesis of a continuous height equality trend during the interwar period that might have been *ceteris paribus* caused by the declining income inequality which Williamson (2000) found. We did not find continuous convergence neither between castes and religious groups nor between occupational groups. A modest regional convergence between the three large regions did not lead to generally declining height inequality in India. We would rather argue that there were two periods of low inequality, the late 1910s, and the early 1930s, and an increasing inequality during the 1920s. The inequality increase during the 1920s was partly caused by better incomes for the more educated groups (such as traders and Sikhs).

Hypothesis (2): During the influenza and famine period 1918-20, we observed relatively low height inequality in India. Traders and landlords suffered relatively more compared to the middle and lower status groups. We have argued that the egalitarian effects of the influenza pandemic were the driving force for the low inequality of the 1918-20 period. The two other factors that contributed to a smaller extent were religious taboos and the lower advantage of well-educated and metropolitan groups during "closed" phases of world trade. We would argue the effects of the 1918-1920 influenza epidemics are one of the most interesting results of this study.

Hypothesis (3): The caste system clearly played a significant role in determining stature of individuals, but it was only the Indian substitute for income and educational differences that were at work in other countries. Upper caste Indians were about 2.9 cm taller than Scheduled Tribe men. Sikhs were even taller, but they lived in a region with high protein proximity advantages. In comparison, height differentials in Europe, North and South America were of a similar dimension (between 2.5 and nearly 5 cm between extreme groups). Interestingly, Indian pastoralists who belonged to low caste and social status were taller compared to the higher caste people - because the milk proximity advantage mentioned above -, which is also an argument against an omnipotent determinism by caste.

Hypothesis (4): In sum, we confirmed the hypothesis of Brennan, McDonald and Shlomowitz (1994) that heights increased modestly during the early 20th century. Between our earliest cohorts and the late 1940, the increase was only about 0.7 cm, which is much lower than in Europe. We also found their hypothesis supported that cheap rice imports did offset the detrimental nutritional effects of declining food production in India, and the declining GDP per capita. The slightly improving disease environment over the 20th century might have played an additional role, certainly after the disastrous influenza pandemic at the beginning of our study period.

Appendix B: Caste System and occupational mobility

In this paper we have focused on typical occupations of different caste groups and their biological welfare. Data about the typical occupation of the caste groups were taken from the introductory chapters of the survey. One important question that arised in this context is occupational mobility. There is a lack of adequate data especially about changes in individual occupation over time. L.K. Mahapatra (1995) was the only one to use census data of 1911, 1921 and 1931 to describe the change and development of traditional occupations of different castes in Orissa state.

Table B1 Percentage of working population following the traditional occupations as their main or first subsidiary occupation

Caste	Percentage of working people in traditional occupations (1921)	Percentage of working people in traditional occupations (1931)
Brahman	27.2	26.1
Kamar	67.7	57.4
Dhoba	85.6	75.1
Kumbhar	83.4	78.2
Tanti	78.1	71.7
Karan	34.4	50.2
Teli	46.7	32.3
Chasa	88.7	N.A
Barhai	49.9	**N.A**
Chamar	67.1	**N.A**
Kewat	82.7	**N.A**
Goura	69.5	**N.A**

Note: N.A stands for non availability of the data.

There was no strong occupational mobility in Orissa during this period for most caste groups. In many cases, two-thirds still worked in their traditional occupations, or used it as their first subsidiary occupations. Notable exceptions were elite groups like Brahmins and Karans. Also we should keep in mind that we were talking about low occupational mobility corresponding to the year of birth of the men covered by the AIAS survey. Their height was mainly determined by their parents' occupation and when we move further backward in time to the fathers of these men whose occupations were determined 2-3 decades before, occupational mobility probably was even lower. Based on this argument we conclude that occupational mobility might not have played a significant role for the late 19th century and the first decades of the 20th century, especially for the rural parts, except for a few elite groups.

Appendix C

Definition of occupational groups is given in this appendix in detail.

Cultiv: Number of males whose primary job classification is cultivation

Agric: Number of males whose primary job classification is cultivation who rent others land for cultivation

Agriclab: Number of males whose primary job classification is agricultural labor

Profess: Number of males who were priests, doctors, and teachers (these occupations were in the hold of Brahmin caste)

Fisher: Number of males whose primary job classification is fishing

Landhold: Number of males who possess vast size of land and hire labors for cultivation

Menial: Number of males whose primary job classification is scavenging, cleaning, leather production and butchering (This occupation category was considered degrading)

Trade: Number of males whose primary job classification is trading

Pastoral: Number of males whose primary job classification is pastoralism

Writing: Number of males whose primary job classification was writing

Skilledc: Number of males who were oil processors, gold smiths, and black smiths

Potter: Number of males whose primary job classification was pot making

Mixed: Number of males who were in other occupations that were not listed above.

Appendix D: Shrinking

When old age people are included in the height sample, differences in mean adult height observed in cross-sectional studies between groups of men of different ages and birth years reflects not only the effects of secular trend but also the effects of shrinking due to aging. The decrease in height that occurs with aging can be attributed to a number of factors. Much of the relevant shrinking will occur in the 30 cm between lumbar and lower thoracic vertebrae.[7] There are seven cervical, 12 thoracic, and five lumbar vertebrae, which means there are 24 intervertebral spaces and disks. When an individual ages, the narrowing of each of these disk spaces results in a loss of anywhere between 0.08 and 0.16 of a centimetre, which leads to a reduction in height of close to 2.5cm or more in total. In addition, older people do not carry themselves as they used to when they were younger. They become little round shouldered or stooped, and they develop kyphosis and all this contributes to a loss of height with age (van Leer et al., 1992).

Interestingly, the length of long bones does not change after reaching their maximum after puberty. Therefore, estimates of long bones such as arm span and height of iliac-crest reflect a secular trend in these bones whereas height and sitting height reflects combined and opposing effects of secular trend and shrinking. Few studies have

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[7] The vertebral column (also called the backbone, spine, or spinal column) consists of a series of 33 irregularly shaped bones, called vertebrae. These 33 bones are divided into five categories depending on where they are located in the backbone.The first seven vertebrae are called the cervical vertebrae. Located at the top of the spinal column, these bones form a flexible framework for the neck and support the head.The next twelve vertebrae are called the thoracic vertebrae. These bones move with the ribs to form the rear anchor of the rib cage. Thoracic vertebrae are larger than cervical vertebrae and increase in size from top to bottom.After the thoracic vertebrae, the lumbar vertebrae are situated. These five bones are the largest vertebrae in the spinal column. These vertebrae support most of the body's weight and are attached to many of the back muscles.

attempted to measure changes in height with aging. A cross sectional study by van Leer et al. (1992) on 13,000 women aged 40-74 found a loss in height of up to 4.9 cm over time from the age 40 to 74. Their study was based on measurements of arm span and height of iliac crest (secular trend) and sitting and standing height (for secular trend and shrinking). They found that the decline in height seemed to begin between the ages of 52 and 56 years.

Longitudinal studies are methodologically more reliable than cross sectional, but there is no single study that is exclusively longitudinal with big samples. The Baltimore Longitudinal study of Aging (BLSA) measured decline in stature using both longitudinal and cross-sectional height (Sorkin et al., 1999). They argued that the relation between age and stature was curvilinear showing that height was lost at an increasing rate with increasing age. In a longitudinal study they found that women lose height more rapidly than men and the rate of loss for both men and women was significantly negative in the five decades of 40-49, 50-59, 60-69, 70-79, and 80-89 years. For the age groups 40-49, height declined by 0.6 cm (mostly after age 45). But for the age groups 50-59 the decline was 0.9 cm. Hence, men lost about 1.6 cm by the time they reached age 60. This study was limited to White men and women. Unfortunately, there are no longitudinal studies in height of non-White and poor populations. Therefore, we have no repeated measurements for populations such as Indian and we know little about the influence of malnutrition. One could imagine on the one hand that malnutrition results in stronger shrinking at higher ages (also by starting) earlier, or on the other hand that shrinking is less pronounced, as stature is low anyways.

Another study by Niewenweg et al. (2003) tried to capture the shrinking using Dutch consecutive nationwide growth studies. They compared individual heights with the average height for a given generation (corrected for secular trend) and a given age (corrected for shrinking). They found a curvilinear relation between age and height and they assume that the effect of ageing on the rate of height loss is largely independent of initial height attained by that person. The same method for correcting secular trend and shrinking cannot be used for our Indian sample as we do not have other data for comparing individual height from our data to the average height for that generation and age. To be specific, the equations derived by this study to reduce experimental noise cannot be used for India as there is no reliable data on secular trend.

The major draw back of all the studies was the restriction of their sample to the educated and middle class people from developed nations where malnutrition is not a problem. There is dearth of information on shrinking in population samples with differential health access, standard of living and education. Also one cannot assume that shrinking does not depend on how tall the person is.

We were curious to know the extent old age shrinking might have had in India. We have no longitudinal measurements (one major Indian anthropologist informed us that there are none, thanks to Parasmani Das Gupta). Then we have used the sitting height and standing height data and constructed the leg length, as we know that sitting height and standing height might have effect of shrinking whereas leg length does not alter. We find actually that shrinking in Punjab (Figure D) was very modest until the age 60. Shrinking is more pronounced only by the time Punjabis reach their late 60’s. This astonishing finding could be overstated by measurement error and should be counter checked by further research (and longitudinal studies in particular), but we tentatively conclude on the basis of what we know until now that shrinking with age was probably less (or at least not more) pronounced than among the tall Westerners of the Baltimore study.

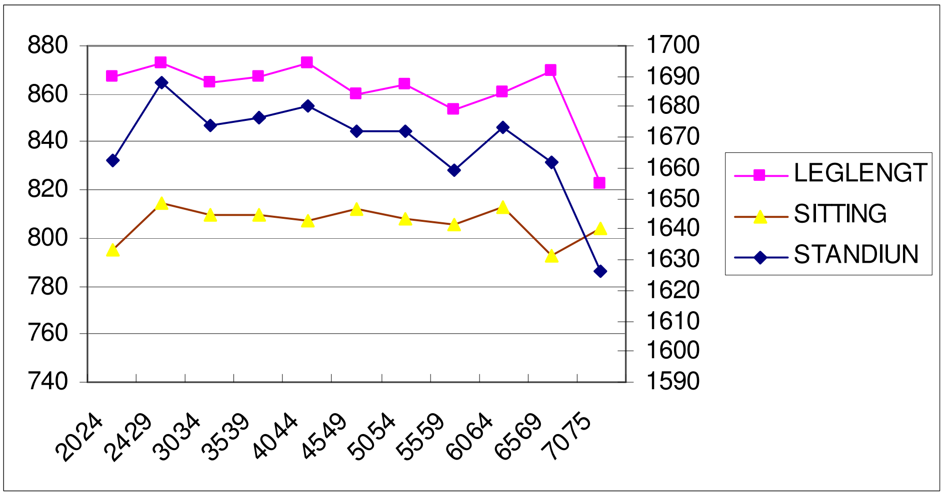

Figure D1: Shrinking based on Punjab data

3. What happened to the welfare of Indians after independence? A study of biological welfare and inequality from 1949-74

Abstract

The transformation of the Indian economy from near-stagnation to one of the most rapidly growing economies has generated a lot of interest in the economic progress of Indians. Economic development, however, does not guarantee that all individuals and groups improve their economic and social status. Accordingly, the aim of this chapter is to study welfare and inequality among Indians from 1949-74. We find that Indian stature improved very little until 1974. The overall stature of people belonging to the bottom of the height distribution could be improved with accelerating development expenditures. Moreover, upper caste Hindus were taller compared to lower caste Hindus. Inequality in biological welfare did not vary significantly over this period. The variability of rain, and the caste and religious system of India affected inequality. From a methodological point of view, using a quantile regression approach allows assessing the impact of macroeconomic indicators on various quantiles of the height distribution. Uncovering the partial impact of variables like development expenditures on different groups could help to make policy interventions more focused and effective.

Keywords: Stature; Heights; Biological Welfare; India; Caste; Religion; Inequality; Quantile regression

3.1. Introduction

The period after 1950 is one of the most interesting periods for studying Indian welfare and inequality, as India attained independence and became a republic by 1950. The transformation of the Indian economy from a near-stagnation phase to relatively higher economic growth compared to the pre-1950 period has generated considerable interest in the economic development of India. In fact, based on the Kuznets hypothesis, an economic expansion could trigger higher inequality and hence does not necessarily improve biological welfare in general. In addition, population growth might have outweighed increasing GDP. The aim of this chapter is to study the welfare and inequality of Indians, and their determinants, from 1950-75.

In the second chapter, we concluded that Indian heights did not exhibit a strong upward trend from 1915 to 1944. The Indian economy was more or less stagnating before independence and also, the welfare of Indians hardly improved. In this chapter, we focus on the welfare and inequality of Indians from 1950-75 as the economy started to move from a stagnating phase to a slow growth phase. Most of the previous research employed economic indicators to analyze changes in welfare and inequality. Unfortunately, the quality of data for the pre-1975 period is not sufficient to study the welfare and inequality by regions, religions, and caste using economic indicators like Gini coefficients. Broadening the database by inserting anthropometric measures enables us to analyze biological welfare and inequality before 1975. Consequently, the aim of the study is to investigate whether improvement in the economy reached different sections of the Indian population.

In particular, important questions hardly addressed by previous research are investigated in this study such as: how did the biological welfare of Indians develop from 1950-75? What happened to inequality in India after the 1950s? Did the increase of the population hinder biological welfare, particularly in this period? Did the heights of Hindus and Muslims develop differently? Did the increase in GDP in the non-agricultural sector improve the welfare of Indians (both rural and urban)? Do we observe an urban and rural divide in the biological welfare of Indians? These welfare and inequality-related questions are addressed using individual data of 51,678 women. Biological welfare is measured using height, whereas inequality is measured by the coefficient of variation in heights.

Sivasubramonian (2004) showed that aggregated real GDP doubled within two decades starting from 1950 - but it took 29 years for GDP per capita to double due to population growth. Nevertheless, GDP only reflects an aggregated picture, and we need to distinguish between growth in the agricultural and non-agricultural sectors to see which sector was responsible for the improvement in heights. Ravallion and Datt (1995) used 20 household surveys for the years 1958-90 to measure the effect of agricultural growth on rural poverty and on the rural labor market. They showed that agricultural growth had no impact on the share of consumption of the poor. Also, Eswaran and Kotwal (1994) argued that India's urban-focused industrialization process has provided few benefits to the rural poor. In this chapter, we attempt to study the relation between improvement in the non-agricultural sector and the biological living standard of both rural and urban women.

India in 1968 had 14 percent of the world's population on 2.4 percent of the world's total land. There was enormous improvement in health conditions that increased the life expectancy from 32 years in 1950 to 51 years in 1968. Although the availability of goods and services increased, per capita consumption did not increase due to the population explosion (Chandrasekhar, 1968; Sivasubramonian, 2004). To incorporate the simultaneous economic expansion driven by growth in the non-agricultural sector and the population increase, we use the net domestic product per capita (NDP) in the non-agricultural sector. Hence, we capture the population explosion arguments of Chandrasekhar (1968) and Sivasubramonian (2004) by using per capita measures of economic activity. Moreover, the incorporation of population growth rates to determine heights can show the impact of population growth on welfare. Lastly, population pressure makes distribution networks vulnerable in times of economic crisis.

During 1950-75, Indian economic growth was influenced by unfavorable situations such as the severe droughts of 1965, 1966, 1972 and 1974. Added to these droughts, India had a border conflict with China in 1962 along with the Indo-Pakistan conflicts of 1965 and 1972. Adding to these events, the oil price shock of 1973 had a drastic impact on economic development. In sum, the Indian situation in these 25 years was dynamic both in positive and negative ways. Using height as a proxy for biological welfare, we can assess how these positive and negative shocks shaped the welfare of Indians.

Did India experience heavy fluctuation or a breakpoint in this period? Virmani (2006) studied how the Indian economy performed since independence focusing on fluctuations and breakpoints. He discussed the fall in GDP growth from 1965-66 that was compounded with the stagnation of agricultural growth and tested for possible breakpoints in this period using a CHOW test. He concluded that there was no structural break in the growth of GDP from agriculture, once the variations in rainfall are accounted for. But the whole issue of the impact of these bad years for the Indian economy on the welfare of Indian people was never investigated.

How was the Indian political situation after independence? Except for the partition years of 1946-47, India did not experience religious violence[8] during the democratic regime (1950s and 60s) of the first Prime Minister, Jawaharlal Nehru. At the same time, during this period, anti-cow slaughter laws were not abolished irrespective of various requests (Wilkinson, 2000). Wilkinson defined 1950 and 1960 India as a consociational state, which is defined as a state that has major internal divisions along ethnic, religious, or linguistic lines, yet nonetheless manages to remain stable due to consultation among the elites of its major social groups. When focusing on religious inequality in India, the political system plays an important role.

Another interesting change during 1950-75 in Indian politics was a shift from the Hindu-Muslim (majority-minority) debate to the caste debate. Especially the North-South divide in religious politics can be defined in a way that in North India, religion played an important role in voting until the 1970s whereas in South India, caste played an important

[8] Unfortunately, Polity IV data did not show any change in democracy and autocracy for this period. The Polity index had a value of 9 during 1950-75. Hence, the available political data could not be used for comparison purposes.

role. Already in the 1960s, people from lower castes came to power in some Southern states like Kerala. It is not very clear if the shift from minority religion to lower castes created a gap in the biological welfare of religious groups especially between Hindus and Muslims. Though many researchers focused on the central question of ethnic differences in India, welfare and inequality issue was hardly addressed. Hence, one important research question is to study the caste and religious inequality in India.

Most of the studies in this period focused on poverty and inequality in the country whereas the aim of the current study is to identify not only the biological welfare of different regions and groups, but also the inequality within regions and groups. Though reliable data of Gini coefficients is available for India, the data is not detailed enough to study inequality by different groups. In addition, we test the relation between Gini coefficients – (measuring income inequality) and heights (which measure biological welfare).

This chapter revolves around four main hypotheses:

Hypothesis 1: Improvement in the non-agricultural state net domestic product increased heights. Though the agricultural sector is predominant in India, improvement of this sector does not allow additional employment opportunities, whereas improvement in the non-agricultural sector provides jobs to surplus workers in the agricultural sector. Moreover, it might lead to the accumulation of human capital.

Hypothesis 2: The Indian caste system created particularly high inequality, and along with caste inequality, religious inequality results in differential heights of various religious groups.

Hypothesis 3: The period 1964-66 showed declining growth rates compounded with droughts. This disastrous period lowered the biological welfare of Indians.

Hypothesis 4: A declining population and better rainfall (a proxy for agricultural production) improved heights and decreased inequality.

In the following section, we discuss the use of anthropometric indicators for studying welfare and inequality. The third section focuses on data and methodology, and section four provides evidence concerning the overall improvement in stature and the heights of different groups like castes, religions and regions. Rural and urban welfare is highlighted in section five, and section six studies inequality and the determinants of inequality. The chapter closes with a conclusion.

3.2. Anthropometric welfare and inequality

Though the study of welfare and inequality has attracted much attention during the last decades, there are limitations posed by the available datasets. Most of the datasets focus on poverty, using the poverty line and poverty gap.[9] Özler, Ravallion, and Datt (1996) created an excellent database on poverty and inequality. Along with this data, we

[9] The poverty gap index measures the mean distance below the poverty line as a proportion of the poverty line where the mean is taken over the whole population, counting the non-poor as having a zero poverty gap. A decline in the poverty gap index reflects a decrease in poverty.

have good macroeconomic indicators available from various works of Sivasubramonian (2004). Though we have good data disaggregated by states, most the data is available only from 1958 onwards. Moreover, some of the indicators like literacy are available only from a census that is decadal. The available data also pose limitations to the analysis of religious and caste inequality, as most of the data are aggregated by state level for rural and urban areas. By using such state-level aggregated, income-based measures, it is difficult to focus on the differential heights of various population groups based on caste and religion.

Moreover, India's economic growth from 1950-75 was accompanied by several droughts and crises. In such situations, we want to really capture the affect of the diverse situations on the welfare of Indians which is not possible using the aggregated state measures. Moreover, it is definitely worth comparing the monetary measures of poverty, inequality and consumption with the non-monetary biological welfare indicator of height. Two methods are employed in this study to measure welfare and inequality. The first is to observe the height levels and trends of various regions, religions, and caste groups. This measure has been successfully used by many economic historians (Komlos, 1996; Baten, 2000B; Moradi and Baten, 2005).

The second method is to study inequality using the coefficient of variation in height. The coefficient of variation can measure overall height inequality efficiently (Baten, 1999, 2000a, 2000b; Pradhan et al., 2003). The coefficient of variation in height (CV) for both children and adults has been successfully employed for adult and child heights (see Baten 1999, Moradi and Baten, 2005; Pradhan et al., 2003). Sahn (2003) explored health inequality in late 20th century India using the height of pre-school aged children with a special emphasis on spatial analysis. He found that inequality was low in Kerala state compared to the other states of India, and the health of children in Kerala was relatively equally distributed. Using the CV in adult height, we try to explore levels and determinants of inequality for various Indian states.

$$CV = \frac{\sigma_h}{\mu_h} \times 100$$

With $h \overset{a}{\sim} N(\mu_h, \sigma_h^2)$ (heights h are approximately normally distributed with the mean μ_h and variance σ_h^2. The CV is reported as a percentage here. In sum, the CV is a measure of dispersion that allows the comparison of the variation of populations.

3.3. Data and methodology

Two major sources were used to study welfare and inequality in India. Anthropometric data were taken from the National Family Health Survey-2 (International Institute for Population Sciences, 2000) whereas economic data were taken from Özler et al. (1996). Both data sets were merged to study the impact of poverty and growth on biological welfare and inequality.

3.3.1. Anthropometric data

The National Family Health Survey-2, conducted in 1998-99 in all 26 states of India, is used in this study for anthropometric data. The NFHS-2 was a household survey with an overall target sample size of approximately 90,000 ever-married women in the age group 15-49. The NFHS-2 is a demographic and health survey collected as part of the Demographic and Health Survey (DHS) program, which is funded primarily by the

United States Agency for International Development. The United Nations Children's Fund (UNICEF) provided additional funding for the nutritional components of the survey in India. Health investigators attached to interviewing teams were given additional specialized training on measuring height in a centralized training program conducted by the International Institute for Population Sciences (IIPS) in collaboration with the All India Institute of Medical Sciences (AIIMS), New Delhi.

This specialized training included classroom training and extensive field practice in schools and communities. Heights of respondents were measured using an adjustable wooden board particularly designed to provide accurate measurements. The target sample was set considering the size of the state (Table 1). A uniform sample design was adopted in all states and the urban and rural samples within each state were drawn separately and, to the extent possible, the sample within each state was allocated proportionally to the size of the state's urban and rural population (International Institute for Population Sciences, 2000). As the sample represents the size of the rural and urban population and also its (International Institute for Population Sciences, 2000) state population share, it can be used for studying not only overall welfare but also welfare by rural and urban areas.

Table 1: Composition of the NFHS-2 sample by major states of India

States	Frequency	Percent
Andhra Pradesh	5721	9.45
Assam	1500	2.48
Bihar	5808	9.59
Goa	91	0.15
Gujarat	3194	5.27
Haryana	1259	2.08
Himachal Pradesh	420	0.69

Jammu	550	0.91
Karnataka	3400	5.61
Kerala	2526	4.17
Madhya Pradesh	4647	7.67
Maharashtra	6133	10.13
Manipur	128	0.21
Meghalaya	93	0.15
Mizoram	47	0.08
Nagaland	84	0.14
Orissa	2327	3.84
Punjab	1524	2.52
Rajasthan	3060	5.05
Sikkim	27	0.05
Tamil Nadu	4682	7.73
West Bengal	5452	9.00
Uttar Pradesh	6801	11.23
New Delhi	823	1.36
Arunachal Pradesh	57	0.09
Tripura	207	0.34
Total	60562	100.00

In general, the distribution of age is relatively close to the age structure (Table 2). Also, the most important question related to the sample is survivor bias. To address this question, a caste or religious sample by birth cohort can be helpful. If mortality were selectively high among certain caste and religious groups, we would expect a slight under-representation of those groups. For this purpose, the share of a caste and religious group by birth cohort was considered. We observe that the share of all castes and religious groups stayed more or less constant over time (Figure 1 and Figure 2). If mortality had caused selectivity, we would have observed a lower share of scheduled castes and tribes that have a lower socioeconomic status. Moreover, the percentage of the sample representing scheduled tribes and castes was close to census data, though the percentage of scheduled castes is slightly higher (Varshney, 2000).

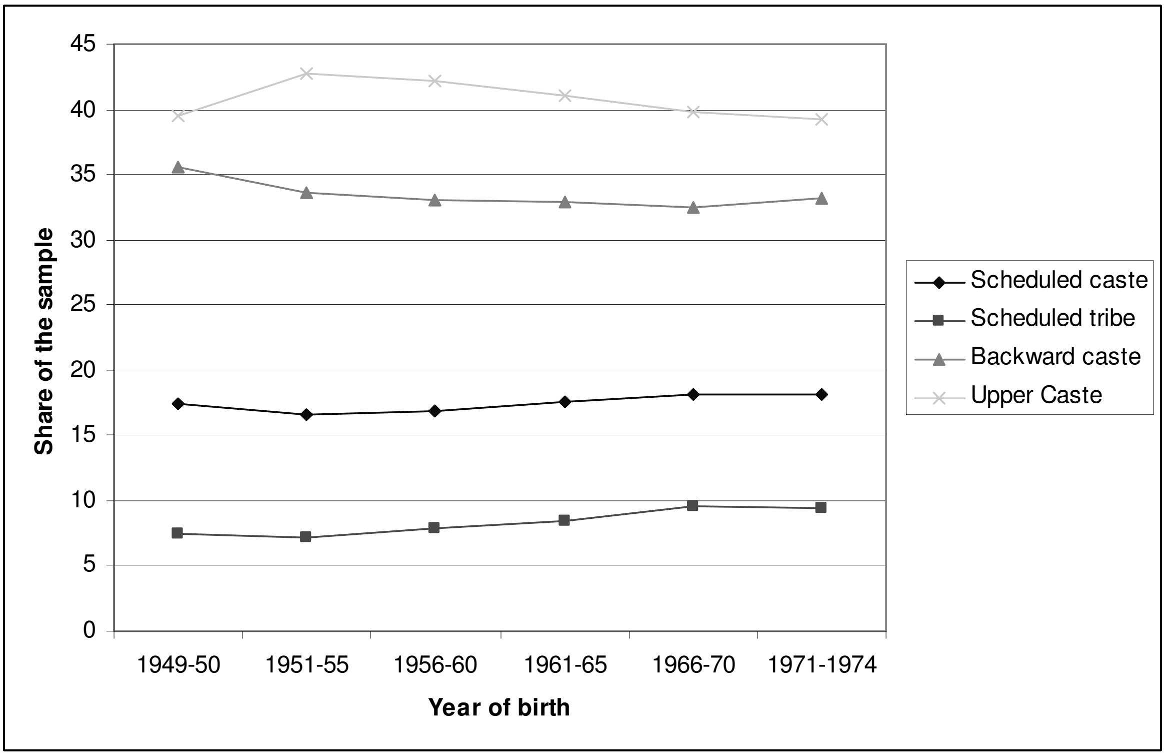

Figure 1: Composition by major castes over time.

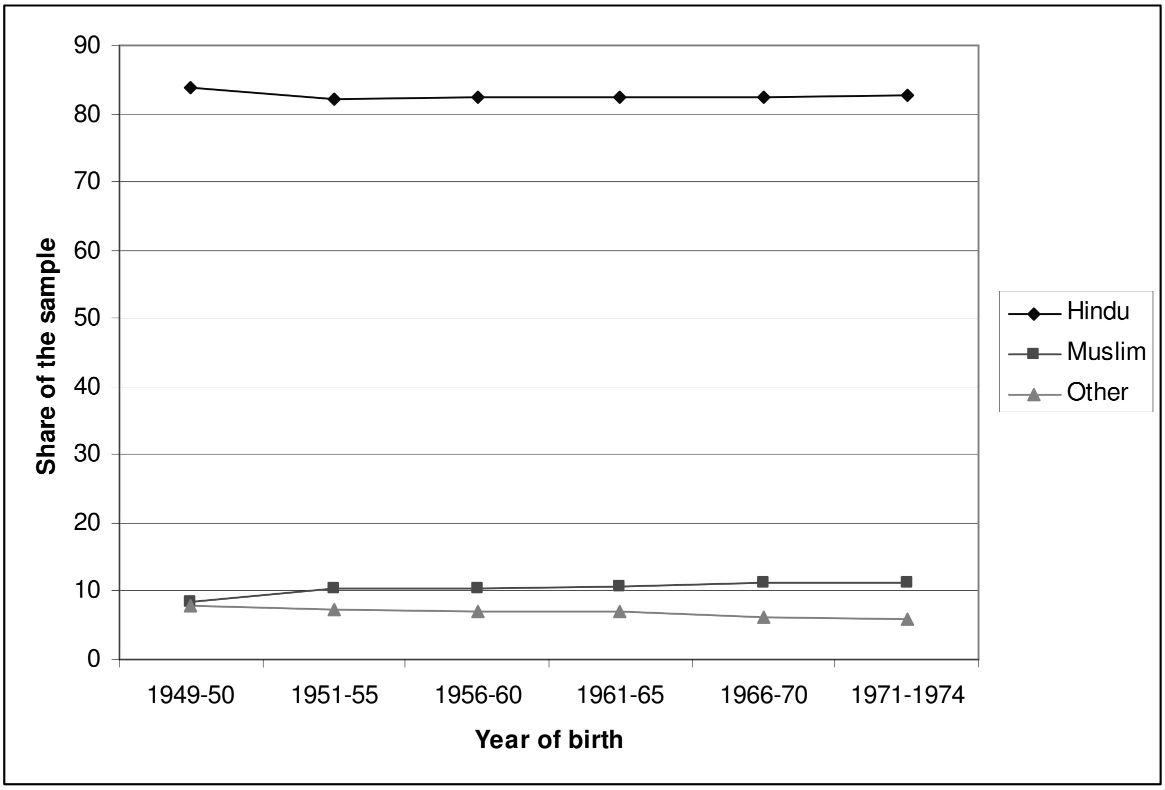

Figure 2: Composition by major religions over time.

Table 2: Composition of the NFHS-2 by age

Age	Frequency	Percent
23-24	5307	8.3
25-29	15321	24.1
30-34	13623	21.4
35-39	12018	18.9
40-44	9811	15.4
45-49	7608	11.9
Total	63688	100.0

The NFHS-2 also provides information about the place of childhood residence which would help us to investigate rural-urban inequality. Other important indicators that were taken from this data base were regions, caste and religion. For studying welfare, individual height data were used whereas for the investigation of inequality, the coefficient of the variation of height was aggregated by state, religion and caste. The data comprise the height data of 60,562 women aged 24 to 45 belonging to all states of India. The dataset used for the regression pertains only to the 14 major Indian states. After removing the extreme height cases (below 100 and above 220 centimeters) the dataset comprises the heights of 51, 678 women representative of the entire Indian population.

Due to insufficient observations, the birth-years 1948 and 1974 were excluded from the data. Out of the total height sample consisting of 60,562 observations representing all Indian states, only 51,678 observations were used for the regression analysis after removing the minor states for which economic data are not available. The heights of women improved steadily from the 1st percentile (138.2 cm) to the 99th

percentile (165.6 cm). Moreover, it is evident that our kurtosis statistics show positive kurtosis (Table 3). The height distribution turns out to have heavy tails and a range from 114 to 199 cm (Figure 3). The major Indian states did not follow a similar distribution pattern in heights. Some states like Madhya Pradesh, Rajasthan, and Gujarat have heavier tails on both sides.

Table 3: Summary statistics showing the distribution of heights in the sample

Percentiles	Height
1	1382
5	1423
10	1443
25	1478
50	1515
75	1554
90	1589
95	1612
99	1656
N	51678
Skewness	0.22
Kurtosis	4.68

3.3.2. Poverty and Growth data

Data for the explanatory variables were taken from Özler et al (1996), "A Database on Poverty and Growth in India." The explanatory variables taken from this dataset are rain, standard deviation in rain, non-agricultural GDP, development expenditures, Gini coefficients for both rural and urban areas, and mean consumption for rural and urban areas, for various states of India. Along with these variables, information about population growth was used to test if states with higher growth rates had decreasing heights. The data are interesting due to the fact that we have rural and urban indicators for inequality and poverty that can be merged with rural and urban biological welfare data.

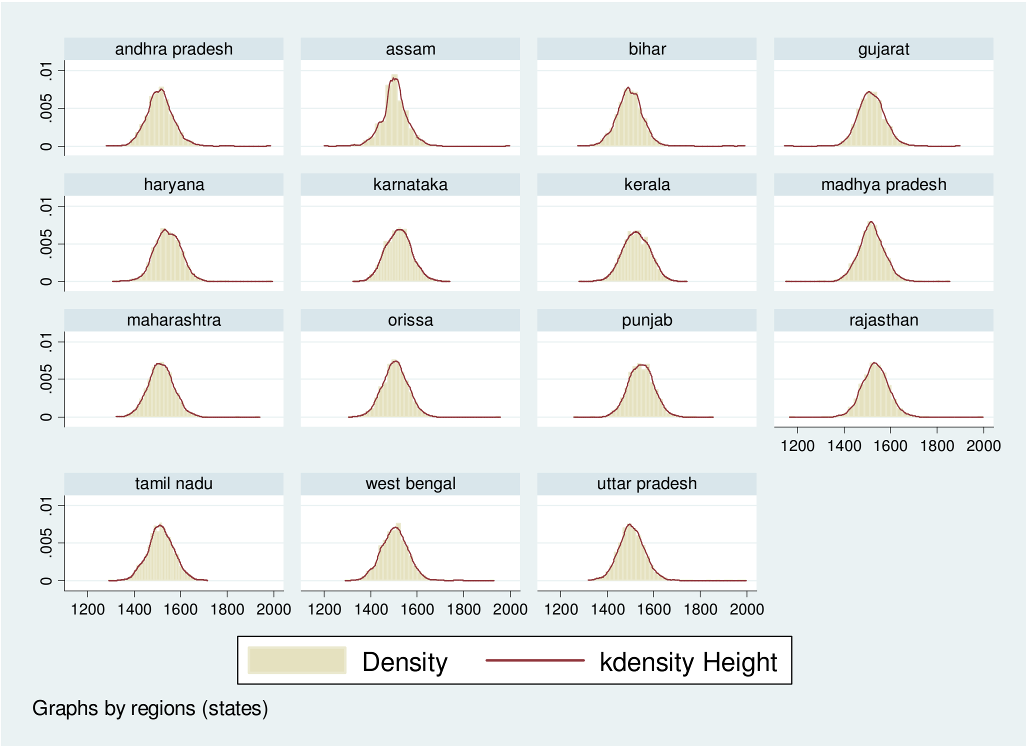

Figure 3: Test of the normal distribution of the sample (by states)

Data for poverty, rain, Gini, NDP (both for the agricultural and non-agricultural sector) and poverty were available only for 15 prime states, though height data were available for all the Indian states. Hence, all models related to height and inequality in height focused on the 14 prime states of India: Andhra Pradesh, Assam, Bihar, Karnataka, Kerala, Gujarat, Madhya Pradesh, Maharashtra, Rajasthan, Orissa, Punjab, Tamil Nadu, Uttar Pradesh, and West Bengal.

Both datasets are merged in such a way that we can study the impact of inequality, consumption and population growth on the biological welfare of individuals. Most of the studies use stature information aggregated for rural and urban areas by state. In this way, we will lose a considerable amount of information, as our dependent variable will be mean height. As our interest is to study the impact of poverty and growth on various sections of the population, it is important to keep the individual height data as they are. For the study of inequality, the coefficient of variation in heights was calculated for different states and five-year cohorts. These height inequality data are later merged with income-based indicators of inequality and poverty. For calculating the CV, height data for any year - by caste or religion - were discarded if the number of observations were less than 30.

3.3.3. Explanatory variables

The Özler database contains detailed statistics on a wide range of poverty and welfare indicators for India. The data are presented separately for the state level and the all-India level from 1950 to 1994. Various sources like the census, the NSS and statistical abstracts were compiled for creating the annual state-level indicators of inequality, consumption, and welfare. Unfortunately, for most variables like development expenditures and rain, data are available only from 1958 onwards.

Population: The population estimates were constructed by Özler et al. using census data from the censuses for 1951, 61, 71 and 81. Between any two successive censuses, the state-sectoral populations are assumed to have grown at a constant (compound) rate of growth, derived from the respective census population totals. We would expect that

Indian population growth had a negative impact on height, as it was argued that population growth can hamper GDP growth and decrease nutritional status (Chandrasekhar, 1968; Sivasubramonian, 2004).

Rodgers (1989) argued that there is little empirical evidence to support the proposition that population growth is a major constraint on the alleviation of poverty. He further argued that population growth is both a cause and a consequence of poverty, and that unraveling the pattern of causation may be an almost hopeless task. Also, Ahlburg (1996) finds no association of population growth with changes in poverty. Using height as a proxy for welfare, we can test the impact of population growth rates with the hypothesis that population growth declines welfare.

Rural real wages: State level data on the annual agricultural real wage for male laborers provided information on wages. Since there is no univariate relationship between changes in the poverty gap index and rural real wages, we obtain additional information on the development of income in rural India. We can check for the impact of wages on rural height using this data. Unfortunately, data on annual urban wages by state were not available.

Rainfall: The monthly average rainfall by state is the simple average of the actual rainfall, where the average is constructed over the four months of the monsoon season (June-September) and over the meteorological sub-divisions in the state. The standard deviation of rainfall is the standard deviation of the monthly rainfall per state over the four months; the monthly rainfall per state is a simple average over the sub-divisions in the state. Moradi and Guntupalli (forthcoming) showed a significantly positive correlation between rainfall and per capita output growth in rice and wheat. Hence, rainfall was used as a good proxy of overall food supply. The standard deviation of rainfall refers to the yearly growth rates, and this was included as an explanatory variable for inequality.

Development expenditures: This state development data includes the expenditure on economic and social services by state governments. Economic services concern agriculture and allied activities, rural development, special area programs, irrigation and flood control, energy, industry and minerals, transport and communications, science, technology and the environment. Social services include education, medical and public health, family welfare, water supply and sanitation, housing, urban development, labor and labor welfare, social security and welfare, nutrition, and relief on account of natural calamities. This indicator will help us to study whether improvements in state expenditures on developmental programs increase heights.

Mean consumption per person:

Using the 21 rounds of the National Sample Survey (NSS), state level mean consumption per person was calculated for rural and urban areas. This helped us in testing the impact of urban consumption on urban heights and rural consumption on rural heights.

NDP per capita in the non-agricultural sector: The real Net Domestic Product (NDP) per capita in the non-agricultural sector was used to see if it had a positive effect on heights. Eswaran and Kotwal (1994) argued that the nature of India's urban-focused industrialization process absorbed little labor from rural areas and hence provided few benefits to poor people from rural areas. Though it was not possible to split this variable into rural and urban, we can still study the differential impact of improvement in non-agricultural sector on rural and urban heights.

Along with the abovementioned variables, data on Gini coefficients measuring income inequality (in percentage), and a headcount index measuring poverty were used. Caste, religion and state variables indicated welfare and inequality by social and geographical structure. Moreover, the significant impact of the 1964-66 bad years was tested using dummy variables for the years 1964, 1965 and 1966.

3.3.4. Caveats of the data

A. Mortality problems of cohort studies

Shorter people had a higher risk of dying at a younger age (Waaler, 1984). Those that survived might have been from a slightly taller selection. Our study period did not have any huge disease outbreaks like the influenza epidemic of 1918 or major famines like the Bengal famine which took millions of lives. As the whole analysis is based on stature data for women, important indicators that could bias our results are maternal mortality and gender discrimination. The regional differences in gender discrimination might create interstate stature differences, as states that discriminated women were likely to have shorter women. By using state dummies, we can control for this to a certain extent. Also, our discussion of survivors by caste and religion did not support the presence of selective mortality (Figure 1 and 2).

B. Environment after infancy

The influence of environmental conditions during the years after infancy and early childhood is also important, especially for short-term deviations from the growth path. However, we rely on the study of Baten (2000B) which found the effect of environmental conditions during the first three years to be so overwhelmingly strong that the later influence on growth has only a very modest impact on final adult height.

C. Place of childhood residence

We could not extract exact information on how long respondents lived in their childhood place of residence. Nevertheless, the variable of childhood place of residence will definitely provide us with better information compared to the current place of residence due to the fact that the current place of residence is affected by (both inter-state and rural-urban) migration.

D. Shrinking of stature

When old-aged people are included in the height sample, differences in mean adult height as observed in cross-sectional studies between groups of women of different ages and birth years reflect not only the effects of a secular trend, but also the effects of shrinking due to aging. As our data comprise adults below 50, we can overlook any impact of shrinking on our data. Moreover, the possible impact of shrinking after age 45 was ruled out when dummies for ages above 45 turned out insignificant.

E. Adolescent growth

We borrowed the findings of Baten (2000B) which showed that the first three years of life are important for determining height. Though our data comprise women aged 15-40, still growing adolescents from age 15-20 were excluded. Late adolescent growth beyond age 20 was tested with regression dummies for all ages above 20. Age 21, 22, and 23 turned out significant and were excluded from the data.

3.3.5. Methodology

The OLS estimator is strongly influenced by outliers due to the fact that large squared residuals are generated. Median regressions can be robust to outliers compared to the OLS. The major difference in the quantile regression compared to the OLS regression is that we use the Least Absolute Deviation approach instead of the Ordinary Least Square approach. For quantiles above the median, higher weight is placed on the residuals above the quantile than on the residuals below the quantile. This pushes the minimization above the median, and for quantiles below the median, less weight is placed on residuals above the quantile. For example, when estimating the 75^{th} percentile, positive residuals have a weight of 1.5 and negative residuals are weighted 0.5. While using quantile regression (QR), we do not restrict ourselves to a particular quantile of the sample but use all observations.

In QR, we assign different weights depending on where an observation lies based on the percentile we estimate unlike OLS regression. For example, when we estimate height in an OLS regression, the underlying assumption is that the included explanatory variables have a uniform effect over the distribution. To study the impact of the explanatory variables on different parts of the distribution of the dependant variable more precisely, quantile regressions (QR) provide powerful insights.

The quantile regression function is written as

$$Q_\theta[\mathbf{y}|\mathbf{X}] = \mathbf{X}\boldsymbol{\beta}_\theta$$

with the data matrix **X** with the dimension n×k, the parameter vector $\boldsymbol{\beta}_\theta$ (k×1), and the dependent variable **y** (n×1), and with n representing the number of observations.

The parameter θ identifies the quantile we are interested in. Another advantage of using quantile regression is the fact that we do not focus on the mean but on different quantiles of the distribution. We obtain additional information by assuming that development expenditures will affect all quantile groups in a different way.

Also, why should we assume that the development of GDP in the non-agricultural sector will improve the living standards of women belonging to lower parts of the height distribution in a similar way compared to the upper parts? It is very likely that very poor women will not benefit from development in the non-agricultural sector. If development in the non-agricultural sector provided additional employment opportunities, it is likely that people with semi-skilled status that belong to the upper parts of the height distribution will benefit. Hence, we estimate the impact of various macroeconomic indicators on various parts of the distribution to get a wider picture of the living standards of various quantiles.

For this reason, we estimate several quantile regressions:

$$Q_{10}[\mathbf{y}|\mathbf{X}] = \mathbf{X}\boldsymbol{\beta}_{10}$$

$$Q_{25}[\mathbf{y}|\mathbf{X}] = \mathbf{X}\boldsymbol{\beta}_{25}$$

$$Q_{50}\left[\mathbf{y}|\mathbf{X}\right] = \mathbf{X\beta}_{50} \text{ Median regression}$$

$$Q_{75}\left[\mathbf{y}|\mathbf{X}\right] = \mathbf{X\beta}_{75}$$

$$Q_{90}\left[\mathbf{y}|\mathbf{X}\right] = \mathbf{X\beta}_{90}$$

The Breusch-Pagan test results confirmed the presence of heteroskedasticity, and to control for heteroskedasticity, standard errors were estimated using the bootstrapping method. The bootstrapping method provides a way to estimate robust standard errors using a re-sampling procedure.

3.4. Levels and trends of welfare

Indian heights grew slightly from 1949-1974 (Figure 4). We see a slight optimistic trend of 0.8 cm (negligible) and interestingly, the stature of Indians reduced when the economy was stagnating in the 1960s. We can conclude that Indian stature was faintly higher compared to the pre-1950 period when height improved by 0.7 cm. But we need to see whether all regions developed in a similar way to get a clear picture of the developments of Indian heights and welfare in this period. In sum, we can say that the overall welfare of Indians did not improve drastically even in the second half of the 20th century.

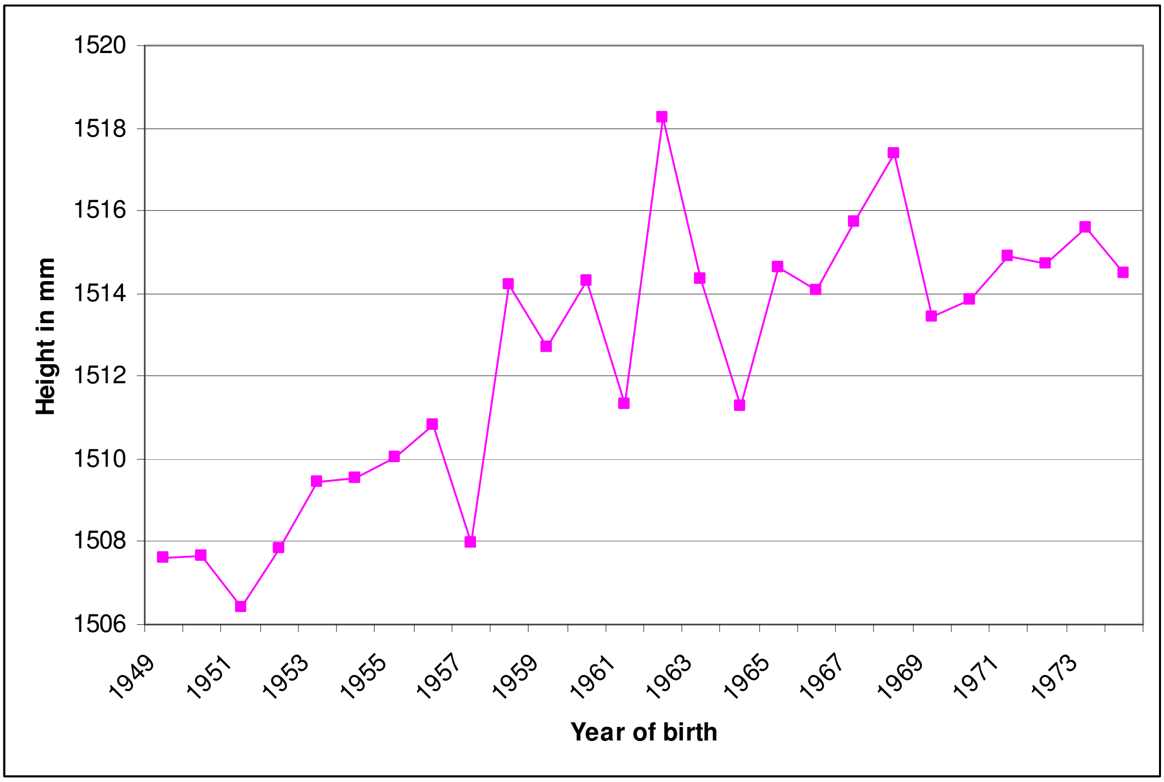

Figure 4: Height in India, 1949-1974

3.4.1. Welfare by regions

The most important feature of Indian regional inequality has not been researched by many researchers except for a few (see Datt and Ravallion, 1998; Sahn, 2003). For instance, the Kerala model shows very clearly that political motivation along with the improvement of education and development expenditure could improve overall welfare and reduce inequality. Kerala moved from having the second-highest incidence of rural poverty around 1960 to having one of the lowest incidences of poverty by the 1990s.

Hence, it is most important to look at regional heights and inequality in heights using the coefficient of variation.

Brennan et al. (1995) found important interstate differences in height mostly for the 19th century and early 20th century using height data. For the second part of the 20th century, the regional diversity of India is evident from the height levels and trends. Based on Figure 5, it is evident that the states of Punjab and Haryana had taller mean heights than the Indian average and that in these regions, agricultural productivity and protein supply are better compared to other states of India. In general, the Northern states have taller women compared to the mean Indian value. Delhi, Haryana, Himachal Pradesh, Jammu and Kashmir, Punjab and Rajasthan show better heights based on the aggregated data in Figure 2. Northeastern and Eastern states (Tripura, Sikkim, Meghalaya, Assam, Orissa, West Bengal and Bihar) perform much worse.

Nevertheless, it is worth studying how heights developed in these 25 years by regions. To make comparisons simple, all 24 states in the sample were classified into 6 regions based on geographical and cultural clustering.

North India: Delhi, Haryana, Himachal Pradesh, Jammu and Kashmir, Punjab, Rajasthan

Central India: Madhya Pradesh

East India: Bihar, Orissa, West Bengal

West India: Goa, Gujarat, Maharashtra

South India: Andhra Pradesh, Tamil Nadu, Kerala, Karnataka

Northeast India: Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim

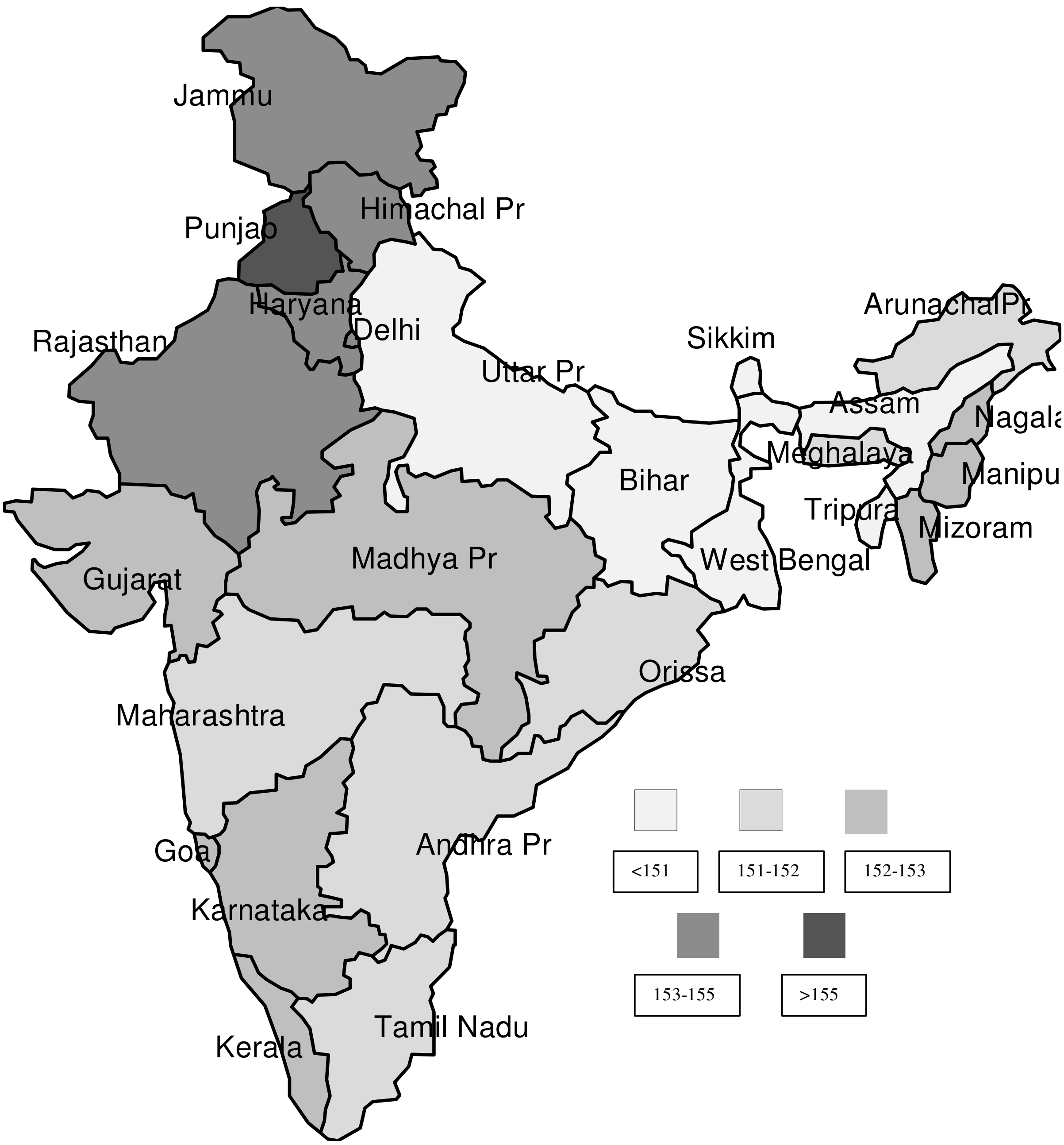

Figure 5: Stature of Indians form various states of India (in centimeters)

Source: NFHS-2

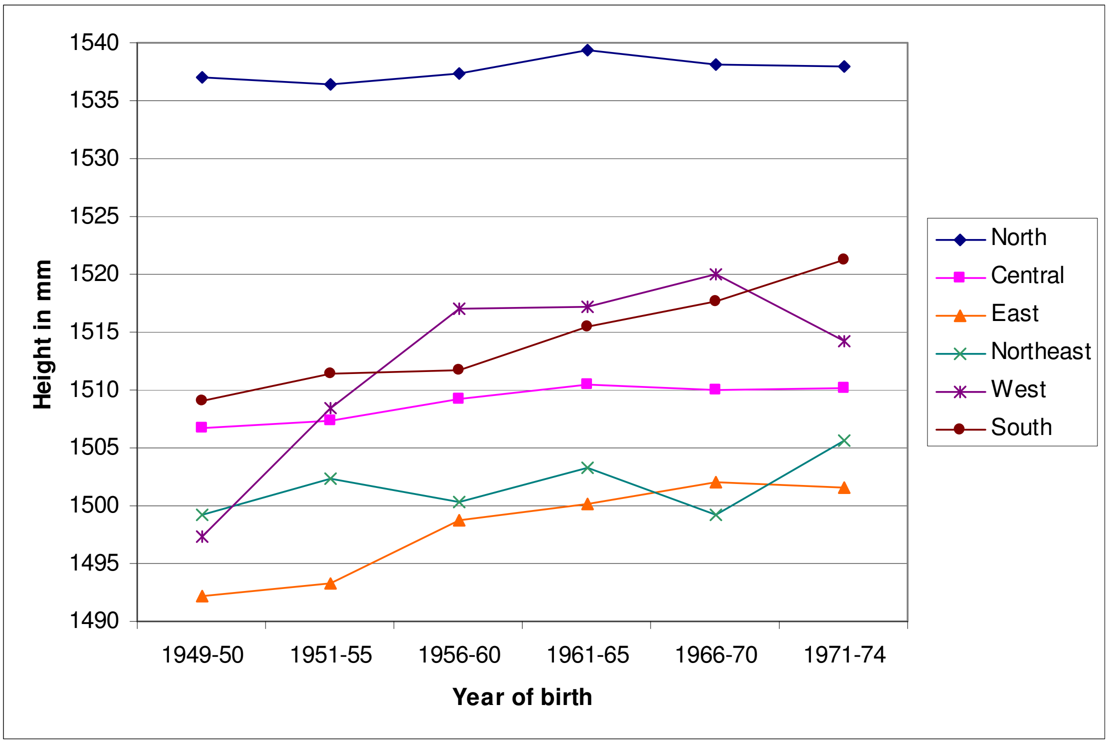

Figure 6: Height in India by region, 1949-1974

Trends in state heights gave us a slight different picture regarding interstate differences in welfare. By looking at Figure 6, it is evident that the heights of Western and Southern Indians improved compared to the Northern, Northeastern and Central states. Eastern states showed a moderate increase compared to the Northern and Central states. The 1974 famine in Maharashtra and the 1973 oil crisis seem to have affected stature in the financial Western regions (Mumbai) more compared to other states. Compared to the pre-independent period, Western heights showed a positive trend whereas Eastern heights ranked lowest as in the 1915-44 years.

3.4.2. Rural-urban disparity in welfare

Several studies have emphasized and reemphasized the rural-urban divide in living standards. These studies suggest that more children from rural areas suffer from malnutrition compared to urban areas (Lipton, 1977; Duncan and Howell 1992). The information available regarding the childhood place of residence can be used to study the Indian rural-urban divide in welfare from 1949-74. It is evident from Figure 7 that rural and urban heights are substantially different, and we see increasing divergence from the 1960s onwards, especially when the Indian economy experienced various droughts, conflicts and the debated structural break in the growth of the economy.

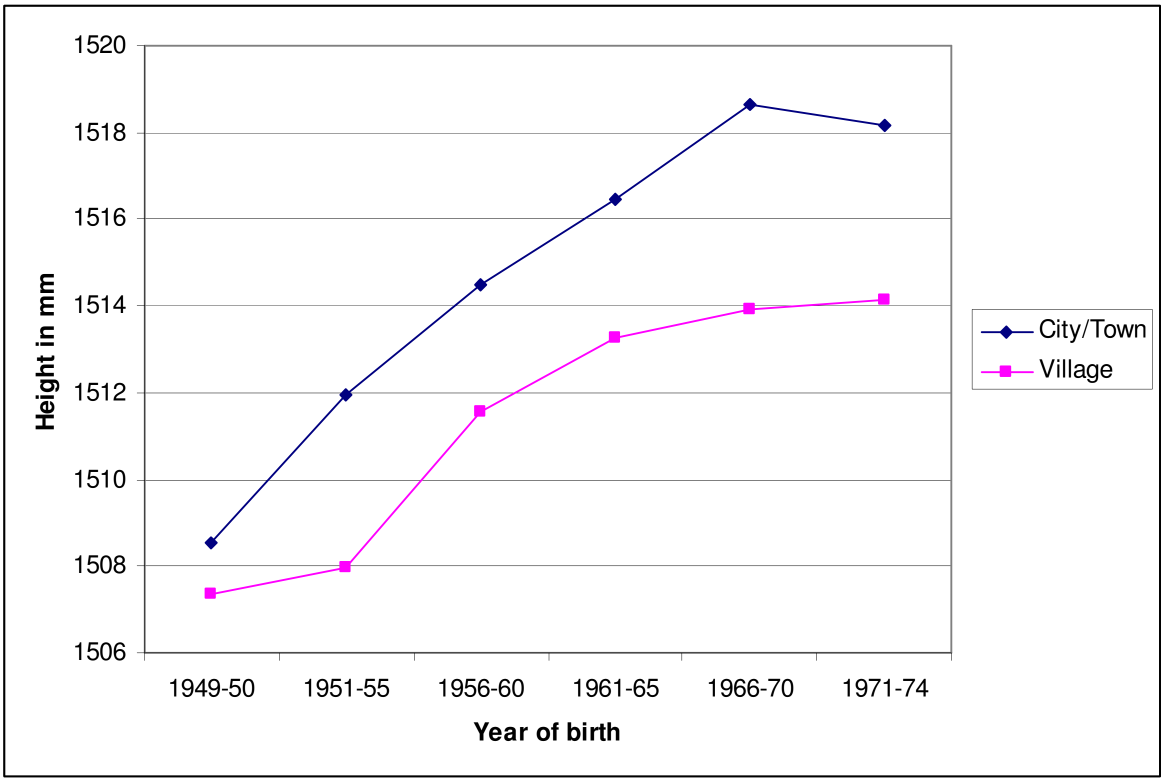

Figure 7: Height in India by rural-urban childhood residence, 1949-1974

However, the convergence of heights did not occur in the 1970s, either, pointing to the fact that perhaps, Indian five-year planning focused more on urban areas for infrastructure and medical facilities compared to rural areas, which improved the former group's biological welfare. Moreover, we cannot overlook the fact that the fertility increase in rural areas was generally higher compared to urban areas in this period, pointing to the possibility of a rural-urban differential created by population pressure.

3.4.3. Welfare by standard of living

The NFHS-2 provided the current standard of living which is a composite index[10] by taking into consideration amenities in the household. We can presume that there

[10] The SLI summary measure is calculated by adding the following scores for each household:

- House type: 4 for pucca, 2 for semi-pucca, and 0 for kachha; (see definition below)
- Toilet facility: 4 for own flush, 2 for public or shared flush toilet or own pit toilet, 1 for shared or public pit toilet, 0 for no facility;
- Source of lighting: 2 for electricity, 1 for kerosene, gas, or oil, 0 for other source of lighting;
- Main fuel for cooking: 2 for electricity, liquid petroleum gas, or biogas, 1 for coal, charcoal, or kerosene, 0 for other fuel;
- Source of drinking water: 2 for pipe, hand pump, or well in residence/yard/plot, 1 for public tap, hand pump, or well, 0 for other water source;
- Separate room for cooking: 1 for yes, 0 for no;
- Ownership of house: 2 for yes, 0 for no;
- Ownership of agricultural land: 4 for 5.0 acres or more, 3 for 2.0-4.9 acres, 2 for less than 2.0 acres or acreage not known, 0 for no agricultural land;
- Ownership of irrigated land: 2 if household owns at least some irrigated land, 0 for no irrigated land;
- Ownership of live stock: 2 if owns live stock, 0 if does not own live stock;
- Ownership of durable goods: 4 each for a car or tractor, 3 each for a moped/scooter/motorcycle, telephone, refrigerator, or color television, 2 each for a bicycle, electric fan, radio/transistor, sewing machine, black and white television, water pump, bullock cart, or thresher, 1 each for a mattress, pressure cooker, chair, cot/bed, table, or clock/watch.

Index score ranges from 0-14 for a low SLI to 15-24 for a medium SLI and 25-66 for a high SLI.

[10] Pucca House: a pucca house is one which has walls and a roof made of the following material:
Wall material: burnt bricks, stones (packed with lime or cement), cement concrete, timber, ekra, etc.
Roof Material: tiles, GCI (Galvanised Corrugated Iron) sheets, asbestos cement sheet, RBC (Reinforced Brick Concrete), RCC (Reinforced Cement Concrete) and timber etc.
Kutcha House: the walls and/or roof are made of material other than those mentioned above, such as un-burnt bricks, bamboos, mud, grass, reeds, thatch, loosely packed stones, etc.
Semi -Pucca house: a house that has fixed walls made up of pucca material, but whose roof is made up of material different from than those used for pucca houses.

cannot be high mobility among these class groups except for a few medium SLI moving to the high SLI category. Yet, the SLI variable was not used as a determinant of the biological standard of living due to the unavailability of other living standard data by different categories. Nevertheless, it was used to observe the relation between the economic standard of living and the biological standard of living.

It is evident from Figure 8 that women having a higher standard of living are taller compared to women with a lower standard of living. At the same time, inequality in terms of mean height difference using SLI ranges between one and three centimeters is not so high compared to other countries, as discussed earlier in chapter 2.

3.4.4. Muslim welfare in India compared to Hindus

The 130 million Muslims in India form the second-largest Muslim population in the world after Indonesia. Unfortunately, limited data are available on the welfare of the Muslim population from 1950 onwards. Hindu-Muslim conflicts and fertility differentials attracted most research interest. This part of the chapter focuses on the heights of Muslims in various parts of India. Important questions are addressed such as: what were the conditions of Indian Muslims immediately after independence? How did the stature of Muslims change from 1950 to 1974? Did the stature of Muslims differ from other religions like Sikhs and Jains? How did within-Muslim inequality compare to Hindus in this period?

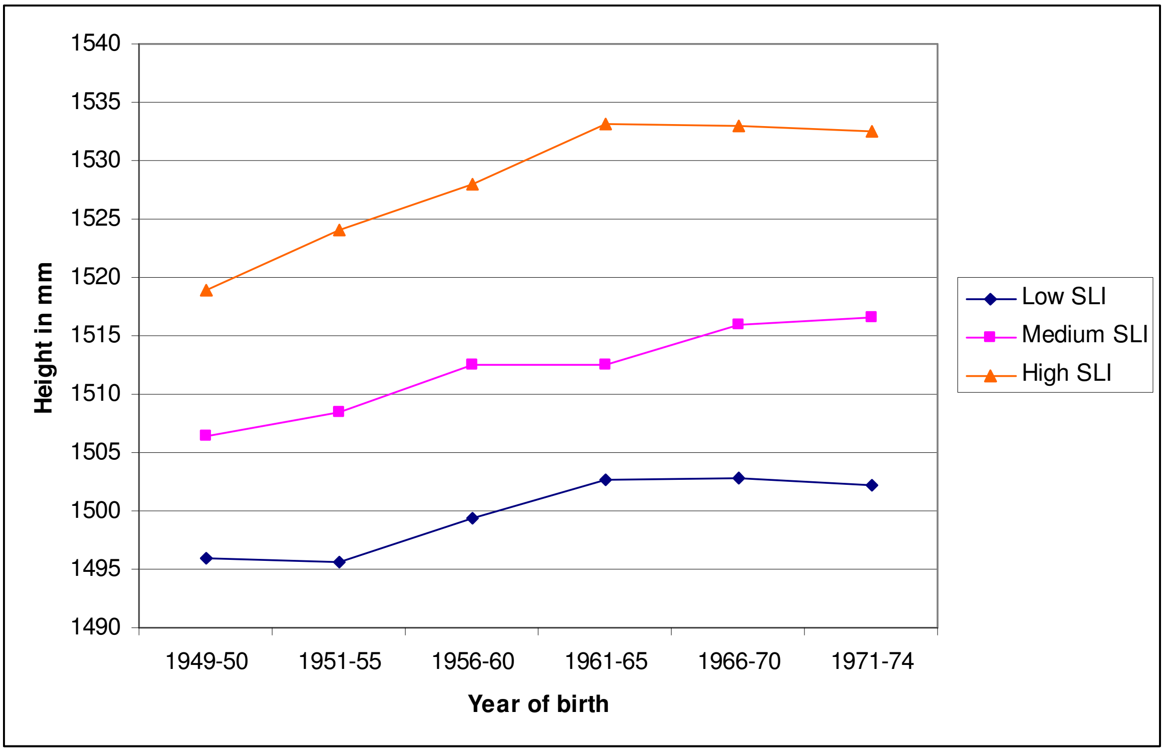

Figure 8: Height in India by standard of living, 1949-1974

Based on Figure 9, we can observe that the stature of Muslims is on par with the welfare of Hindus in general. We neither observe any huge variation in the welfare of Muslims compared to other religions, nor any divergence between Hindus and Muslims. Most of the Sikh men were residing in Punjab and Haryana where agricultural productivity and protein supply was high. Jains were mostly in trade occupations that yielded high incomes, which was reflected in their height. In addition, the religious groups of the Sikhs and Jains had a relatively egalitarian society with no caste hierarchy.

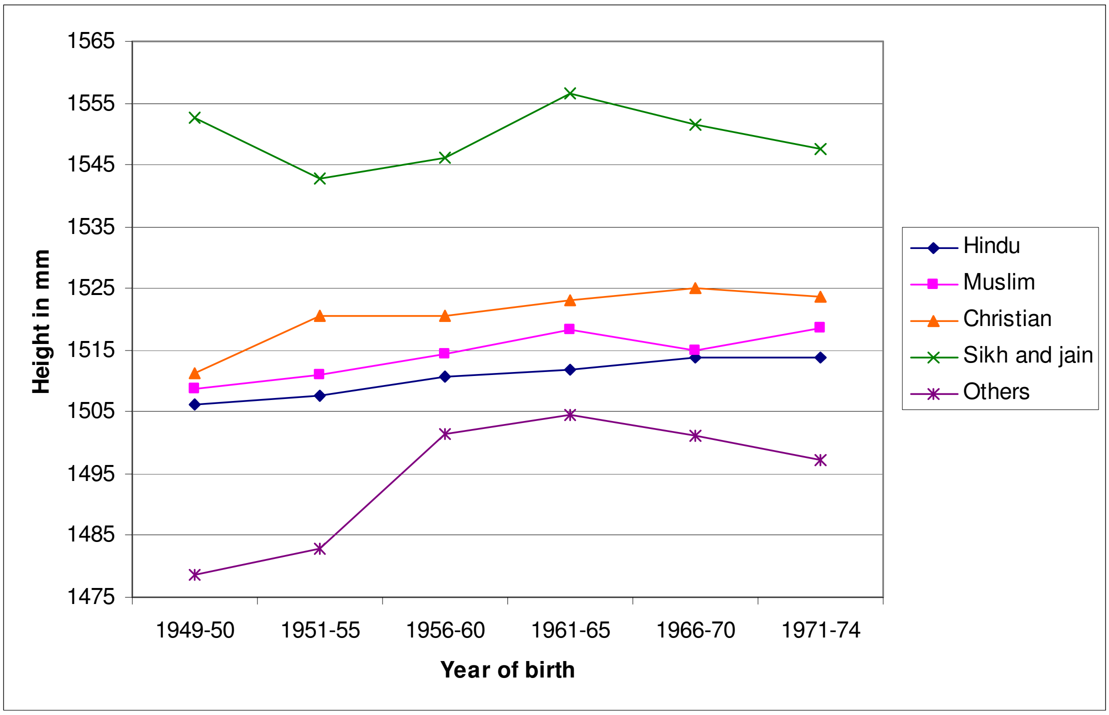

Figure 9: Height in India by religion, 1949-1974

3.4.5. Welfare by caste

The Indian caste system is a peculiar system that has been in use for several centuries, and it still plays an important role in contemporary Indian welfare, inequality, and the political system. The caste system[11] is an endogamous system where every person is born into a caste and married within the same caste. There are four different major levels of the system: upper castes and dominant castes, backward castes, scheduled castes and scheduled tribes. Within each of these categories are the actual "castes," within which people are born, get married, and die. The Hindu caste system is hierarchical and is

[11] The existence of a unique caste system and its functions were discussed in the second chapter of this thesis.

organized as displayed in Figure 10, with the upper and dominant castes having a generally higher social and economic status, and more political power compared to the other three categories below.

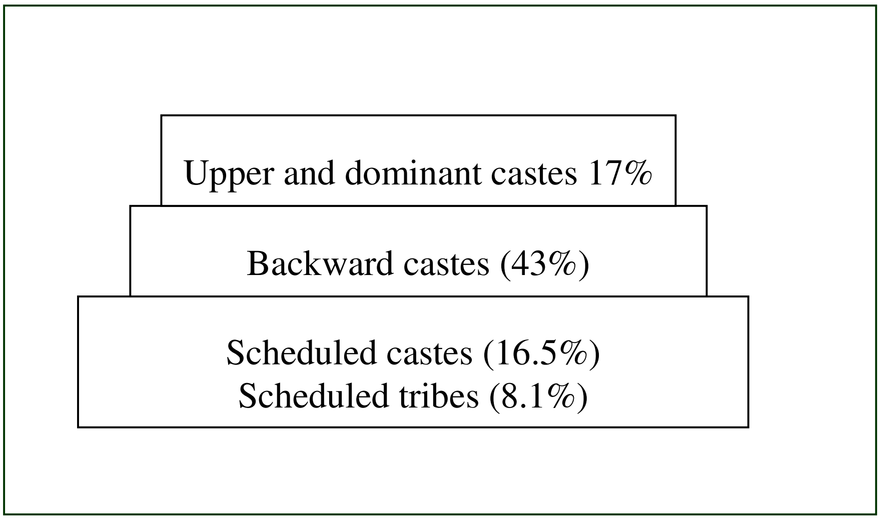

Figure 10: Top to bottom view of the caste hierarchy among Hindus in India along with their distribution during 1980 and 1990.[12]

Source: Varshney (2000)

The majority of the population belongs to the scheduled castes, tribes and other backward castes, and less than 20 percent of the population belongs to the upper caste Hindu population (Figure 10). Caste played an important role especially until the mid 20th century by deciding about occupations and income. Since independence, the Indian caste system has been paid much attention and some states have tried to reduce the disparity between castes by the introduction of policies. For instance, Kerala started major policies

[12] This distribution pertains only to Hindus, other religions are excluded.

in terms of land distribution and compulsory education especially after the communist party's first democratic victory in 1957.

However, the most important question is whether welfare differed between various groups? Was the abovementioned slight upward trend shared by all caste groups? Brennan, McDonald and Shlomowitz (2002) argue that height differentials between major castes increased after the mid-1930s. Intercaste differences in stature were also observed in all their studies for the early 20th century (Brennan et al., 1995, 1997, 2000, 2003). We can test if height differentials between major states, castes and religious groups were increasing in the period under study.

From Figure 11, we can clearly observe that stature was higher among women belonging to the upper caste compared to any other group. We can also observe a divergence in the stature of the schedule castes and upper castes, with the height gap between these two caste groups being the highest (ranging from 1 to 2 cm). Also, the same divergence pattern is found when we compare scheduled castes and middle castes. The scheduled castes and middle castes had similar levels and trends in height in 1950, and the gap between their mean heights increased by nearly 1.2 cm until 1974. In consequence, we can support the findings of Brennan et al. about caste inequality even in the second half of the 20th century. What could explain this increasing gap between castes? It might be due to the fact that the middle castes benefited more from the economic growth, especially in the non-agricultural sector, whereas the scheduled castes received hardly any benefit as is evident from their stagnating heights.[13] In sum, higher

[13] Intercaste and interreligious marriage cannot explain the height gap between the scheduled caste and other groups, as there was hardly any intercaste and interreligious marriage in this period.

caste people, who were taller, had better access to food, health and education compared to the lower castes among Hindus, and over time, middle caste women benefited more.

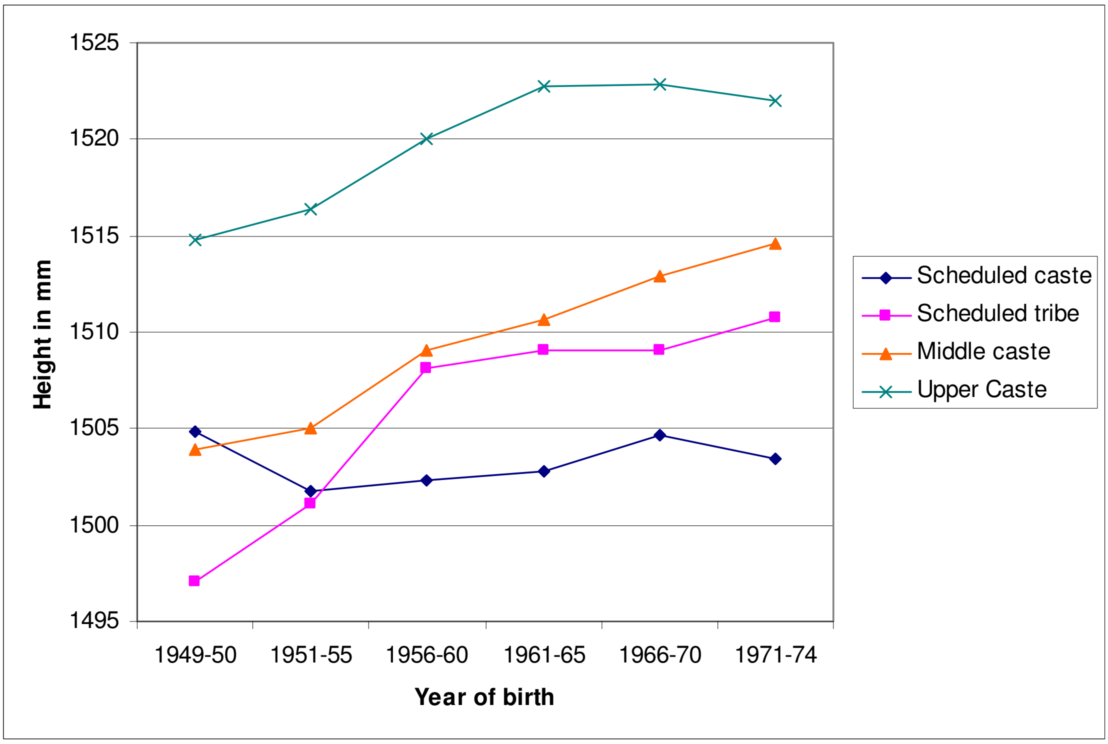

Figure 11: Height in India by caste, 1949-1974

When comparing the caste and religious welfare in the post-1950 period to the 1915-1944 pre-independent India (chapter 2), we find interesting similarities. In the pre-independent period, scheduled tribes were shortest, a development which continued in the post-independence period until 1955. From 1955 onwards, the scheduled castes were the shortest. Also, the gap between the middle castes and the scheduled castes increased in the post-independence period. Among different religious groups, Sikhs (along with Jains) were the tallest in both the pre-independence and the post-independence period. Also, the trend of declining heights among Sikhs in the pre-independence period continued until 1950.

3.4.6. Inequality in India

As discussed earlier, inequality was measured using the coefficient of variation in height. Within India, inequality was declining at a very slow pace in 1949-74 (Figure 12). Inequality was lowest during 1955-63 and increased in the bad years which began in 1964. Also, we find that inequality was less volatile in the last years of the study.

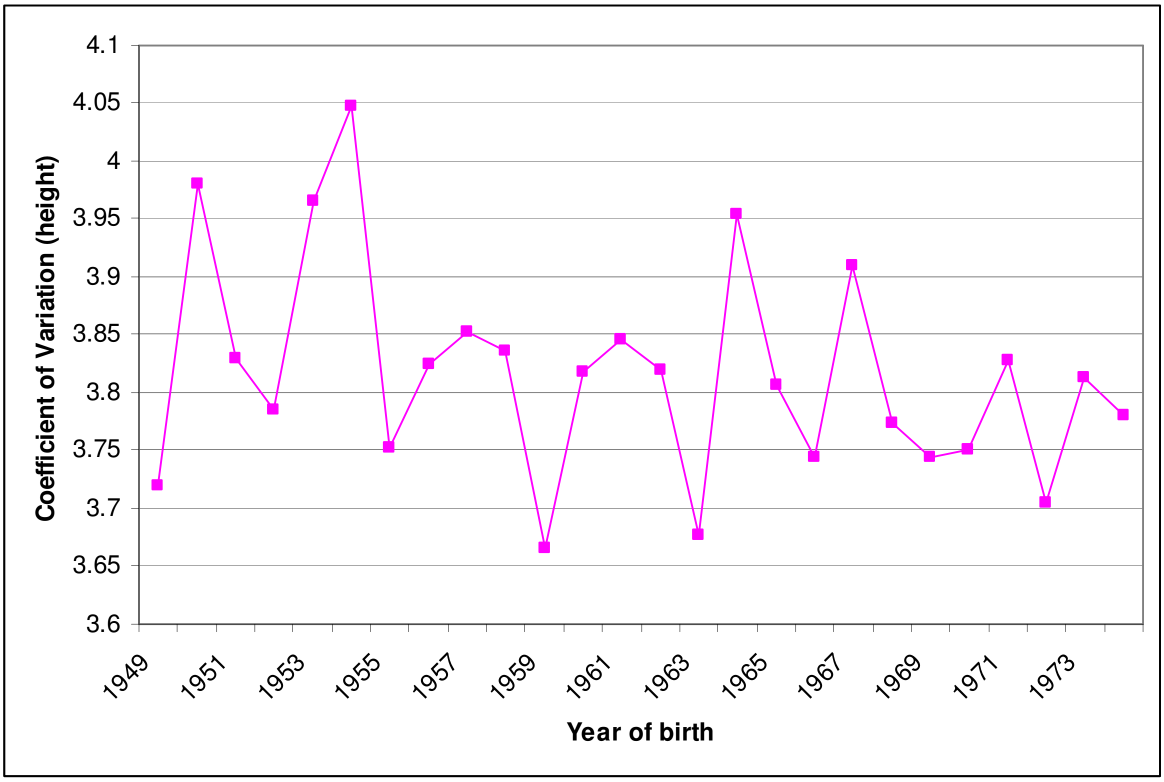

Figure 12: Coefficient of variation of height in India as a measure of inequality, 1949-1974

It is also interesting to study inequality within rural and urban areas. For this purpose, coefficients of variation in heights for rural and urban areas are constructed separately. The results on within-rural and urban inequality obtained by using the coefficient of variation in heights of rural and urban areas yield interesting insights (Figure 13). Inequality within rural areas showed a continuous reduction, whereas inequality in urban areas increased little during 1949-74. What could explain this development? It is evident from Figure 5 that women from urban areas benefited more from the growth of the economy compared to rural areas. Perhaps, these urban benefits were not equally distributed to all groups living in the urban areas, this being reflected in the higher within-urban inequality compared to rural areas.

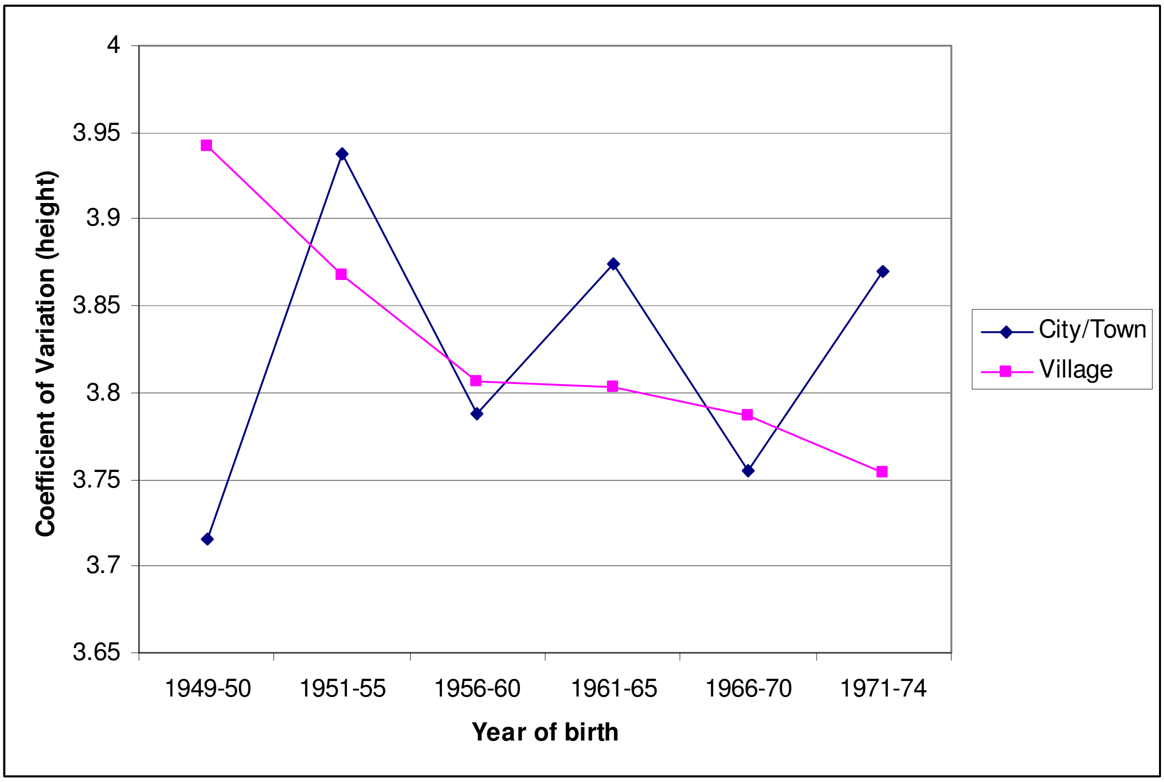

Figure 13: Coefficient of variation of height in rural and urban areas as a measure of inequality, 1949-1974

3.5. Determinants of welfare

Interestingly, the major determinants of welfare affected various parts of the height distribution in a different way. As India had a high rural and urban disparity, three different quantile regressions were performed for rural, urban and India for 10, 25, 50, 75, and 90 quantiles, respectively. The determinants of Indian heights in rural, urban and overall India showed interesting results.[14] Simultaneous quantile regression was used to run regressions for different quantiles at the same time.

3.5.1. Determinants of rural welfare

The first part of the analysis comprises the determinants of rural welfare like population, rain, development expenditures, the Gini coefficient for rural areas, rural real wages, rural mean consumption per day in rupees (real) controlling for the bad period 1964-66, caste, religion and states, using dummies. The second part of the analysis comprises the determinants of urban stature like population, rain, development expenditures, the Gini coefficient for urban areas and mean consumption per day in rupees (urban) controlling for the bad period 1964-66, caste, religion and states, using dummies. The third and final part focuses on the determinants of overall stature using the same set of variables discussed above except for rural real wages and the Gini coefficient, as this indicator focuses on rural areas.

Population growth did not affect the height of women in all parts of the height distribution (Table 4). Interestingly, development expenditures seem to improve the

[14] To control for heteroscedasticity, standard errors were estimated using the bootstrapping method.

heights of people belonging to the lowest quintile. Two variables that were significant in all quantiles are upper caste and other religion (religion other than Hindu and Muslim).

Table 4 Determinants of rural welfare in India from 1950-75

	Q10	**Q25**	**Q50**	**Q75**	**Q90**
Population Growth	-176.08	-199.60	-70.62	-206.75	-248.36
Rain	-2.5	-0.53	0.27	0.95	1.27
Development expenditure share in GDP	4.97	3.30*	1.24	3.41	3.98
Real NDP per capita in the non-agricultural sector	4.15	6.63	13.65**	16.02**	14.55*
Gini coefficient	2.42	5.02	3.67	8.93	6.58
Real wage	4.33	2.08	1.44	-2.03	-7.76
Mean consumption	3.83	-6.07	-4.11	-6.79	-6.05
Caste					
Other castes (reference)					
Upper caste	10.04**	11.00**	13.0**	13.30**	13.66**
Religion					
Hindu (reference)					
Muslim	-3.04	-2.88*	-2.0	-0.44	1.11
Other Religion	7.0**	6.54**	9.70**	8.99**	9.56**
Year 64-66	-1.91	-1.85	-1.4	-1.59	0.06
States					
Andhra Pradesh (reference)					
Assam	-10.94*	-1.19	-11.50*	-16.79**	-17.01*
Bihar	-8.01*	-8.94**	-9.2**	-10.77**	-15.25**
Gujarat	7.09	4.41	0.38	3.43	4.11
Karnataka	8.20*	7.51**	8.49*	8.42*	5.43
Kerala	13.18*	13.77**	15.65**	18.27**	15.15**
Madhya Pradesh	10.26*	12.45**	11.79**	11.25**	9.22*
Maharashtra	2.69	-1.73	-5.3	-9.19*	-12.33*
Orissa	-4.07	-1.91	1.77	2.81	-1.74
Punjab	26.41**	26.69**	23.32**	24.35**	23.05**
Rajasthan	22.24**	22.05**	23.85**	24.58**	24.19**
Tamil Nadu	0.48	3.97	4.35	3.74	-0.01
Uttar Pradesh	-4.62	-5.31**	-4.58*	-4.14	-7.71*
West Bengal	-10.35	-18.63	-19.26**	-18.78**	-23.83**
Constant	1434.3**	1492.1**	1522.9**	1559.5**	1606.0**
Number of observations	27256	27256	27256	27256	27256

*/** denotes significance to the 5%/1% confidence level.

Women belonging to the upper castes were taller compared to women from other castes, which support the assumption that the caste system is one of the major determinants of welfare in India. Also, the impact of the caste variable increased continuously when moved from the lower to the upper quantiles. The study of the correlation between religion and welfare in India was also addressed in an efficient way by this quantile regression, as it showed that more religious inequality existed in the 25^{th} percentile of the distribution compared to the upper half. Muslims were shorter compared to Hindus in the 25^{th} percentile, pointing towards an unequal biological welfare of Hindus and Muslims in rural India (for the 10^{th} percentile, the significant level is 10 %). Compared to Hindus and Muslims, the height of women belonging to other religions was better in all parts of the distribution, reflecting the possible impact of protein proximity. In general, people from the Sikh and Jain religions consume more milk and milk products compared to Hindus and Muslims.

Improvement in the per capita Net Domestic Product of the non-agricultural sector improved the stature of women from the 50^{th} percentile of the distribution significantly, and this significance persists in the whole upper part of the distribution. Real wages did not affect the height of women in this period. The most important finding in this context is the positive effect of development expenditure on the heights of women in the 25^{th} percentile. Heights and Gini coefficients in the upper quantiles of the distribution showed a significant impact only at the 10 % significant level. This clearly shows that income inequality - measured by Gini coefficient - is beneficial for women belonging to the upper parts of the height distribution in terms of an improvement of stature.

The debate on how the 1964-66 economic and drought shock affected welfare was answered by the inclusion of dummies for the years 1964-66. We found that the bad period 1964-66 was not accompanied by a negative influence on heights.[15] The state dummies for various quantiles demonstrate which states did better in improving the living standards of nutritionally “relatively” poor people. Thus, the state dummies provided us with a very interesting picture of rural interstate differences for the period after 1950. Punjab and Rajasthan did well in terms of the biological living standard of people belonging to the relatively poor rural quantiles. Also, Kerala and Karnataka had a better biological standard of living compared to Andhra Pradesh. The states that performed poorly in all quantiles were Assam, Bihar and Uttar Pradesh. West Bengal was not worse off until the 25th percentile, whereas it showed a decline in heights compared to Andhra Pradesh in all the upper quantiles. In sum, we can also conclude that interstate height differences are similar to interstate poverty differences. (Ravallion and Datt, 1995). This is especially true in the case of Punjab, Assam, Bihar, UP, and Kerala.

A quick comparison of OLS and quantile coefficients would shed light on the benefits of quantile regression. For this purpose, we compare the coefficient of the higher caste variable. It is evident from Figure 14 that belonging to the upper caste is better in the upper quantiles compared to the lower quantiles and OLS coefficient. Also, it is clear that OLS provides limited information about differences in the effect of caste on height of various groups.

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[15] Heights declined during the 1964-66 bad years at 10 % significant level for women belonging to 0.25 and 0.1 quantile.

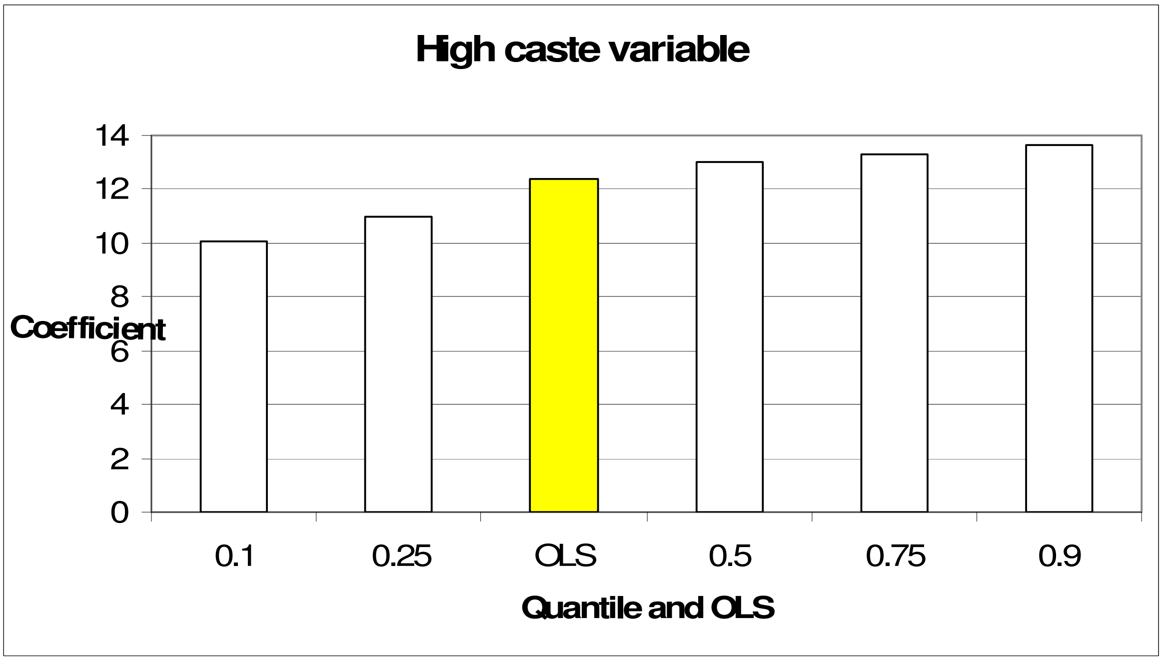

Figure 14: Comparison of coefficients using quantile regression and OLS regression.

3.5.2. Determinants of urban welfare

Urban determinants differed considerably from rural ones (Table 5). Most explanatory variables turned out to have had no impact on urban heights. Caste once again emerged as one of the most important variables, as women from the upper castes enjoyed relatively better stature compared to women from other castes in all parts of the distribution. Compared to Hindus and Muslims, women from other religions enjoyed a relatively high biological standard of living in most parts of the distribution.

None of the determinants of development expenditure, Net Domestic Product in the non-agricultural sector, urban inequality (Gini), monsoon rain, and population growth showed any impact, irrespective of the quantile. State differences in heights emerged less clearly in the urban heights model compared to model of rural heights. Kerala and Madhya Pradesh had taller urban heights only in the 75th percentile compared to Andhra Pradesh. Punjab and Rajasthan showed higher biological welfare over most of the distribution except for the 10th percentile. Beyond the 50th percentile, it turned out that Tamil Nadu had a higher urban biological living standard compared to Andhra Pradesh.

Table 5 Determinants of urban welfare in India from 1950-75

	Q10	**Q25**	**Q50**	**Q75**	**Q90**
Population	-559.60	-237.96	434.67	197.98	1107.34
Rain	6.05	1.18	-1.18	-2.45	0.91
Development expenditure	7.62	6.23	5.20	1.03	4.30
Real NDP per capita in the non-agricultural sector	14.53	5.98	-11.67*	-3.58	-16.18
Gini coefficient	-4.53	-14.22	-6.85	-5.85	2.76
Caste					
Other castes (reference)					
Upper caste	13.32**	12.97**	12.03**	11.24**	19.67**
Religion					
Hindu (reference)					
Muslim	-0.84	1.92	4.22	2.15	-0.32
Other Religion	8.45	6.42**	9.22*	11.47**	13.00**
Year	3.64	1.13	-0.64	-1.96	-4.77**
States					
Andhra Pradesh (reference)					
Assam	-3.74	-2.48	-9.75	-9.05	-23.71
Bihar	-7.68	-8.51	-6.98	-2.59	-12.75
Gujarat	6.85	2.03	11.41*	9.13	6.79
Karnataka	0.75	-2.49	7.49	11.45	10.49
Kerala	-7.26	0.92	5.23	21.75*	9.84
Madhya Pradesh	13.13	10.58	4.81	12.73*	2.38
Maharashtra	-10.12	-4.25	8.57	9.64	8.77
Orissa	-6.18	-10.78	-4.41	5.03	-8.86

Punjab	18.04	14.37**	24.59**	25.60**	19.92*
Rajasthan	16.2	12.37**	12.20*	21.06**	14.15
Tamil Nadu	4.01	4.27	10.74*	12.28*	22.74*
Uttar Pradesh	-4.90	-7.48	-9.26	-6.32	-8.39
West Bengal	-14.42	-11.88	2.34	5.61	5.46
Constant	1449.99	1530.06	1521.93	1566.85	1523.6
Number of observations	8621	8621	8621	8621	8621

*/** denotes significance to the 5%/1% confidence level.

3.5.3. Determinants of overall welfare

In the previous models, rural and urban stature was determined separately. The current part focuses on overall heights by looking at economic, demographic and social determinants (Table 6). State differences showed a more or less similar picture as model 1 (Table 4) where we estimated rural welfare. The upper castes enjoyed better welfare compared to the lower castes, whereas women from other religions had a better nutritional status compared to Hindus in all parts of the distribution.

Table 6: Determinants of overall welfare in India from 1950-75

	Q10	**Q25**	**Q50**	**Q75**	**Q90**
Population	-225.56	-215.61	-26.54	-147.91	-181.23
Rain	0.29	-0.04	-0.23	-0.21	0.73
Development expenditure	5.41*	3.57*	2.55	2.66	3.31
Real NDP per capita in the non-agricultural sector	7.97	7.42	9.90*	9.11*	8.04
Mean consumption	2.49	-2.88	-1.79	-4.66	-9.73
Caste					
Other castes (reference)					
Upper caste	10.84**	11.83**	12.63**	12.86**	14.39**
Religion					
Hindu (reference)					
Muslim	-2.04	-1.47	-0.90	0.25	-0.32
Other Religion	8.1**	6.38**	9.90**	10.42**	11.77**
Year	-1.04	-0.97	-0.66	-1.41	-0.32

States					
Andhra Pradesh (refer)					
Assam	-12.17	-2.39	-10.88**	-16.36**	-19.58**
Bihar	-9.94*	-9.06**	-9.49**	-10.46**	-15.06**
Gujarat	5.82	3.91	2.86	5.77*	5.59
Karnataka	5.02	4.86	8.09**	9.60**	7.02*
Kerala	8.54*	11.44**	14.69**	19.89**	13.41*
Madhya Pradesh	9.68*	11.69**	10.88**	12.17**	10.09**
Maharashtra	-3.18	-3.52	-3.63	-2.01	-5.69
Orissa	-4.75	-2.63	0.07	1.69	-3.55
Punjab	24.96**	23.51**	22.32**	22.78**	19.70**
Rajasthan	21.92**	21.74**	22.64**	25.17**	24.70**
Tamil Nadu	0.70	4.01	4.24	6.84**	4.69
Uttar Pradesh	-5.83*	-6.71**	-5.60**	-5.48**	-8.64**
West Bengal	-12.91**	-15.65**	-14.02**	-12.58**	-15.83**
Constant	1439.1**	1496.53**	1528.66**	1578.30**	1631.21**
Number of observations	37494	37494	37494	37494	37494

*/** denotes significance to the 5%/1% confidence level.

Development expenditure improved the heights of women belonging to the 10th and 25th percentile, whereas Real Net Domestic Product per capita in the non-agricultural sector improved the heights of women belonging to the 50th and 75th percentile. Uttar Pradesh, West Bengal, Assam and Bihar turned out as performing poorly in most parts of the distribution. Kerala, Punjab, Rajasthan and Madhya Pradesh had higher biological welfare. The impact of the bad period of 1964-66 was insignificant in all parts of the distribution.

3.6. Determinants of inequality

To study the determinants of inequality in India, the coefficient of variation in height was used (Table 7). Poverty, the rural-urban gap in mean consumption, the standard deviation in rain, population growth, regions, caste and religion were taken as determinants of inequality. The inequality model helped to analyze inequality by state, religion and caste along with consumption and poverty-based indicators. Interestingly, deviation in rain increased inequality, from which it can be concluded that negative developments in agriculture worsened inequality.

Table 7: Determinants of inequality in India from 1950-75

Mean Consumption (Rural Urban gap)	-0.97*
Head Count Index (poverty)	-0.37
Standard Deviation in rain	0.001*
Upper caste	0.08
Reference (other castes)	
Religion	
Muslim	-0.12*
Other Religion	0.03
Hindu (reference)	
States	
Andhra Pradesh (reference)	
Assam	-0.39
Bihar	0.05
Gujarat	-0.03
Haryana	0.19
Karnataka	0.23
Madhya Pradesh	0.12
Maharashtra	-0.17
Orissa	0.10
Punjab	-0.18
Rajasthan	0.18
Tamil Nadu	0.35*
West Bengal	0.00
Uttar Pradesh	0.40**
Year	0.05
Constant	4.49**
Adjusted r square	0.06
N	196

Information related to rural and urban mean consumption was available, and a variable was thus constructed to show the rural-urban gap in mean consumption. Improvement in the rural-urban gap in mean consumption reduced inequality. Poverty did not show any relation to inequality. Higher castes displayed higher inequality whereas Muslims showed lower inequality compared to Hindus. This is perhaps indicative of the variability in the Hindu religion due to the complex caste structure, whereas Islam is relatively egalitarian compared to Hinduism. Moreover, Tamil Nadu and Uttar Pradesh showed higher inequality compared to Andhra Pradesh. In sum, we can conclude that Indian inequality decreased during 1949-74, with a narrowing gap between rural and urban living standards, and an absence of heavy fluctuations in rain.

3.7. Conclusion

How did the height of Indians change in the 25 years of our study period? It is evident that the stature of Indians grew slightly, from 1508 to 1516 millimeters. When compared to the modest increase in heights in the pre-1950 period (0.7cm), we could observe a negligible optimistic trend (0.8cm). However, the chapter on the pre-1950 period focused on male heights whereas the current study is about women. We do not know if male height grew more in the post-1950 period compared to female ones.

Determinants of welfare and inequality added new insights related to the welfare of Indians after independence. Improvement in the per capita net domestic product of the non-agricultural sector improved the living standards of rural women in the central and upper part of the distribution. This might be related to the fact that the non-agricultural sector might improve the living standards of the middle class and rich people compared to the poor by providing the former with opportunities in the semi-skilled and skilled sector. The improvement of the rural living standards in the upper parts of distribution supports the arguments of Eswaran and Kotwal (1994) that the rural poor did not benefit from the Indian industrialization process. The hypothesis that improvement in the Net Domestic Product of the non-agricultural sector improves heights can be accepted. It is also evident that an increase in development expenditure improved the overall stature of women belonging to the 10^{th} and 25^{th} percentiles.

The caste system in particular created high inequality in welfare, and we were able to prove that women belonging to the upper castes were tall in both rural and urban areas. The hypothesis of overall Hindu-Muslim inequality must be partially rejected. Except for the rural born women in the 25^{th} percentile, it was evident that Hindus and Muslims were not significantly different in all parts of the distribution in rural, urban and overall India. In sum, the hypothesis that the caste system created inequality in heights can be accepted completely, whereas that of Hindu-Muslim inequality had to be rejected. Regional diversity in stature was evident in all models. Kerala, Punjab, and Rajasthan showed higher stature compared to Andhra Pradesh, whereas Assam, Bihar, Uttar Pradesh, and West Bengal showed poor stature. The bad years of 1964-66 did not reduce the heights of both rural and urban women. The use of the coefficient of variation in height to study inequality also provided new insights. Furthermore, any deviation in rain increased inequality, from which it follows that a negative impact on agriculture worsened inequality. Interestingly, Tamil Nadu and Uttar Pradesh showed higher inequality compared to Andhra Pradesh. Any improvement in terms of a declining rural-urban gap in mean per capita consumption would reduce overall inequality.

4. Anthropometric Evidence of Gender Inequality in India

I am thankful to Dr. Alexander Moradi and Daniel Schwekendiek for giving the opportunity to use the database we have collected together for our respective joint papers.

4. Anthropometric Evidence of Gender Inequality in India [16]

Abstract

Recent literature of development economists and demographers on gender inequality confirmed the existence of a resource allocation bias against the girls in India. A number of different indicators like mortality, education, employment, freedom, access to resources and health, and malnutrition were used to study gender bias against females. This research can be extended further by using a relatively new indicator, namely gender differences in stature. Indian gender disparity in the incidence of child malnutrition is high when compared to other developing countries, especially Africa and South Asia. Monsoon rains, development expenditure and rice output were the main predictors of gender disparity for the period 1950-75. Gender dimorphism was high when natural disasters occurred rejecting the female resiliency argument for India. Moreover, Indian South Africans showed higher gender dimorphism compared to Africans, Coloured and White South Africans, which highlights that gender differences depend on cultural aspect of gender discrimination.

Keywords: Gender, Stature, India, Mortality

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4.1. Introduction

Many economic historians used height as a measure of net nutrition and living standards (Fogel et al., 1983; Komlos, 1985; Steckel, 1995; Floud and Harris, 1997; Harris, 1994; Steckel and Floud, 1997; Baten 2000A, Baten 2000B). The average height of a larger population group is mostly influenced by the quality and quantity of nutrition and the disease environment. Some researchers have extended the anthropometric research to investigate gender inequality in a historical context (Brennan et., 1977; Johnson and Nicholas, 1995; Nicholas and Oxley, 1993; Baten and Murray, 2000; Horrell, et al., 1998).

Most of the anthropometric historical studies focused on the 19th century gender inequality, whereas contemporary research of development economists has analysed recent trends. Moreover, most of the research on Indian gender inequality uses other indicators like differences in education, employment, access to resources, the missing women concept, and excess female mortality (Bardhan, 1974; Rosenzweig and Schultz, 1982; Sen, 1990; Klasen, 1998; Mishra et.al., 2004). To fill the paucity of research on gender inequality using anthropometric data, this paper attempts to study gender inequality by using stature data.

Human stature is an outcome of complex interaction between environmental and genetic factors. According to Eveleth and Tanner (1976), two genotypes that could produce the same adult height under optimal environmental circumstances produce different heights under circumstances of deprivation. Thus, children that would be taller in a well-off community would be shorter under poor economic conditions. Moreover, their heights might vary if the environmental stimulus essential for child's growth was lacking. We can use these findings for studying gender differences in adult stature. Substantial gender difference in environmental inputs is reflected in stature difference between females and males.

Biologically, men and women have differences in the nature of growth, final adult size and behaviour. Males have a larger stature, more robust cranial and facial features, along with greater muscularity and strength (Frayer and Wolpoff, 1985). However, apart from these biological differences, other determinants like nutrition, health care, and disease play an important role in determining stature differences between men and women. In this context, this chapter focuses on the central question why gender differences in stature exist. Also, the aim of the chapter is to investigate gender differences in stature by socio-economic and cultural factors to study intricacies of gender inequality. For example, Dangour et al., (2003) showed that heights among children in Kazakhstan declined and heights of girls developed worse than boys' due to religiously-induced discrimination in the labour market.

When we focus on gender inequality in India, contemporary issues revolve around the missing women concept. Gail Omvedt – already in 1978 - stated that India's low sex ratio is the "starkest index of gender discrimination" that stems from less food and health care for girls. Several researchers worked on low female-male ratios using social, economic, and cultural arguments (Natarajan, 1972; Mitra, 1979; Mies, 1980; Sen, 1990; Mayer, 1999). Simultaneously, several researchers applied other gender inequality indicators by using economic, social, cultural and human capital factors to investigate its complexity (Sen, 1985; Das Gupta, 1987; Basu, 1989; Kishor, 1993; Agarwal, 1984; Subramanian and Deaton. 1991; Murthi et al., 1995; Agnihotri, 1995; Bhargava and Osmani, 1997; Kingdon, 2002). Nevertheless, using gender dimorphism defined as the difference between male and female height relative to male height for studying gender inequality was never done previously.

Though for several decades' development economists and demographers iterated and reiterated the existence of gender discrimination in India using a variety of indicators. They confirmed that there was no improvement in the status of women and female children. For example, a recent study by Borooah (2004) showed a neglect of girl children in India both in terms of diet and immunisation against disease using a sample of over 4000 children between the ages of 1 and 2 years.

To structure the complex picture of gender inequality of health in India, a conceptual framework could be helpful (see Figure 1). The idea of this framework is to include cultural factors that make the mechanism of discrimination easy to accept in the form of gender differences in wages, work load or dependency during old age. Moreover, it is not totally clear if the cultural preference for male children is a vicious circle that is accentuated by economic factors like payment of dowry and old age dependency.

Another characteristic, we come across frequently when we discuss about gender inequality in India, is the North-South divide (Dyson and Morre, 1983). North India is biased against women with lower female-to-male ratios compared to the South and this is attributed to Aryan culture of the North vis-à-vis Dravidian culture of the South. Crosscousin and uncle-niece marriages in South India were also one of the reasons given for relatively higher female status compared to North Indian villages that strictly follow exogamy. North Indian women after their marriage start their life in a new village and family where it is difficult to claim their rights. Moreover, North Indian women neither inherit property nor transfer property rights.

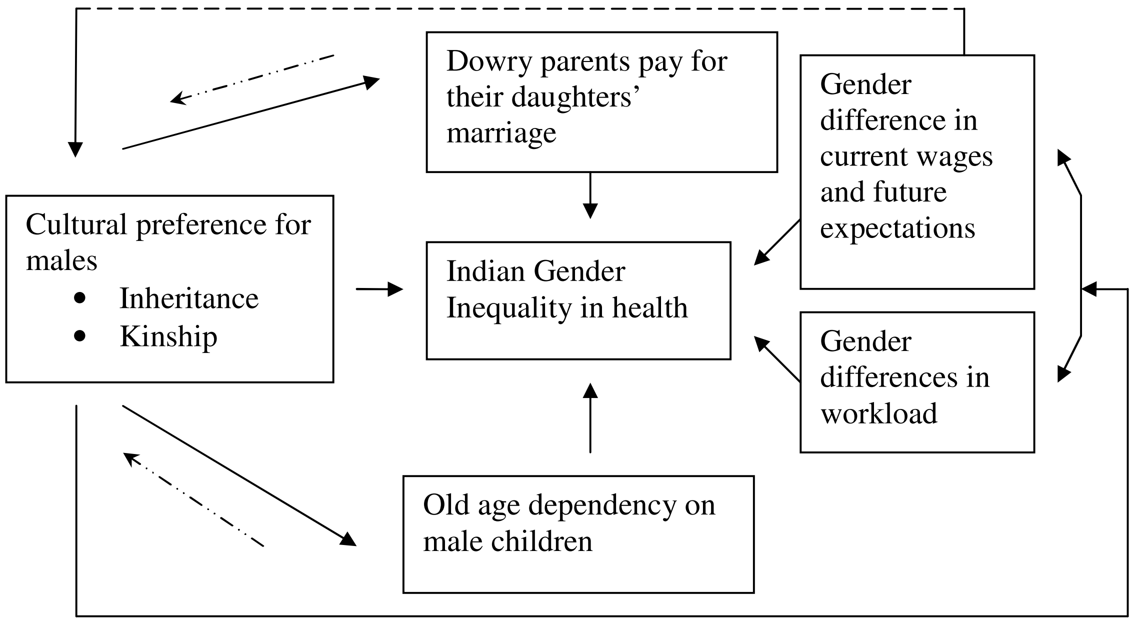

Figure 1: Cultural and Economic expectations and the causes of gender inequality in India.

Brennan et al. (1997) based on their data on Indian immigrants to Fiji from North and South India found that male to female height ratio was higher in North India compared to South India for the later parts of the 19th century. Unfortunately, this paper could not focus on the North-South divide as most of the available data for gender differences in stature is restricted to South, and 'not very North' West India and partly East India.

Summing up, mean male stature is greater than female stature across regions over time. However, the interesting observation is the degree of variation in stature within and between populations. First, we argue that gender differences in stature can be used to answer some important questions such as: which societies discriminated females and what are the major determinants of discrimination? Did the gender difference in stature increase or decrease during the observed period? Are females biologically robust? If so, how to separate the biological robustness of females from gender discrimination? Does the female biological standard of living improve with female labour participation rates and agricultural productivity? Did the gender dimorphism increase during famine and crisis periods? Is India doing worse compared to other parts of the world because of the complex gender discrimination accentuated by culture?

4.2. Biological research on stature dimorphism

4.2.1. Why do men and women have different statures from biological point of view?

In biological view, a large male usually shows the importance of male territoriality or competition for females. In general, among primates, males are typically much larger than females, whereas human beings are less dimorphic compared to other primates indicating that size differentials have been subject to rapid evolution. Sexual dimorphism varies nevertheless between different animal species and taxa. Rensch was the first prominent researcher who pointed out that in taxa in which males are the larger sex, sexual dimorphism increases with body size. This became the popular Rensch rule[17] (1950, 1959) and his research opened a new research avenue for many biologists' focusing on sexual differences (Gray and Wolfe, 1980; Gaulin and Boster, 1985; Gustafsson and Lindenfors, 2004).

Why is this important for us when we focus on gender inequality? The research argument is that if the difference in male and female stature increases with increasing height it does not help us in recognizing gender inequality by looking at increasing differences in the height of males and females. So before using gender differences in stature straight away, we need to focus on the indicator and methodological issues.

Gray and Wolfe (1982) compared mean heights of men and women in various population groups and supported increasing dimorphism with increasing height. Later Gaulin and Boster (1985) criticized Gray and Wolfe's findings as statistical artefact due to small sample size. Recently, Gustafsson and Lindenfors (2004) tested if populations with larger stature were exhibiting more dimorphism using adult male and female data that are above 19 years from 124 population groups where most of the recordings were from the later part of the 20th century.

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[17] Moreover, Rensch claimed that this rule is also true for "subspecies of a species" which was later tested by many researchers.

Also this area of research more or less stagnated till end of 80's and from 1982 onwards we find more research papers related to this issue.

Gustafsson and Lindenfors rejected the hypothesis of increasing dimorphism with increasing stature in humans - using phylogenetic method[18] to correct for errors arising as a consequence of populations sharing a common ancestry. Hence Gustafsson and Lindenfors controlled for genetic ancestry to compare evolutionary dimorphism. By using male and female heights from a variety of published sources, they rejected the Rensch hypothesis that sexual dimorphism in stature increases with increased stature in humans.

Holden and Mace (1999) related sexual division of labour and sexual[19] dimorphism by observing 76 aboriginal populations. Comparing sexual division of labour data[20] with sexual dimorphism data of various population groups they concluded that sexual dimorphism in stature is negatively correlated with women's labour force participation. They argued that this negative association stems from sex-biased parental investment. This argument can also be tested further to accept the use of sexual differences in stature for studying gender inequality.

4.2.2. Are females robust?

Many studies have found a decrease in male-female height differences under conditions of nutritional stress and an increase in dimorphism with improved diet. Based on their finding and biological theorizing, they hypothesised that women are more resilient during

[18] Phylogeny is the evolutionary history of a group of organisms and the modern phylogenetic investigations are based on molecular data, primarily nucleotide sequences. Basically, the more closely related two organisms are the more genes they will have in common.

[19] While discussing biological literature the term sexual dimorphism and in the other parts the term gender dimorphism was used.

[20] "Ethnographic Atlas" was used to taken sexual division of labor data

crisis periods (Wolanski and Kasprzak, 1976; Gray and Wolfe, 1980; Brauer, 1982; Lieberman, 1982; Stini, 1985). They argued that males are more susceptible to fluctuations in nutritional quality and show greater impairment in long bone growth compared to females under the same food deficits (Clutton-Brock and Harvey, 1984). Also several studies for prehistoric periods covering North America (Hamilton 1982), Mexico (Nickens 1976), Europe (Frayer 1984), India (Kennedy 1984), China, and Southeast Asia (Brace et al. 1984) support the “female robustness or female resiliency” hypothesis. These studies mostly focus on prehistoric time periods and have small sample sizes and there is a dearth of detailed in-depth statistical analysis using a larger sample.

Researchers that supported the female robustness argument also believed that a long-term nutritional shortage would not only mean a reduced adult height size in both sexes but also a higher impact on men. Research on mortality during famine by several researchers also show that females are more robust compared to males and male mortality is high during famine period (see Macintyre, 2002 for excellent review on gender differences in mortality during famines). However, the recent research by Newmayer and Plümper (2006) showed that gender gap in life expectancy during disasters was biased against females in a sample of 141 countries over the period of 1981-2002. In fact, they argue that the negative impact on female life expectancy is directly proportional to the strength of disaster.

Based on varied opinion on female robustness, it is difficult to conclude if female resiliency exists. Recent research by Baten and Murray (2000), and Moradi and Guntupalli (Forthcoming) demonstrated that during stressful periods female stature was affected more relative to male heights. Besides, we can argue that despite of existence of female robustness reduction in female heights relative to male heights would implicitly mean gender discrimination. Likewise, we have to differentiate female robustness from their physiological strength relative to the workload and exposure to disease.[21] We cannot overlook the physical differences between males and females. But at the same time we have to consider the fact that gender discrimination increases especially during stressful periods like famines and natural disasters. To get a precise answer, we need to compare female robustness by age group in 'general' situations and also in 'specific' situations like famine and disasters using different indicators and better samples to achieve robust results.

4.2.3. How to segregate gender differences from biological differences?

Besides the biologically determined differences in height, the intra household allocation of resources could favour one gender disproportionately. We must be careful with the terms 'gender inequality' and 'gender dimorphism' that focuses on differences between males and females constructed through psychological, cultural and social means. The intention of this research is not to measure sexual dimorphism ascribed by biology, anatomy, hormones and physiology but to capture bias against girls in terms of food, health care and workload.

[21] Latest report by institute of medicine (2001) gives nice overview of gender differences in health and exposure to disease.

Adult stature is a cumulative measure of the nutrition available for human growth over the growing period to adulthood reflecting the impact of environmental insults and inputs. The gender dimorphism indicator- using gender differences in stature- reflects differential access to food and health facilities, and differential access to education due to 'son preference.' Moreover, using short run height data for relatively homogenous population we cannot really capture dynamism in sexual dimorphism but gender dimorphism. Typically both males and females have genetic threshold level of height which can be altered especially in girls by differential treatment in terms of nutritional and health inputs (Borooah, 2004).

4.3.0. Advantages of using gender dimorphism

Why has gender dimorphism particular advantages compared to other commonly used indicators? Many scholars have used mortality as an indicator to measure gender discrimination. First of all there is a paucity of systematic evidence and research work to show long-term changes in the health of Indian women relative to men based on state-wise mortality data especially before 1950's. In the same way, data on morbidity and dietary habits are also not available in detail for various states even from 1950's. As India is a large country with a lot of regional variation in terms of agriculture productivity, climate, development expenditures, caste system and inequality, disaggregated state wise longitudinal data is definitely required to have in-depth focus of dynamics of gender dimorphism. For instance states in South India especially Kerala did better in terms of reducing gender inequality- along with the improvement in over all welfare- relative to other states by its policies

Recently, declining Indian sex ratio received a lot of attention and this indicator was used by many researchers for measuring gender discrimination in India (Natarajan, 1972; Omvedt, 1978; Mayer' 1999). But Mayer (1999) argued that education, employment and mortality data were better indicators compared to the sex ratio for measuring gender discrimination as he could not find relation between sex ratio and work participation. He argued that discrimination and differencing values placed on women's labour made a relatively minor direct contribution to the trend in sex ratio.

Some development economists and demographers showed that females' life chances are affected by greater deprivation in food and their focus was on gender inequality in nutrition. Nonetheless a review on female disadvantage on access to food by DeRose et al, (2000) showed that there was lack of evidence for a general bias against females in calorie intake. This lack of evidence could be attributed to two major arguments. First, the available data perhaps does not reveal the existing gender differences in access to food in spite of its existence. In the second place, the female disadvantage was mainly related to other aspects of life but not to food. However, data on access to food and calorie consumption did not show the real gender discrimination due to systematic bias (Strauss and Duncan, 1998). Systematic bias exists due to the fact that female requirements were lower in part because they were shorter relative to males and this shortness was partly determined partly by their inferior dietary intake from childhood. Thus, low intake would cause small size, which in turn could be used to justify low intake (DeRose et al. 2000).

Most of the nutrition studies focused exclusively on food intake ignoring the aspect of access and use of health care. For example, a country level study by Hill and Upchurch (1995) showed no link between female malnutrition and excess female mortality pointing to the differential investment in health care. Basu (1989) showed clear evidence of differential investment in health care. She found that even though boys in Delhi have higher malnutrition rates than girls, they have lower death rates. So by using gender dimorphism we could focus both on nutritional insults and lack of health care.

Moreover, the measurement of gender differences in child food intake is tricky to quantify. For instance breast feeding practices are complex to interpret based on the 'nutritional value' mothers put for their milk. Some population groups might rate breast milk as less healthy input compared to mushy and child food available in the market. If the breast milk is valued lower, girl child met get exclusive breast feeding to avoid other costs. It would be contrasting if breast milk is valued higher. Moreover, food distribution also depends on the composition of family (Mishra et al, 2004). First daughter might be treated better relative to subsequent daughters especially in the absence of sons.

In this context of growing research and drawbacks regarding the use of calorie consumption, life expectancy, mortality and sex ratio data, gender inequality in stature could provide new insights to the gender area of research. Using stature data we could measure the cumulative effect of nutritional status from childhood. Also it is important to study nutritional insults and health care deprivation from childhood to adult hood instead of looking only at the current nutritional well being. Furthermore, accessibility of state-wise stature data was relatively good especially for the pre-1975 period.

4.4. Hypotheses

Hypothesis I

Larger stature dimorphism did not occur among groups that were relatively taller. Rensch's rule was not applicable in a cross-sectional group. Rejection of this hypothesis would help us in using gender dimorphism as an indicator for studying gender inequality.

Hypothesis II

India had higher gender inequality compared to other parts of the world. Gender difference in child malnutrition and biased against females were higher in India and this was induced not only due to economic conditions but also due to cultural bias against girls.

Hypothesis III

Monsoon rain and rice productivity had inverse relation with gender inequality. Also, gender dimorphism decreased with increasing development expenditures and real wages.

Hypothesis IV

Dimorphism in stature increased during natural disasters. Female height decreased relative to male height during floods, and other natural disasters in India. Female resiliency argument is tested with Indian data using this hypothesis.

Hypothesis V

Indian gender discrimination was also imbibed in culture and it was observed among Indians living in South Africa. Gender dimorphism among Indians in South Africa was higher compared to other racial groups.

4.5. Data and Methodology

4.5.1. Data

Various data sources were used for this study to accept the working hypothesis. Both international and Indian anthropometric sources were taken into consideration for constructing gender database for this research. As the hypotheses constructed for this study were difficult to solve by using a single source multiple sources were incorporated. All the sources along with the methodology were described in this section in detail later.

4.5.1.1. Male female world height data

Data published by Gustafsson and Lindenfors (2004) was used to test if taller people exhibit higher dimorphism (Hypothesis 1). This data set consisted of male and female height of 153 population groups mostly from the latter part of the 20th century. This data was purely cross-sectional and consisted of adults from the age 19. Most of the data was comprised of tribal groups from various continents and covered all the continents. The list of all the population groups by continent is available in appendix E Table 1.

4.5.1.2. Child Malnutrition data

The hypothesis that India had particularly high gender discrimination could be tested by using *Global Database on Child Growth and Malnutrition.* After controlling for economic and political factors, we could test if India had higher gender inequality compared to other countries, especially Asian, African, and Latin American.

The *Global Database on Child Growth and Malnutrition*[22] (CGM) was maintained by the WHO. Initiated in 1986, the United Nations and the German Government funded a three-year-project to build up a worldwide nutritional surveillance database in order to characterize the nutritional status of children in various countries (De Onis and Blössner, 1997, 2003). Data were mainly collected from published articles, governmental statistics, NGO statistics, and the UN agencies. All the surveys fulfilled the basic criteria such as population based and probabilistic sampling, minimum sample size, standardized raw data based on the NCHS-reference population and standardized measurement techniques (De Onis and Blössner 2003).

The data used for this study consisted of only the national representative surveys. Though data based on various regional surveys were available, they were not included due to huge regional variation within those countries. For the descriptive part of the paper all the three indicators of child malnutrition were shown whereas for the world map only height for age z-score is used to investigate gender differences in stunting. The list of all the countries in the data is available in appendix F Table 1.

[22] Thanks to Daniel Schwekendiek for giving this opportunity to use our world child malnutrition data for my gender research.

4.5.1.3. Indian adult male and female height data

The National Nutrition Monitoring Board (NNMB) carried out its third nutrition survey in 1996-97 covering rural areas in the Indian states of Andhra Pradesh, Gujarat, Karnataka, Kerala, Maharashtra, Orissa and Tamil Nadu. In each state about 100 villages from eight geographically distant districts were selected in this survey. Mean heights for both sexes who were older than 20 years were reported in five-year age groups to reduce bias from age heaping. We excluded the age groups above 50 years since individuals start to loose stature rapidly from this point of time (Baten and Murray, 2000; Guntupalli and Baten, 2006). This study was based on 9,112 men and 13,566 women aged 20-50 and the data was aggregated by state and five-year birth cohorts starting in 1950 and ending in 1975.

4.5.1.4. State wise economic data

Data for all of our explanatory variables[23] were drawn from the database of Özler et al. (1996), “A Database on Poverty and Growth in India” except for information on rice output, which was from “Agriculture and Climate Data Set” by Sanghi et al. (1998). The explanatory variables were organized in such a way that they were related to economic and agricultural conditions these individuals faced during early childhood. In sum using the NNMB survey we could see the gender differences in height, its trend, levels and determinants and by merging it with other data, we can focus on determinants of heights.

[23] Information for kerala was not available for the agriculture data.

This data were used to test if developmental expenditures lowered gender inequality in India. Along with development expenditure, information on rain, standard deviation of rain, real wages and Gini coefficients were used. Many studies had found a reduction in male-female height differences under conditions of nutritional stress and an increase in dimorphism with improved diet (Brauer 1982, Gray and Wolfe 1980, Lieberman 1982, Stini 1985). But there was no coherence in this research as the recent studies related to female life expectancy during disasters showed opposing results. To test the female resiliency hypothesis in the Indian scenario, we will focus on what happened to gender dimorphism in India when natural disasters occurred using the third NNMB survey.

4.5.1.5. Natural Disasters data

The data for disasters are taken from the EM-DAT database created by WHO and Belgian government. CRED (Centre for Research on the Epidemiology of Disasters) created. The main objective of the database is to rationalize decision making for disaster preparedness, as well as providing an objective base for vulnerability assessment and priority setting. EMDAT contains essential core data on the occurrence and effects of over 12,800 mass disasters in the world from 1900 to present. The database is compiled from various sources, including UN agencies, non-governmental organizations, insurance companies, research institutes and press agencies. This data gives detailed information regarding natural disasters and technological disasters. As our hypothesis is to study the impact of natural disasters on gender inequality, we will select only natural disasters like windstorms, cyclones, earthquakes, and droughts. Twenty natural disasters were identified for the study period using this data.

4.5.1.6. Gender dimorphism among South African Indians

Gender inequality in India was also accentuated by cultural son preference (Dyson and Moore, 1983; Kishor, 1993). Kishor (1993) using data from 1981 census found that cultural factors explained more about excess female mortality than labour force participation. In this line, if the gender discrimination was also accentuated by culture, Indian community living in South Africa must also show higher gender dimorphism relative to the other population groups. The data on South Africans were the only available data that provided information of height of males and females born during 1948-75 by different races including Indian.

The data of 1998 South Africa Demographic and Health Survey (SADHS, 1998), which was the first nation-wide demographic health survey, were used to test the impact of Indian culture on gender dimorphism. The heights of various race groups were aggregated for the research purpose by 5 year birth cohort from 1948 to 1975. SADHS forms a base in researching gender differences of Indians abroad. This would also open avenue for further research on cultural aspects of gender inequality by comparing height differences of males and females of Indians compared to other racial or migratory groups.

SADHS not only collected information related to maternal and child health but also on adult health and height. Though this South African sample was mostly Africans, it had information about Indians, Colored people and Whites as well. SADHS was based on 13,802 adults and 76 percent of the sample comprised Africans whereas Indians added up to only to 3.4 percent of the sample. Indians were over-sampled in the study as the composition of Asians in South Africa was only 3 percent of the population. Nonetheless, SADHS would help us in throwing light on gender differences of Indians in South Africa.

4.5.2. Methodology

4.5.2.1. Gender dimorphism in Adults

Gender dimorphism[24] (also known as Sexual Size Dimorphism by biologists and anthropologists) was calculated in most of the studies as the difference between male and female height whereas some contemporary studies used the ratio between male and female stature. In this study gender dimorphism was calculated as the difference between the mean heights of the genders expressed as a percentage of male height[25] (Moradi and Guntupalli, Forthcoming). The analysis of determinants of gender dimorphism focused exclusively on adult males and females that reached their final adult stature.

$$GD1 = \frac{maleheight - femaleheight}{maleheight} \times 100$$

4.5.2.2. Gender inequality in children

It is important to study gender differences in child malnutrition along with the gender differences in adult biological standard of living as children were more sensitive to negligence in terms of both food allocation and accessibility to health facilities.

[24] Gender dimorphism in the formula is expressed as GD

[25] Thanks to Joerg Baten and Alexander Moradi for discussion regarding the use of the relative indicator of gender dimorphism

Though most of the paper was focused on adult heights, a small section was devoted to study gender differences in child malnutrition. Child malnutrition could be measured using stunting, wasting and underweight indicators using Z-scores.

For calculating Z-scores the children's height for age, weight for height, and weight for age for a particular group or country is considered in comparison with an international reference standard. If a child falls significantly short of the international reference standard in any of these three dimensions, we can categorize the child as malnourished (stunted, wasted, or underweight).

$$Z - score = \frac{O - MD_R}{SD_R}$$

O is the observed value of height or weight at a certain age of a country or sub-group we are interested in, MD_R is the median of the reference population and SD_R is the standard deviation of the reference population. Stunting can be defined as percent of children falling below two standard deviations (-2SD) for height for age (HAZ). Underweight was defined as percent of children falling below -2SD for weight for age (WAZ); and wasting was defined as percent of children falling below -2SD (World Health Organization, 1986) for weight for height (WHZ). Z-scores are also sex-independent, thus permitting the evaluation of children's growth status by combining sex and age groups. Using the malnutrition indicators of male and female children of World sample gender inequality in child nutritional status was calculated.

$$\text{GD2} = \frac{\text{\% of Males malnourished}}{\text{\% of Females malnourished}} \times 100$$

The most important question was which indicator was the best one for researching gender discrimination among children? Stunting or chronic malnutrition, reflected by deficits in height per age, is a stable indicator in terms of short term fluctuations and could also help in focusing on gender differences in a robust way relative to other indicators. Moreover, stunting does not alter in a short period which helps us in focusing on long-term factors including insufficient protein and calorie intake, frequent infection, non availability of health care, and poverty. Unlike weight related indicators, height is not influenced by the outbreak of diarrhoea or short term nutritional fluctuations. Moreover when we have no control on seasonality in food availability, short-term nutritional stress and disease outbreak, stunting is a better indicator. Nevertheless, wasting and underweight could help us to have an overview of gender differences in malnutrition in a broad way though they could not help us in studying the short term or acute consequences of nutritional stress.

4.5.3. Caveats of using gender dimorphism

Most of the data that could be used especially for India was aggregated only by state. To recognize the complexity of gender inequality, we need to have data with information related to region, education, occupation of parents, and standard of living. The data available for analysing gender inequality in India lacks such detailed information. Also, most of the data was cross-sectional, and there is a need to have longitudinal data to study the dynamics of gender inequality.

Moreover, data on heights sometimes included still growing adolescents and shrinking old aged people. As we did not have exact information on gender differences in shrinking and growth spurt, it was important for us to have data of fully grown adults below the age of 50. Most of the demographic health surveys (DHS) include heights of ‘mothers only’. The very recent DHS incorporated data of both males and females (both mothers and non mothers), which helps us in future cross-country comparison of gender inequality. Most of the data consists of Southern and Western states of India; hence, we cannot extend these results for uncovering the alleged North-South concerning gender specific inequality in India.

4.6. Results

4.6.1. Is sexual dimorphism high among taller people?

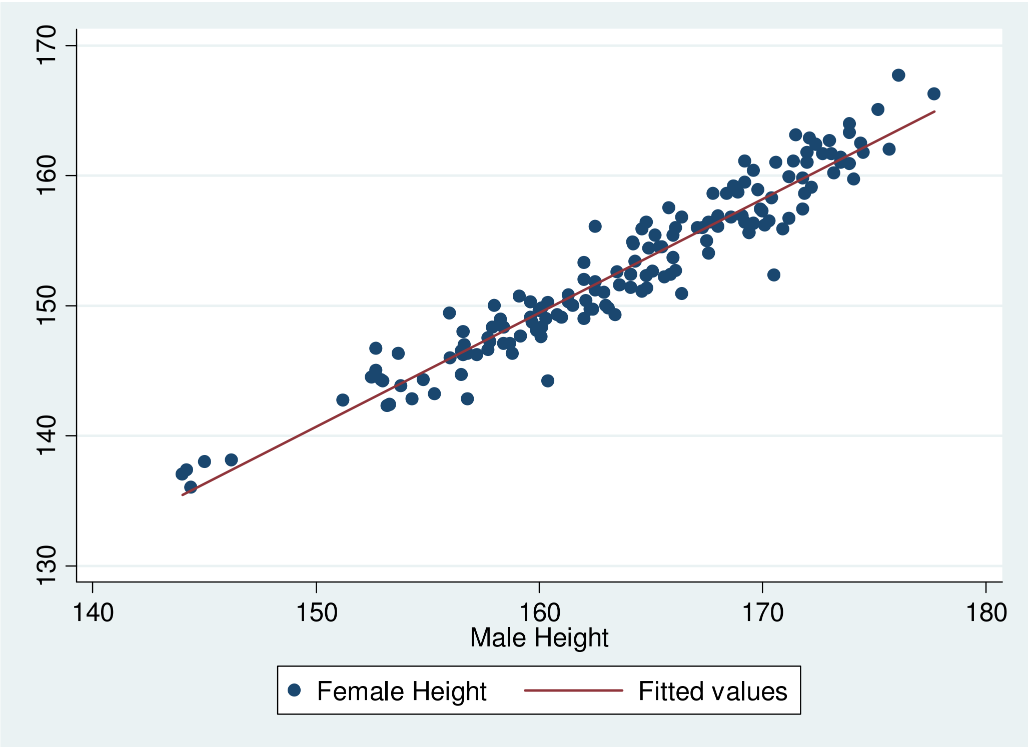

Figure 2: Relation between male and female height across various population groups

Source: Gustafsson and Lindenfors, 2004

Looking at the relation between male and female heights in our cross-sectional sample is essential when we take differences in stature as an indicator for gender differences. If gender dimorphism increases with increasing stature of males, we could not take higher dimorphism as a proxy for gender inequality. Unless we could reject this Rensch's rule it is not be possible for us to argue in favour of using gender differences in stature as an indicator for studying gender differences in health and nutritional inputs in a household. If we accept that improving living standards improve heights of both males and females, we also have to confirm that divergence in male and female heights reflects gender bias against females.

To observe if dimorphism in stature increases with increasing stature of males, Gustafsson and Lindenfors data (2004) were used that consisted of male and female heights of 124 population groups from the last decades of the 20th century representing all the continents of the world. A scatter plot of male and female heights shows a positive linear relation (see Figure 2). In order to reject the Rensch's rule, we need to focus on different population groups to rule out genetic differences in gender dimorphism if it exists (see Figure 3).

Scatter plots of the relation between dimorphism and male heights did not provide us with additional evidence for increasing dimorphism with increasing heights. Asia had the strongest relation between heights and gender dimorphism, whereas Europe showed no relation. Based on this evidence, we cannot not accept Rensch's rule. As expected, we observed a very strong correlation (see Table 1) between male and female heights (0.96), whereas male heights and dimorphism had weak relation. Using the current data, we cannot accept Rensch rule and we need to have a longitudinal data to study dynamics of gender dimorphism. If we see that overtime with improvement in male heights dimorphism increases, we might have to consider a modified methodology for using height for studying gender inequality.

Along with the pure cross-sectional nature, the data has a moderate sample size. It would be beneficial to have gender differences in workload patterns or nutrition data for these population groups to uncover further determinants of gender dimorphism. Moreover, this data consists of still growing people mostly from age 19 and shrinking people from age 50 making cross-country comparison difficult.

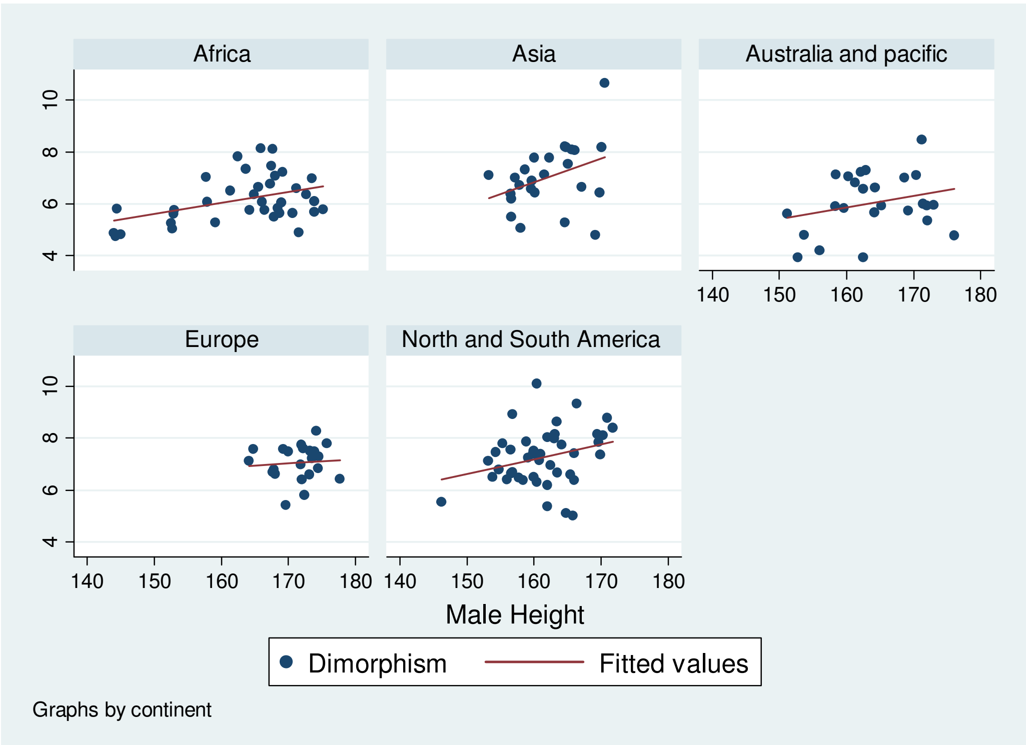

Figure 3: Relation between male and female height in various continents

Table 1: Correlation matrix of male height, female height and dimorphism

	Male height	Female height	Dimorphism
Male height		0.96**	0.44*
Female height			0.18*

*/** denotes significance to the 5%/1% confidence level.

4.6.2. Gender differences in world child malnutrition

Nube and Van Den Boom (2003) using relatively larger sample concluded that female adult nutrition relative to men in south/southeast Asia was unfavourable compared to other developing regions, especially Sub-Saharan Africa by using Body Mass Index. Nonetheless a study on gender differences in child nutrition on world level was missing. Most of the country studies of child malnutrition showed that boys are prone to malnourishment compared to girls except for South Asia, and some African countries and South American countries. The aim of this study was to compare India to other parts of the World. Moreover, having a world view could show which regions discriminate female children. Gender differences in malnourishment are calculated by taking the ratio of male and female malnourishment.

Though most of the paper was focused on using the adult height for researching gender inequality, child anthropometry was taken into consideration due to two reasons.

First, the accessibility of child malnutrition data by gender was better relative to adult height data. Second, we could focus on gender discrimination during the end of the millennium to make cross-sectional comparison of gender situation in the World in a short span. The Global Database on Child Growth and Malnutrition (CGM) that had information of 98 countries was used to see which countries discriminate girl child the most and the following method was used to calculate gender inequality in child malnourishment.

$$\text{GD2} = \frac{\text{\% of Males malnourished}}{\text{\% of Females malnourished}} \times 100$$

If the ratio is 100, we can say that both male and female children have equal advantage. If the ratio is below 100, it shows disadvantage of girls whereas ratio above 100 shows disadvantage of boys. It is evident from Figure 4 that among Asian countries India, China, Vietnam and Bangladesh discriminated girls relative to boys. In Africa, South Africa, Central African Republic, Namibia, and Mauritania showed more female malnutrition relative to males. Moreover, we found that the gender discriminatory belt in Africa was not really spatially aggregated like in the case of Asian continent. In South America only Colombia and Peru showed more female malnutrition. Other than the above mentioned countries Turkey, Kazakhstan, and Russia also showed relatively higher gender inequality. Astonishingly, Australia showed high gender dimorphism and by looking at the data carefully, we can observe nearly 1 percent of malnutrition rates. So the results we have from Australia should be dealt with caution. In sum, Asia was evidently showing higher gender discrimination compared to any continent in the world and spatial congregation of the gender belt was also evident in the South Asian and South East Asian region.[26] But the central question of this research paper "Is India having higher gender dimorphism even in Asia" could be answered by looking at gender difference in India using different indicators of child malnutrition compared to the average of World, Asia and South Asia.

All the three indicators of Indian child malnutrition (stunting, underweight and wasting as discussed earlier in the section 5.2.2) by gender difference were compared to Asia and World average though stunting was the most reliable one. Indian data showed higher bias against girls compared the world, Asia and South Asia. Gender gap in malnutrition measured by underweight and wasting indicators also showed severe discrimination against girls in India (Table 2).

India showed higher female stunting, wasting and underweight not only compared to World average but also to South Asian average. Based on this we could argue that India had higher gender bias in the world due to higher female malnutrition rates despite of the so called relative female advantage pattern most of the countries follow.

[26] Australia is also the only developed country that conducts such malnutrition surveys despite of its low prevalence.

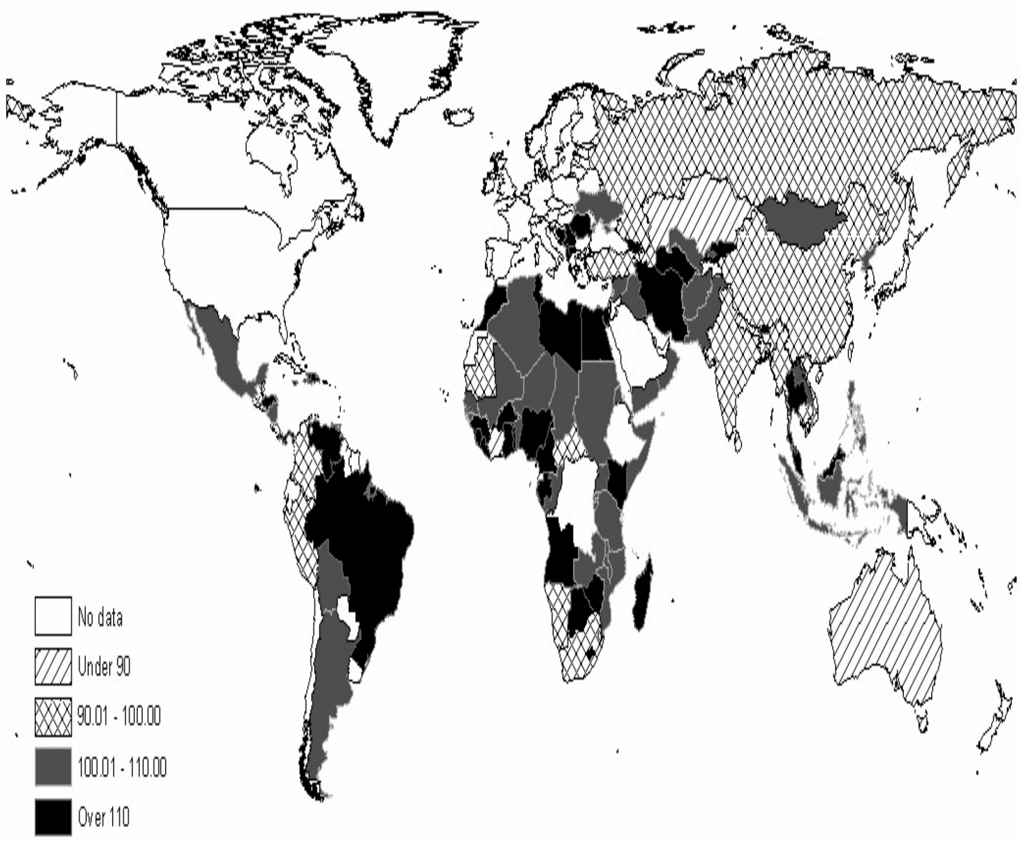

Figure 4: Gender differences in the world malnutrition

Source: The Global Database on Child Growth and Malnutrition (CGM)

Table 2: Gender differences in the world malnutrition with a special focus on India using global data base.

	Stunting (%)	Wasting (%)	Underweight (%)
World	-1.54	-0.92	-0.54
Asia	-0.4	-0.89	-0.03
South Asia	0.97	-1.52	1.25
India	2.8	-0.5	3.5

4.6.3. Gender dimorphism in India from 1950-75

We will now shift our focus on the determinants of the gender dimorphism. To find the determinants of gender inequality in stature NNMB (National Nutrition Monitoring Bureau, 1991, 1999) data were used as discussed in the data section. Before looking at the determinants of gender dimorphism, we will observe trends and levels of gender dimorphism from 1950-75 in various states of India for the rural areas.

In the case of Orissa we could see overall increase in gender dimorphism during the study period whereas Kerala showed reduction in general except for a sudden strong increase in the 1970's due to oil crisis and food crisis of 1960's. Gujarat and Maharashtra showed increase in gender dimorphism whereas Andhra Pradesh showed positive sign in terms of declining gap between female and male heights. Surprisingly, Gujarat showed a continuous decrease in dimorphism in stature from 1945-1965 that was followed by an increasing trend. Some regions of Maharashtra had food crisis during 1970-73 and during this period we could observe that gender dimorphism was increased.

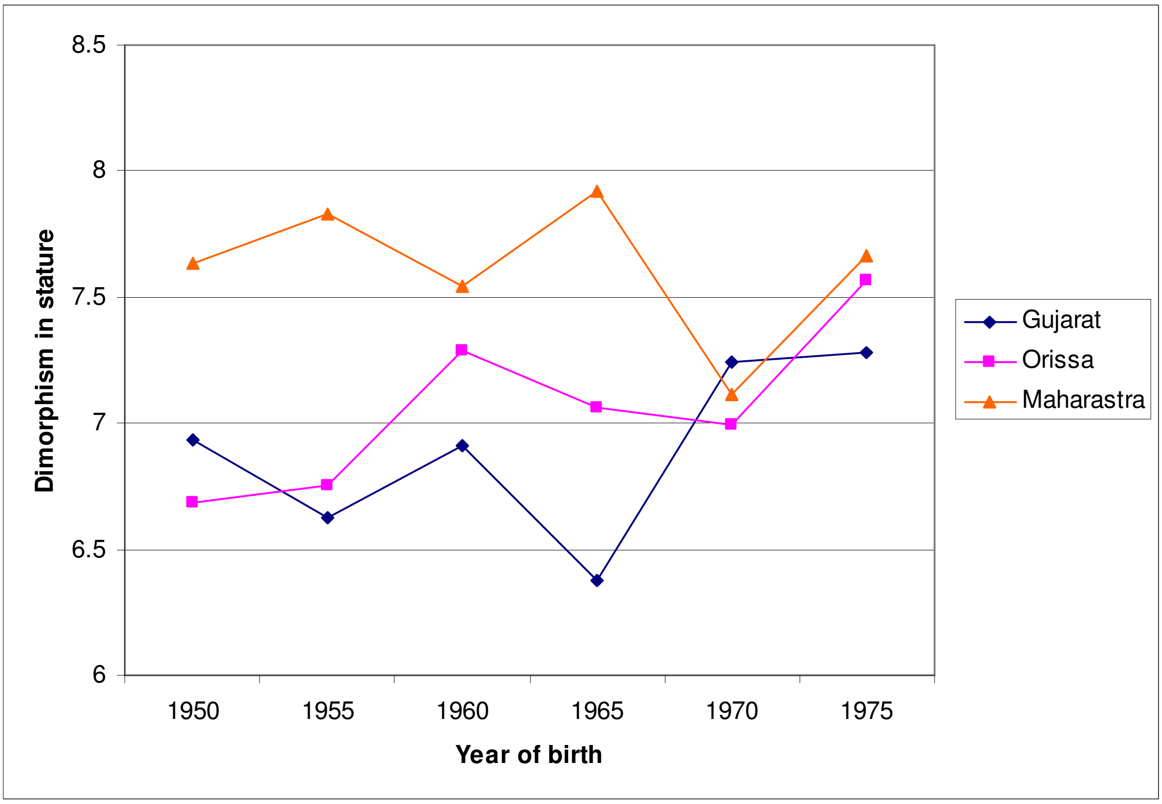

Figure 5: Gender dimorphism in height from1950-1975 in Western and Eastern India

During 1970 Orissa suffered from food shortage that was followed by a storm and cyclone in 1971 that took nearly 10,000 lives. During this bad period of Orissa, we again could see increasing dimorphism. It is slightly surprising to see that Kerala has higher gender dimorphism compared to other states especially during 1950's. Nevertheless, Kerala improved its welfare and decreased its inequality only from 1957 and we can see the positive impact of policies due to the continuous decline in the gender dimorphism.

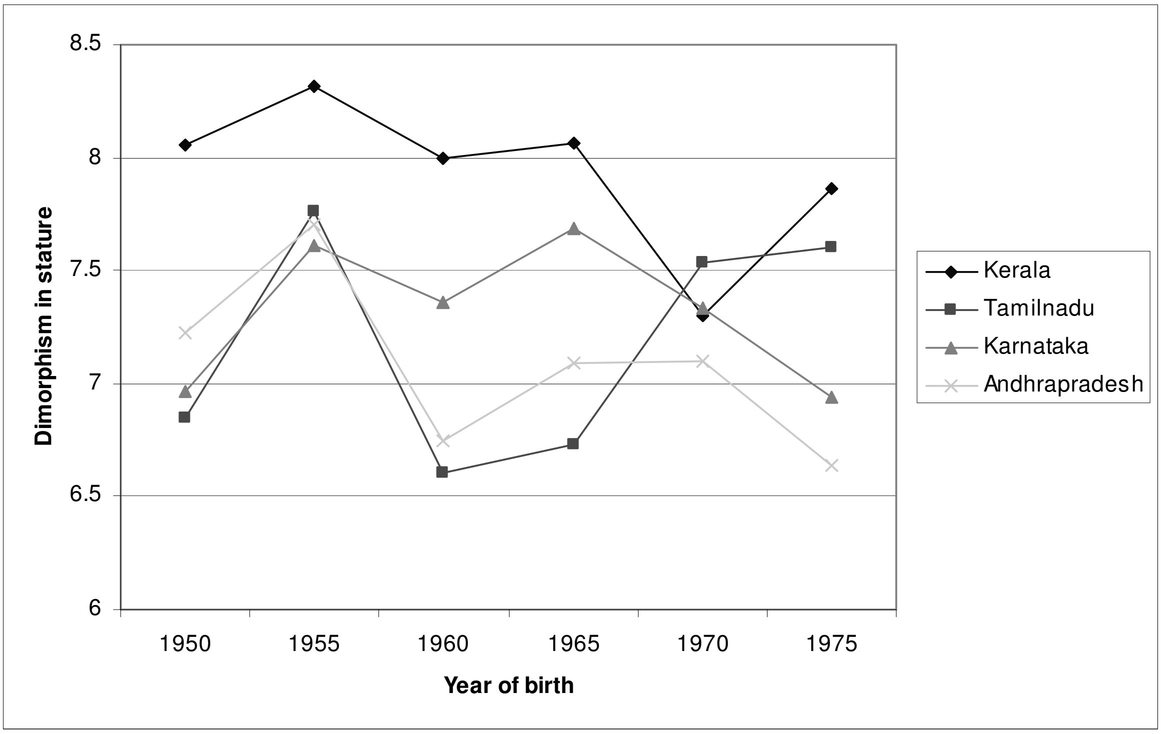

Figure 6: Gender dimorphism in height from1950-1975 in Southern India

4.6.3.1. Determinants of gender dimorphism in India from 1950-75

Data for all of our explanatory variables were drawn from the database on poverty and growth in India (Özler et al., 1996) and agriculture and climate data (Sanghi et al., 1998). This database contains detailed statistics on a wide range of topics in India. The data are presented at the state level and at the all-India level separately from 1950 to 1994.Various sources like census, NSS and statistical abstracts were complied for creating the annual state-level indicators of inequality, consumption, and welfare. Unfortunately most of the variables have data from 1958 only.

Rainfall: The monthly average rainfall by state is the simple average of actual rainfall, where the average is constructed over the four months in the monsoon season (June-September) and over the meteorological sub-divisions in the state. The standard deviation of rainfall is the standard deviation of the monthly rainfall for the state over the four months; the monthly rainfall for the state is a simple average over the sub-divisions in the state. Rainfall during monsoon was important for Indian agriculture productivity especially before irrigated dependent agriculture became popular. Typical weather pattern in most part of the India was 3 months of monsoon season between June and September that would bring 90 % of the rainfall followed by 9 months of dry weather. Therefore, monsoon rain could be used as a proxy for crop output to see if good monsoon rain helps in reducing welfare inequality between males and females.

Moradi and Guntupalli (Forthcoming) showed a significantly positive correlation between rainfall and per capita output growth in rice and wheat. Hence, rainfall was used as a good proxy of overall food supply. The standard deviation of rainfall refers to the yearly growth rates and this was included as an explanatory variable for inequality. Moreover, taking standard deviation of rain could allow us to study if deviation in rainfall, that has negative impact on agricultural productivity, is detrimental for welfare of women relative to men.

Rural real wages: State level data on the annual agricultural real wage for male labourers provided information of wages. We can check for the impact of wages on dimorphism using this data.

Development expenditures: This state development data includes expenditure on economic and social services by state governments. The economic services include agriculture and allied activities, rural development, special area programs, irrigation and flood control, energy, industry and minerals, transport and communications, science, technology and environment. The social services include education, medical and public health, family welfare, water supply and sanitation, housing, urban development, labour and labour welfare, social security and welfare, nutrition, relief on account of natural calamities. This indicator will help us to study if improvement in state expenditures on developmental programs decreases inequality.

Rice output per capita: "Agriculture and Climate Data Set" by Sanghi et al. (1998) provided rice output data. Using this data per capita rice output is constructed by dividing the quantity of rice output of a year by the population of that particular year. Rice output per capita variable will help us in studying the impact of availability of food on gender dimorphism. Also, rice was the staple and important crop in most of these states including Gujarat and Maharashtra during 1950-75. Data for Kerala was not available for rice out put per capita data.

Gini: Gini expressed in percentage helped in studying the relation between monetary inequality and gender inequality using anthropometric data.

4.6.3.2. Results

The data set comprised of mostly Southern and Westerns states and did not focus on North-South divide. Most of the states were rice intensive states, and what we could study was gender inequality within these rice intensive Southern and Western Indian regions.

Table 3: Determinants of the gender dimorphism in height from1955-1975

	OLS	OLS	Fixed effects
Rainfall during monsoon months	-0.08**	-0.07**	-0.10**
Standard Deviation inthe yearly rainfall	0.03**	0.03**	0.043**
Rural Real Wage	-0.02		-0.18
State Development expenditures	-0.03**	-0.02**	-0.037**
Rice output/capita	0.05**	0.04**	0.05**
Gini	-0.01		0.09
Constant	-0.61**	-0.49	-0.79*
R^2-adj.	0.32	0.33	0.61
N	24	24	24

*/** denotes significance to the 5%/1% confidence level.

Both OLS and panel fixed effects regression results revealed very interesting results. Rainfall in general seems to decrease gender dimorphism in stature whereas standard deviation in rain increases bias against girls. Standard deviation in the yearly rainfall increases gender inequality and showed positive coefficient. A large standard deviation would mean that rainfall as well as harvests, income and food supply were highly volatile in the five-year period. Based on the results we could argue that volatility in monsoon rain had more detrimental consequences for girls than for boys.

Rice cultivation seemed to be detrimental for the health status of women especially during 1950-75 after controlling for the other factors. To answer this negative relation between gender gap and rice output, we need to have a close look at the agricultural pattern. Productivity increased in Northwest India, Gujarat, Tamil Nadu, Costal Andhra Pradesh and Southern Karnataka in association with good irrigation combined with increasing inputs like labor. Why is this important to answer the question of increasing gender dimorphism with increasing rice output?

We knew that rural women play a very important role for rice cultivation both in contemporary and historical societies. In general rice cultivation requires female labor for transplanting and weeding, while wheat cultivation was exclusively handled by males (Bardhan, 1974). Especially, in the irrigated areas, women's relative labour participation was higher in weeding, fertilising and harvesting tasks, in comparison with the rain fed areas. Moreover, in India in the 1950s and 1960s, output in crops increased because of an expansion in the cultivated area (Kabra 1990). Labour input was a complementary production factor to land. Since women could contribute an important share of the labour force in rice cultivation (Dyson and Moore, 1983), an increasing workload could reasonably reduce the care for girls.

In general, state development expenditures had significant negative effect on the gender discrimination measured by height. We accept our hypothesis that development expenditures could reduce the gender disparity. Development expenditures could reduce gender inequality in the form of investment in education and water supply. Also infrastructure benefits women tremendously by saving time they spend (for example reduction in the workload of mothers to carry water). Moreover, improvement and accessibility of transport system in general increases accessibility to the health care that would allow parents to give equal access to boys and girls.

Gini coefficient and rural real wages had insignificant affect on gender inequality. In sum, the findings also support our view, that height dimorphism was a valid indicator of gender discrimination. In fact the findings point to the fact that gender dimorphism in stature reduces with the improvement in overall nutritional situation, development expenditures and workload. Moreover, as the example of Kerala shows policies could reduce gender disparities in education and health, and there is a lot of scope for further research about political policies and inequality. One of the major caveats of this analysis is a small number of observations (N=24). Unfortunately, it was difficult to obtain data before 1955 and it was not possible to have access to the individual data. Moreover, for Kerala we did not have data for agriculture variables. Hence our regression analysis is dependent on few observations posing caution to our results.

4.6.4. What happened to gender dimorphism in India during disaster period?

The final hypothesis of the study was that dimorphism in stature increased during famine periods. Macintyre (2002) implicitly stated that mortality of males exceeded that of females in famine periods using data from various famines that represented diverse populations, time and countries. She confirmed that famines increased male mortality stronger compared to female mortality. The female mortality advantage was highest between ages 20-45 and this advantage was associated to the biological resiliency of women.

Is the relation between famines and female mortality so simple? In fact, most of the studies focusing on the relation between famine and mortality overlooked two important aspects. First, females were shorter compared to males due to their lower consumption and health care since childhood. As a consequence, they could survive better during stressful periods, as they were conditioned to lower intake and their calorie needs were relatively low due to their short height. Second, famine mortality was caused more often by subsequent disease outbreak and not by starvation itself. In this case, we need to consider not only the female biological advantage, but also important aspects like the higher exposure of 'male breadwinners' to epidemic.[27]

In sum, there is a need to see the picture beyond the popular female biological advantage argument, as females definitely are discriminated in stressful periods. If all the contemporary research pointed to the fact that female discrimination exists in India, we must be able to see it despite of their biological advantage during "stressful periods". For the same purpose, disaster data (EM-DAT) created by WHO and supported by the Belgian government were used. The data comprises of natural disasters, technological disasters and complex emergencies. Based on this data, we obtain information on 20

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[27] National Academy of Sciences report (2001) has recently published an excellent review on sexual differences in health. It also shows that males do not differ from females in terms of their responses to infections, regardless of whether the invading organism is a virus, bacterium, mycobacterium, or parasite. Most sex differences in humans are caused by differences in exposure (at societal level) instead of differences between males and females at the individual, organic or cell level.

natural disasters in the 7 Indian states we are interested in for studying gender dimorphism. One earthquake, 15 windstorms, one drought and three floods happened during the study period (Table 4). In the regression, a dummy variable for the event of a disaster was used. Though information about the type of disaster, deaths and injured was available, it was not used due to insufficient observations.

Table 4: Natural Disasters in India from 1955-1975

Disaster type	**Earth Quake**	**Flood**	**Windstorm**	**Drought**
Andhra Pradesh	0	0	3	0
Gujarat	0	2	2	0
Karnataka	0	0	0	1
Kerala	0	0	0	0
Maharashtra	1	0	1	0
Orissa	0	1	3	0
Tamilnadu	0	0	6	0
Total	1	3	15	1

The regression analysis using a dummy variable for the occurrence of disaster showed interesting results. It is evident from Table 5 that natural disasters increased gender dimorphism significantly. Moreover, the significant positive relation between disaster occurrence and gender dimorphism continues even after controlling for the indicators we have used in our previous model. Based on these results, we can clearly reject the female resiliency argument at least for Indian scenario.

Table 5: Determinants of the gender dimorphism: Special focus in disasters

	OLS	OLS
Disasters **Reference (no disaster)**	0.51**	0.30*
Rural Real Wage	-0.01	
Rainfall during monsoon months	-0.07*	
Standard Deviation in the yearly rainfall	0.02*	
Rice output/capita	0.05**	
State Development expenditures	-0.02*	
Gini	-0.21	
Constant	-0.53**	0.89
R^2-adj.	0.44	0.06
N	33	44

*/** denotes significance to the 5%/1% confidence level.

4.6.5. Gender dimorphism among Indians in South Africa?

We wanted to test if preference for son and other cultural factors in India play an important role in deciding gender inequality. This hypothesis was tested by looking at South African data that had information about heights of adult males and females by birth year for four different races including Indians. A first glance at the Figure 7 shows clearly that there was definitely difference in gender inequality between Indians and other races.

Indian South Africans had higher gender dimorphism compared to other race groups due to anti-female cultural factors they have carried from India.

To make sure that this relation was statistically significant, regression analysis (OLS) was performed. Data was aggregated by five-year birth cohorts to solve the problem of age heaping to certain extent. It was clearly evident from the results (Table 6) that Indians had the highest gender dimorphism compared to Africans (predominantly Bantu speaking tribes), Whites, and Colored.[28] All the year dummies turned insignificant pointing out the fact that race mattered more and dimorphism remained static from 1948 to 1975.

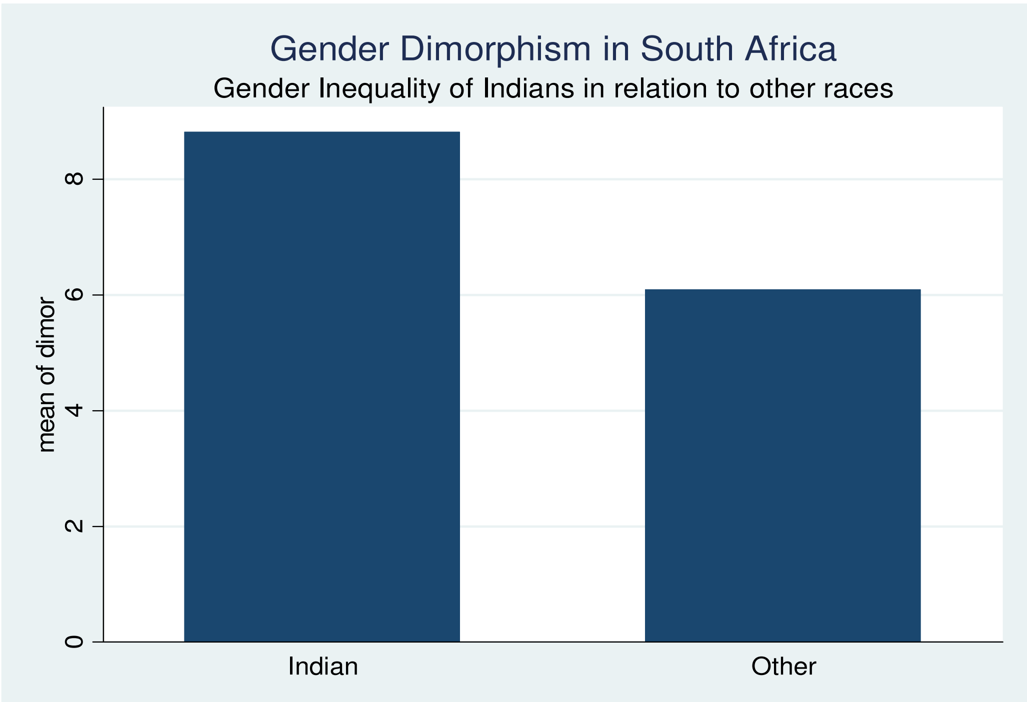

Figure 7: Gender dimorphism among South African Indians

[28] Indian South Africans are mostly from Gauteng, Cape town and Kwa Zulu-Natal

Table 6: Gender dimorphism in height among South African Indians compared to other race group from 1948-75

Race	**Coefficients**
White	-0.11*
African	-0.32**
Coloured	-0.29**
Indian (reference)	
Year dummies	
1948-50	0.05
1951-55	0.01
1956-60	-0.01
1961-65	0.03
1966-70	0.06
1971-75(reference)	
Constant	0.87
Adj R-squared	0.74
N	24

*/** denotes significance to the 5%/1% confidence level.

4.7. Conclusion

Gender discrimination has been studied previously by using various indicators such as education, employment, nutrition, calorie intake, and mortality. In this study we used a new measure 'Gender Dimorphism in Stature' and argued that this could be used as an indicator for measuring gender discrimination by taking various data sources. By using stature differences, we explored the inter-state differences and the gender discrimination trend.

First, we do find that male and female heights are strongly correlated. Second, we see that the correlation between male heights and gender dimorphism is weak. Based on the evidence seen from the world dimorphism data that showed varied relation between gender dimorphism and male heights in different continents we could support the fact that stature could be used as an indicator for researching gender inequality. Additionally, we found very high gender differences -using height per age z-scores of child below 5 years old- in India compared to other developing countries in Africa, Latin America and South Asia.

We further explored the determinants of gender differences and found that monsoon rain decreases gender inequality, and deviations in monsoon rain increase bias against girls. Moreover, development expenditures seem to reduce gender disparity. Increasing rice output increases gender dimorphism showing that excess of female work in rice cultivation can be detrimental for female health. Interestingly, we did not find enough evidence for female robustness argument. The occurrence of natural disasters showed an increase in dimorphism pointing towards increasing female disadvantage during “bad periods” relative to males.

The cultural explanation of gender bias was found very strong by observing the height differences in South African Indians. It was clearly evident that Indian community in South Africa had high gender dimorphism compared to Africans, Whites and Coloured. Based on the current findings, we can support the use of height as a measure for studying gender inequality. Nonetheless there is scope for further research by exploring more datasets to make a comprehensive regional and panel analysis.

Appendix E

Table 1

For investigating Rensch rule the following tribal or country data were used. The sample in sum consists of 154 observations covering 58 groups all over the World. For instance 10 Pygmoid groups from various regions of Africa were included the Pygmoid category.

Number	Group	Continent
1	Assyrians	Asia
2	Bhutanese	Asia
3	Chukchi	Asia
4	Druse	Asia
5	Iranian	Asia
6	Korean	Asia
7	Koryak	Asia
8	Kurdish	Asia
9	Mongol	Asia
10	Nentsy	Asia
11	Saudi	Asia
12	Tungus	Asia
13	Atayal	Asia
14	Bunun	Asia
15	Javan	Asia
16	Khasi	Asia
17	Paiwan	Asia
18	Philippine	Asia
19	Sea Dayak	Asia
20	Semai	Asia
21	South Chinese	Asia
22	Bane	Africa
23	Bantu ne	Africa
24	Bantu nw	Africa
25	Bantu se	Africa

26	Bedik	Africa
27	Biaka	Africa
28	Fulani	Africa
29	Gur	Africa
30	Hadza	Africa
31	Hausa	Africa
32	Ibo	Africa
33	Khoi	Africa
34	Kru	Africa
35	Mbuti	Africa
36	Nilotic	Africa
37	Peul	Africa
38	Pygmoid	Africa
39	San Kung	Africa
40	Volta	Africa
41	Yoruba	Africa
42	Basque	Europe
43	Belgian	Europe
44	Czechoslovakia	Europe
45	Dutch	Europe
46	English	Europe
47	Finnish	Europe
48	French	Europe
49	German	Europe
50	Greek	Europe
51	Hungarian	Europe
52	Irish	Europe
53	Italian	Europe
54	Lapp Finnish	Europe
55	Norwegian	Europe
56	Polish	Europe
57	Portugese	Europe
58	Russian	Europe
59	Sweedish	Europe
60	Yugoslavian	Europe
61	Australian	Australia and pacific
62	Bougainville	Australia and pacific
63	Fiji	Australia and pacific
64	Luangiua	Australia and pacific
65	Malatia	Australia and pacific
66	Manus	Australia and pacific
67	Samoa	Australia and pacific
68	Society	Australia and pacific
69	Tokelau	Australia and pacific
70	Tolai	Australia and pacific
71	Anha	Australia and pacific

72	Awin	Australia and pacific
73	Highland E	Australia and pacific
74	Ok	Australia and pacific
75	Arawakan	North America, South America & Greenland
76	Aymara	North America, South America & Greenland
77	Bari	North America, South America & Greenland
78	Caingang	North America, South America & Greenland
79	Eskimo	North America, South America & Greenland

Table F

Data coverage by country

Countries		Year	Continents and sub-continents	Wasting	Stunting	Underweight
1	Afghanistan	1997	Asia (South-central Asia)	X	X	X
2	Albania	2000	Europe (Southern Europe)	X	X	X
3	Algeria	2000	Africa (Northern Africa)	X	X	X
4	Angola	2001	Africa (Middle Africa)	X	X	X
5	Argentina	1996	LAC (South America)	X	X	X
6	Armenia	2001	Asia (Western Asia)	X	X	X
7	Australia	1996	Oceania (Australia- New Zealand)	X	X	X
8	Azerbaijan	2000	Asia (Western Asia)	X	X	X
9	Bangladesh	2000	Asia (South-central Asia)	X	X	X
10	Benin	2001	Africa (Western Africa)	X	X	X
11	Bhutan	1999	Asia (South-central Asia)	X	X	X
12	Bolivia	1998	LAC (South America)	X	X	X
13	Bosnia and Herzegovina	2000	Europe (Southern Europe)	X	X	X
14	Botswana	2000	Africa (Southern Africa)	X	X	X
15	Brazil	1996	LAC (South America)	X	X	X
16	Burkina Faso	1999	Africa (Western Africa)	X	X	X
17	Burundi	2000	Africa (Eastern Africa)	X	X	X
18	Cambodia	2000	Asia (South-eastern Asia)	X	X	X
19	Cameroon	1998	Africa (Middle Africa)	X	X	X
20	Central African Republic	1995	Africa (Middle Africa)	X	X	X
21	Chad	2000	Africa (Middle Africa)	X	X	X
22	Chile	2001	LAC (South America)			
23	China	2000	Asia (Eastern Asia)	X	X	X
24	Colombia	2000	LAC (South America)	X	X	X
25	Comoros	2000	Africa (Eastern Africa)	X	X	X
26	Congo, Dem. Rep.	1995	Africa (Middle Africa)	X	X	X
27	Costa Rica	1996	LAC (Central America)	X	X	X
28	Côte d'Ivoire	1999	Africa (Western Africa)	X	X	X

29	Croatia	1996	Europe (Southern Europe)			X
30	Djibouti	1996	Africa (Eastern Africa)	X	X	X
31	Dominican Republic	2000	LAC (Caribbean)	X	X	X
32	Ecuador	1998	LAC (South America)			
33	Egypt, Arab Rep.	2000	Africa (Northern Africa)	X	X	X
34	El Salvador	1998	LAC (Central America)	X	X	X
35	Eritrea	2002	Africa (Eastern Africa)	X	X	X
36	Gabon	2001	Africa (Middle Africa)	X	X	X
37	Gambia, The	2000	Africa (Western Africa)	X	X	X
38	Georgia	1999	Asia (Western Asia)	X	X	X
39	Ghana	1999	Africa (Western Africa)	X	X	X
40	Guatemala	2000	LAC (Central America)	X	X	X
41	Guinea-Bissau	2000	Africa (Western Africa)	X	X	X
42	Guinea	2000	Africa (Western Africa)	X	X	X
43	Guyana	2000	LAC (South America)			
44	Haiti	2000	LAC (Caribbean)	X	X	X
45	Honduras	2001	LAC (Central America)	X	X	X
46	India	1999	Asia (South-central Asia)	X	X	X
47	Indonesia	1995	Asia (South-eastern Asia)	X	X	X
48	Iran, Islamic Rep.	1998	Asia (South-central Asia)	X	X	X
49	Iraq	2000	Asia (Western Asia)	X	X	X
50	Jamaica	1999	LAC (Caribbean)	X	X	X
51	Jordan	2002	Asia (Western Asia)	X	X	X
52	Kazakhstan	1999	Asia (South-central Asia)	X	X	X
53	Kenya	2000	Africa (Eastern Africa)	X	X	X
54	Korea, Dem. Rep.	2000	Asia (Eastern Asia)	X	X	X
55	Kuwait	1997	Asia (Western Asia)	X	X	X
56	Kyrgyz Republic	1997	Asia (South-central Asia)	X	X	X
57	Lao PDR	2000	Asia (South-eastern Asia)	X	X	X
58	Lebanon	1997	Asia (Western Asia)	X	X	X
59	Lesotho	2000	Africa (Southern Africa)	X	X	X
60	Liberia	2000	Africa (Western Africa)	X	X	X
61	Libya	1995	Africa (Northern Africa)	X	X	X
62	Macedonia, FYR	1999	Europe (Southern Europe)	X	X	X
63	Madagascar	1997	Africa (Eastern Africa)	X	X	X
64	Malawi	2000	Africa (Eastern Africa)	X	X	X
65	Malaysia	1999	Asia (South-eastern Asia)	X	X	X
66	Maldives	2001	Asia (South-central Asia)	X	X	X
67	Mali	2001	Africa (Western Africa)	X	X	X
68	Mauritania	2001	Africa (Western Africa)	X	X	X
69	Mauritius	1995	Africa (Eastern Africa)			
70	Mexico	1999	LAC (Central America)	X	X	X
71	Mongolia	2000	Asia (Eastern Asia)	X	X	X
72	Morocco	1997	Africa (Northern Africa)	X	X	X
73	Mozambique	1997	Africa (Eastern Africa)	X	X	X

74	Myanmar	2000	Asia (South-eastern Asia)	X	X	X
75	Namibia	2000	Africa (Southern Africa)	X	X	X
76	Nepal	2001	Asia (South-central Asia)	X	X	X
77	Nicaragua	2001	LAC (Central America)	X	X	X
78	Niger	2000	Africa (Western Africa)	X	X	X
79	Nigeria	1999	Africa (Western Africa)	X	X	X
80	Oman	1998	Asia (Western Asia)	X	X	X
81	Pakistan	2001	Asia (South-central Asia)	X	X	X
82	Panama	1997	LAC (Central America)	X	X	X
83	Peru	2000	LAC (South America)	X	X	X
84	Philippines	1998	Asia (South-eastern Asia)	X	X	X
85	Qatar	1995	Asia (Western Asia)	X	X	X
86	Romania	2000	Europe (Eastern Europe)	X	X	X
87	Russian Federation	1995	Europe (Eastern Europe)	X	X	X
88	Rwanda	2000	Africa (Eastern Africa)	X	X	X
89	Samoa	1999	Oceania (Polynesia)			
90	São Tomé and Principe	2000	Africa (Middle Africa)	X	X	X
91	Senegal	2000	Africa (Western Africa)	X	X	X
92	Serbia and Montenegro	2000	Europe (Southern Europe)	X	X	X
93	Sierra Leone	2000	Africa (Western Africa)	X	X	X
94	Singapore	2000	Asia (South-eastern Asia)	X	X	X
95	Somalia	2000	Africa (Eastern Africa)	X	X	X
96	South Africa	1999	Africa (Southern Africa)	X	X	X
97	Sri Lanka	2000	Asia (South-central Asia)	X	X	X
98	Sudan	2000	Africa (Northern Africa)	X	X	X
99	Syrian Arab Republic	2000	Asia (Western Asia)	X	X	X
100	Tajikistan	2000	Asia (South-central Asia)			
101	Tanzania	1999	Africa (Eastern Africa)	X	X	X
102	Thailand	1995	Asia (South-eastern Asia)	X	X	
103	Timor-Leste	2002	Asia (South-eastern Asia)	X	X	X
104	Togo	1998	Africa (Western Africa)	X	X	X
105	Trinidad and Tobago	2000	LAC (Caribbean)	X	X	X
106	Tunisia	1997	Africa (Northern Africa)	X	X	X
107	Turkey	1998	Asia (Western Asia)	X	X	X
108	Turkmenistan	2000	Asia (South-central Asia)	X	X	X
109	Uganda	2001	Africa (Eastern Africa)	X	X	X
110	Ukraine	2000	Europe (Eastern Europe)	X	X	X
111	Uzbekistan	2002	Asia (South-central Asia)	X	X	X
112	Venezuela, RB	2000	LAC (South America)	X	X	X
113	Vietnam	2000	Asia (South-eastern Asia)	X	X	X
114	West Bank and Gaza	1996	Asia (Western Asia)	X	X	X

115	Yemen, Rep.	1997	Asia (Western Asia)	X	X	X
116	Zambia	2002	Africa (Eastern Africa)	X	X	X
117	Zimbabwe	1999	Africa (Eastern Africa)	X	X	X

5. Inquiry into the Simultaneous Existence of Malnutrition and Overweight in India

Abstract

India is facing a double burden of overnutrition and undernutrition; hence, the combination of a high proportion of malnourished people and an increasing proportion of obesity needs further exploration. This paper focuses on the Body Mass Index of Indian women using National Family Health Survey to investigate the simultaneous existence of malnutrition, and overweight and obesity. The aim of this study is also to answer if urban and rural residence is an important predictor compared to standard of living. Moreover, the hypothesis of stunting leading to obesity was tested. The regression analysis results show that malnutrition is particularly serious for rural and illiterate women with low standard of living. Obesity is becoming a substantial problem for urban, well-educated, women with high standard of living. Quantile regression uncovers the varying impact of socio-economic factors across different BMI quantile groups. The regional difference in specific BMI quantiles obtained through quantile regression is pivotal in terms of policy recommendation.

Keywords: India, stunting, obesity, underweight, nutritional transition, quantile regression

5.1. Introduction

Many developing countries face a double burden of overnutrition and undernutrition contrary to the general view that malnutrition is typical of these countries. Several researchers highlighted that malnutrition is highly prevalent in developing countries, despite increasing overweight proportions. Nutritional transition occurs due to large shifts in diet and physical activity patterns, particularly in the last one or two decades of the twentieth century (Popkin et al., 2001; Griffiths and Bently 2001; Popkin, 2003). These changes affect on average stature, weight and life expectancy as well as morbidity through nutrition-related non-communicable diseases.

A recent study by Mendez et al. (2005) shows that India is one of the few exceptions - in their sample of 36 developing countries[29] - where malnutrition prevalence is higher compared to overweight problems. They emphasized that India exhibited a high persistence of undernutrition (21.3 percent of urban and 48.2 percent of rural women) compared to other developing countries especially in the rural areas (0.7-16.5 in urban areas and 0.6-21.5 percent in rural areas).

In recent years, there has been a remarkable increase of interest in the nutritional problems of women in developing countries- including India- where 790 million people do not have enough to eat. India has 204 million people who are facing starvation (FAO, 1999). Contrastingly, the prevalence of overweight and obesity increases in India and

[29] 19 countries in sub-Saharan Africa, 18 in Latin America and the Caribbean (including Brazil and Mexico), 2 in East and South Asia (China and India), 3 in Central Asia (all former Soviet republics), and 4 in North Africa and the Middle East (including Egypt and Turkey)

many developing countries. This is a phenomenon that is gaining more attention. However, until now there is still a dearth of research regarding the simultaneous existence of both malnutrition and obesity in India.

With more than a quarter of the population below the poverty line, chronic poverty seems to be disproportionately high among highly marginalized groups such as scheduled castes (Untouchables in the past), scheduled tribes, the elderly, women and people with disabilities (Mehta and Shah, 2003). Multiple disadvantages tend to reinforce mutually so that people in these groups stuck by one factor are likely to face others as well (De Hann and Lipton, 1998). For instance most of the people living in the scheduled castes and tribes have lowest social status and are likely to have low education, low income and poor health.

In contrast, diet-related diseases including obesity, diabetes mellitus, cardio vascular disease, hypertension, and stroke are increasing in India due to changes in dietary patterns and life style (Anate et al., 1998). Rapid changes in diets and lifestyles resulting from industrialization, urbanization, economic development and globalization have a significant impact on the nutritional status of populations with nutritional transition (Griffiths and Bentley, 2001; Shetty, 2002).

However, India has not yet exhibited an increase in the prevalence of obesity among urban poor that is characteristically observed in Chile, Brazil, and Morocco. Albala et al. (2002) showed that the largest burden of obesity has been placed on the poor in Chile. In case of Brazilian women as noted by Monteiro et al. (2002) obesity has substituted undernutrition[30] and the shift in obesity among poor is already occurring for Brazilian women (not yet men). In Morocco – as stated by Benjelloun (2002) - income is positively associated with obesity, whereas education is inversely related with obesity. However, much less is known about the double burden of Indian adults.

Most of the nutritional research in India has concentrated either on malnutrition or overweight. Due to this fact, very little has been done on the real emerging problem: a mixture of malnutrition and overweight. Moreover, most of the research is focused on certain vulnerable groups, states and regions (for example Griffiths and Bentley, 2001; Shukla et al, 2002). Summing up, there is still dearth of research on the dangerous combination of an already existing high proportion of malnutrition among vulnerable groups, and an alarmingly increasing proportion of overweight and obese population among elite groups in India.

5.2. Overview of food consumption in India

How did Indian calorie consumption change overtime? To answer this question calorie consumption data of the past 35 years were studied. Calorie consumption per person per day data -using Food and Agriculture Organization (FAO, 2005)- from 1967-2002 for India shows an increase from 2041 calories to 2420 calories in India, though it is still lower compared to other nutritional transition countries like China, Brazil, and developed country like USA (Table 1). Protein consumption stagnated in India over time,

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[30] Previously poor women in Brazil had higher malnutrition rates and currently they are having obesity issues which prove nutritional transition in a higher level compared to India.

whereas fat consumption increased strongly – but it is far from other countries with nutritional transition like Brazil and China.

The share of total dietary consumption from various food products in India indicates that carbohydrates still plays a major role (Figure 1) compared to other countries, though its share of total dietary energy declined slightly overtime. The share of energy from pulses - that forms a major source of vegetable protein among Indians - declined considerably, whereas the share of energy from fats among Indians increased continuously from 1969-2002 (Figure 2). Unfortunately, we do not have food consumption data by region, religion and ethnicity to study the groups that consume high caloric and fatty food.

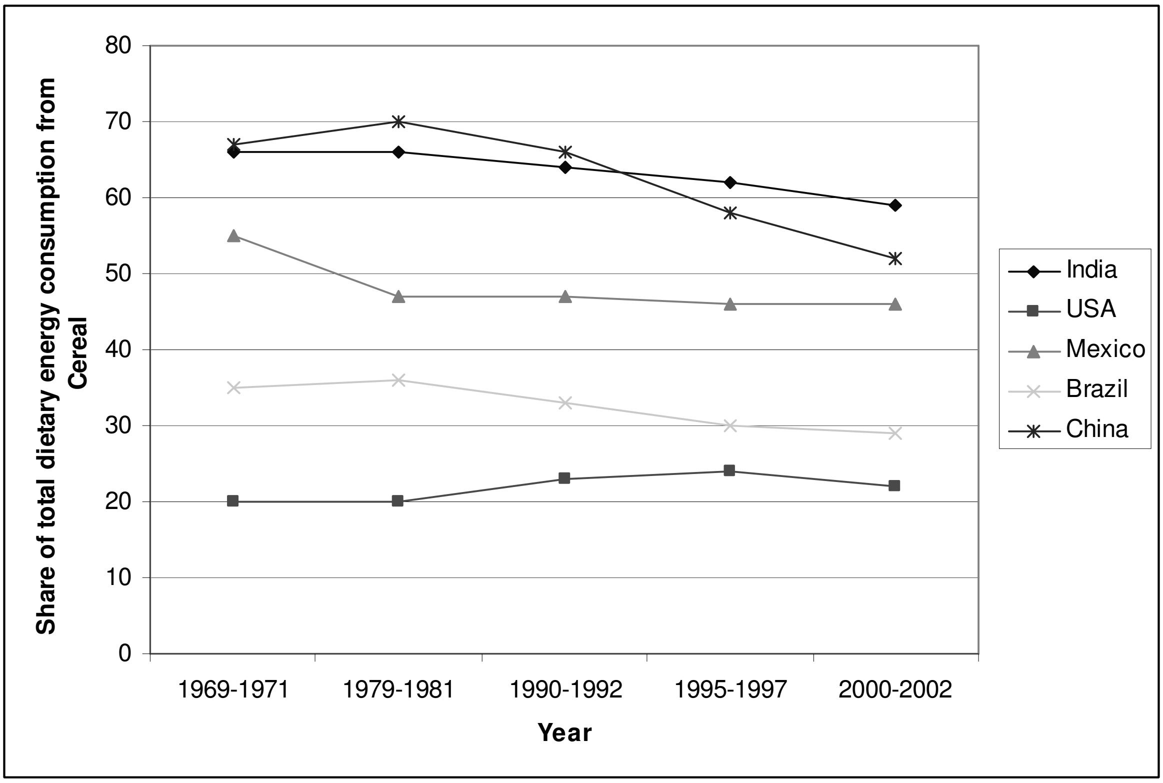

Figure 1: Share of total dietary energy consumption from Cereal and related products
Source: FAOSTAT

Table 1: Food consumption measured in gram/per person /per day for proteins and fat

	1967-71	1990-92	2000-2002
Calorie			
India	2041	2366	2420
China	1994	2707	2958
USA	3035	3502	3794
Brazil	2428	2812	3010
Protein			
India	51	57	56
China	47	66	82
USA	99	108	114
Brazil	61	70	81
Fat			
India	30	41	51
China	24	55	87
USA	119	140	157
Brazil	46	84	92

Source: FAOSTAT

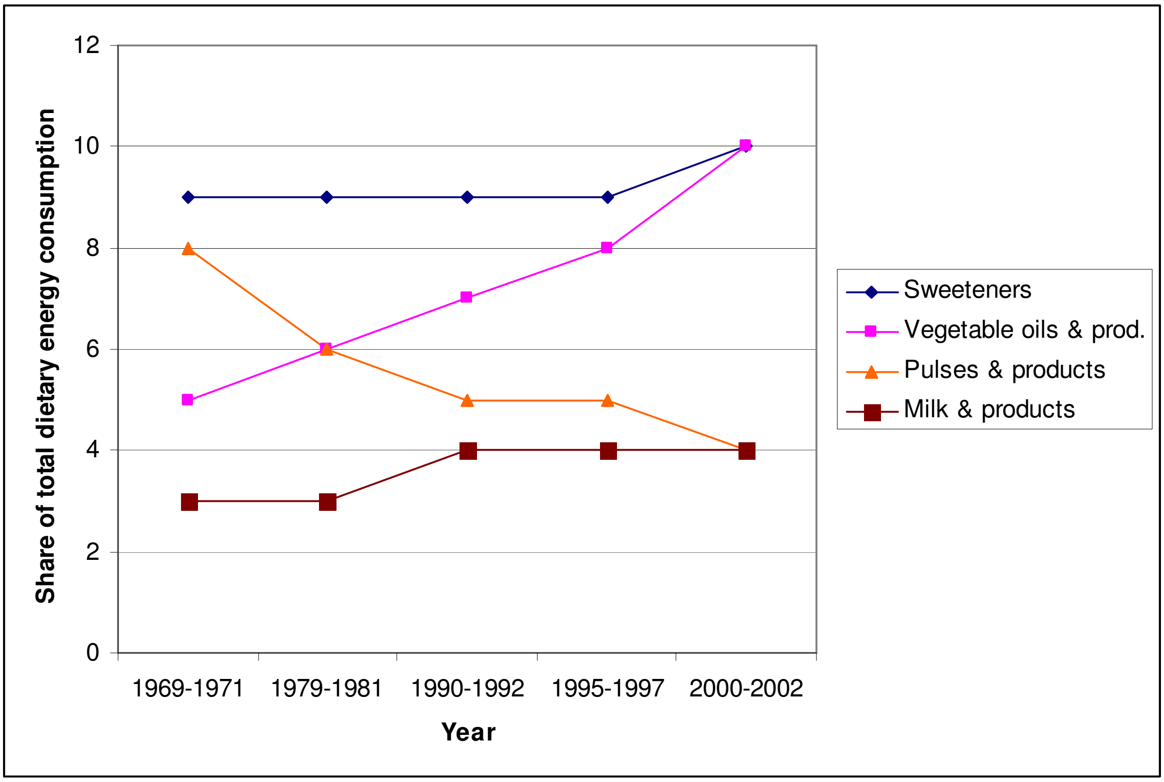

Figure 2: Share of various food items in total dietary energy consumption in India (FAOSTAT)

5.3. Hypotheses

Many questions in this area of research still remained unravelled like: Which states of India have the highest double burden? Is urban and rural residence an important predictor of BMI compared to standard of living? Is there any difference in the occurrence of this double burden by religion and caste? How to study effectively the nutritional transition phenomenon? What differences do we see when we use macro economic data compared to individual data? What is the best econometric method that can be used to investigate this double burden efficiently? Do we see this shift due to Indians changing living standards since the childhood?

All the issues stated above are classified into three important hypotheses that question the impact of regional, social, and economic factors on malnutrition, and overnutrition using ‘individual data’. At the same time while discussing hypotheses using macro data some scatter plots were made to show sometimes macro data does not really show the in-depth picture especially in a country like India where there is very high between country and within country inequality in terms of indicators like calorie intake, income and education.

5.3.1. Hypothesis (1)

Urbanization seems to be an important factor for determining overweight and obesity (Griffiths and Bentley, 2001; Shetty, 2002). Popkin (1998) hypothesised that an increase in urbanization leads to changes in diet regarding fat content of food, animal products, sugar, and polished grains, along with more sedentary life style, compared to the rural counter parts. Along with urbanization, another commonly discussed indicator that determines the nutritional status of individuals is the standard of living, measured in terms of income. Research on the relation between fat consumption and income in Philippines (Bisgrove and Popkin, 1996), China (Ma and Popkin, 1995), and India (Shetty, 2001) shows an increase in fat consumption with income. In addition, Drewnowski and Popkin (1997) find a strong relation between income and fat consumption on the individual and household level.

Contrarily, simple scatter plots (Figure 3)[31] using state level information illustrate that there is no relation between urbanisation and obesity in India, and there seems to be a positive relation between urbanisation and underweight. Popkin (1998) argued that urban women have higher obesity, whereas simple scatter plots do not confirm this relation. To confirm the hypothesis -whether being urban and rich leads to obesity-individual BMI data were tested with the compound variable of urban/rural place of residence and standard of living (details related to the standard of living variable is shown in short foot note 9 and in detail in chapter 3).

5.3.2. Hypothesis (2)

Stunting in childhood continues into adulthood, resulting in adults of short stature (Darnton-Hill & Coyne, 1998; Popkin et al., 1996; Scrimshaw, 1995) and increases the risk of obesity and cardiovascular diseases. Ravelli et al. (1999) argue that undernutrition

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[31] Data of aggregate figures of state wise obesity and malnutrition are taken from National Family Health Survey whereas Urbanization (percent of urban population) is taken from Government of India statistics

during early gestation was associated with higher BMI (Body Mass Index[32]) and higher waist circumference in 50 year-old women.

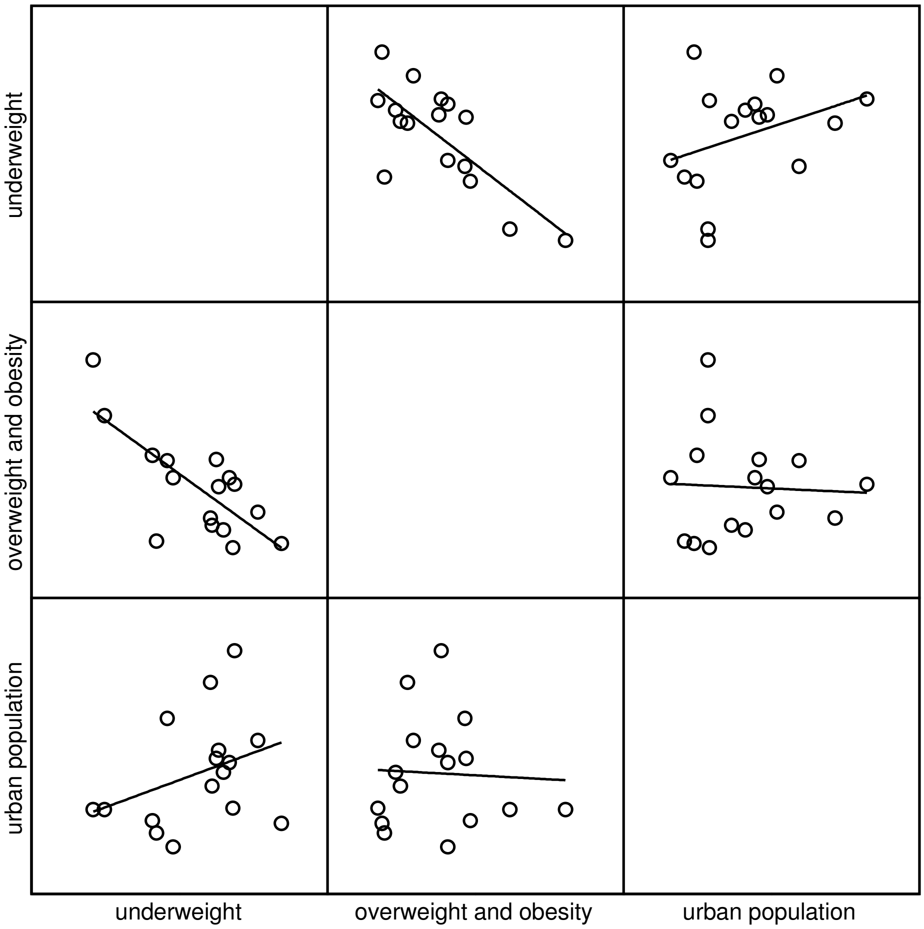

Figure 3: Scatterplots show the relation between urbanization and nutritional status.

A recent study by Florencio et al. (2001) in Alagoas, one of the poorest states in Brazil, found a strong coexistence of stunting and obesity. Nearly 30% of the stunted Alagoas individuals suffered from overweight/obesity. The related concept of a 'thrifty phenotype' is perhaps of much greater immediate concern in resource-poor countries according to Prentice. The term 'thrifty phenotype' was coined by Hales and Barker to

[32] From now on Body Mass Index would be termed as BMI

describe the disadapted metabolic state arising as a consequence of a fetus that has been undernourished and, hence, forced to adopt a series of survival strategies appropriate to its frugal early nutrient supply but maladaptive if nutritional conditions improve later in life (Prentice 2003).

Furthermore, these research findings suggest that obesity is possibly occurring in India as an outcome of undernutrition in the early life. Even though we will test this hypothesis using individual data, it is interesting to see on the state level by plotting the prevalence of obesity by state domestic product. Based on the scatter gram of state development products (here after would be named SDP) and nutritional status, (Figure 4 and 5[33]) we can see that high levels of SDP were associated with a high percentage of overweight and obese people, whereas underweight and SDP have a negative relation.

On an aggregated level we can observe the relation between the percentage of women that are below 145 cm[34] and prevalence of overweight in 16 major states of India to have an overview (Figure 6).[35] Interestingly, the scatter plot reveals a negative interrelation between prevalence of stunting and the proportion of overweight. However, the empirical models could confirm or correct the impression obtained from analyzing simple scatter plots and hence provides a more precise picture. So we will test this hypothesis whether stunted people in India are more obese by using individual information.

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[33] Aggregate data for nutrition is taken from National Family Health Survey-2 whereas SDP data are taken from Government of India statistics for the year 2001-2002

[34] Women below 145cm were taken as stunted women as per National Family Health Survey-2

[35] Aggregate level data for this figures are taken from National Family Health Survey-2

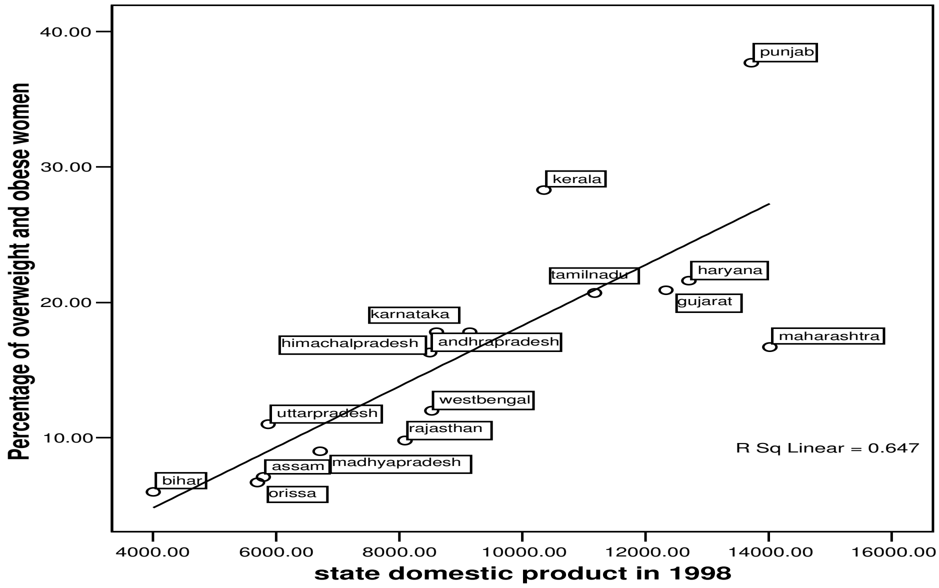

Figure 4: Scatterplot of state domestic product (SDP) and overweight and obesity

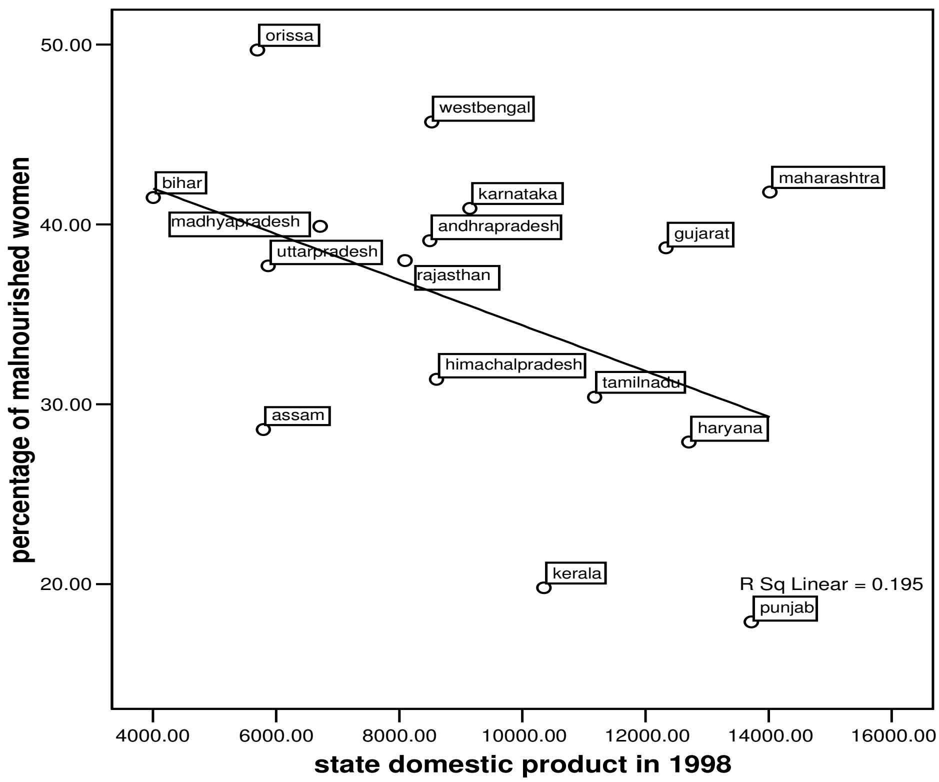

Figure 5: Scatterplot between state domestic product and malnutrition

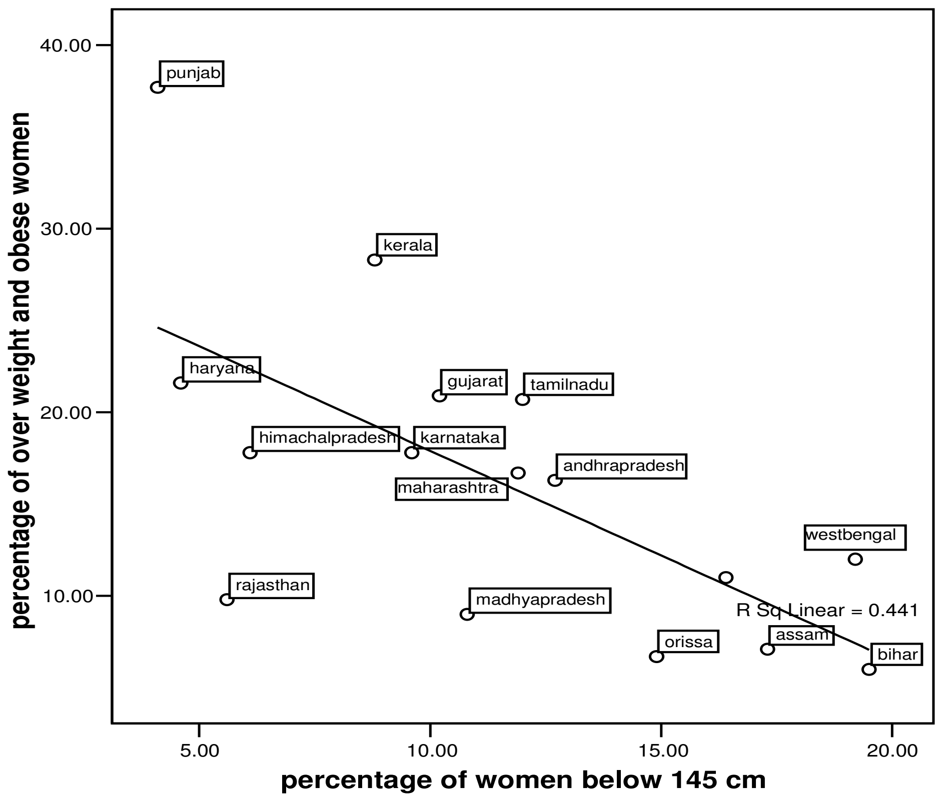

Figure 6: Scatterplot between stunting, and overweight and obesity

5.3.3. Hypothesis (3)

The third hypothesis revolves around the empirical way of capturing the double burden. Binary and multinominal logistic models and Ordinary Least Square (OLS) regressions are commonly used analytical tools to measure the impact of various socio-economic variables on nutritional status. However, we can argue that especially in countries with nutritional transition, quantile regressions represent a more efficient way of uncovering the partial impact of socioeconomic factors. The analysis is not focused on the average observation as in OLS regressions – but we incorporate more information using the distribution (quantiles) of BMI. This hypothesis states that quantile regression (Table 7) is the best way of investigating dual existence of malnutrition and under nutrition or not. For instance place of residence (rural or urban) and standard of living might affect the center and tails of the distribution in a different way. Hence QR will describe the distributional impact of explanatory variables on different quantiles of the dependent variable.

5.4. Data and methodology

As discussed earlier BMI is used to focus on the nutritional transition in India. Nutritionists have found it convenient to analyse weight given height (Body Mass Index), which is a popular indicator, used for assessing the contemporaneous health of the adult population. The BMI, which is defined as the weight in kilograms divided by the height in meters squared (kg/m2) can be used to assess both thinness and obesity. This section will discuss the data source and some methodological issues.

As per the World Health Organization's BMI classification (World Health Organization, 1985) 6 groups have been identified. For Women, a BMI less than 16 is classified as very thin, BMI 16-16.99 is classified as moderately thin, a BMI 17-18.49 is classified as mildly thin, a BMI 18.5-24.9 is classified as normal, a BMI 25-29.9 is classified as overweight, and finally a BMI above 29.9 is in the obese category.

5.4.1. Data

This paper focuses on examining the nutritional status of Indian women with anthropometric indicator BMI using the National Family Health Survey -2 (NFHS-2[36]). National Family Health Survey-2 is a large-scale, multi-round survey conducted in a representative sample of households throughout India. The NFHS is a collaborative project of the International Institute for Population Sciences, India, ORC Macro, USA, and the East-West Center, USA. NFHS was funded by the United States Agency for International Development (USAID) with supplementary support from the United Nations Children's Fund (UNICEF) for the nutrition part (International Institute for Population Sciences, 2000).

The survey covers a representative sample of about 91,000 ever-married women in the age group of 15-49 years from 26 states in India. They were covered in two phases, the first starting in November 1998 and the second in March 1999. The survey provides state-level estimates of demographic and health parameters as well as data on various socioeconomic components.

Health investigators attached to interviewing teams were given additional specialised training on measuring height and weight in a centralized training programme conducted by International Institute for Population Sciences (IIPS) in collaboration with the All India Institute of Medical Sciences (AIIMS), New Delhi. This specialized training included classroom training and extensive field practice in schools and communities.

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[36] From now on NFHS-2 would be used to refer to National Family Health Survey-2

In the NFHS-2 survey, BMI index excluded women who were pregnant at the time of the survey and also women who had given birth during the two months preceding the survey. The mean BMI for women in India is 20.3, varying within the narrow range of 19–23 for the different groups (International Institute for Population Sciences and ORC Macro, 2000). In India, more than one-third (36 percent) of women have a BMI below 18.5, indicating a high prevalence of nutritional deficiency.

5.4.2. Variables in the multivariate analysis

This paper attempts to study the characteristics of nutritional transition in India by taking into account region[37], education, standard of living and place of residence, religion and ethnicity using binary logistic regression and quantile regression.

Age and age square

Using age as an explanatory variable we can study the changing probability of malnourishment and obesity with age. Age Square focuses on the nonlinear relation between age and BMI. Previous research mostly showed that BMI increases with age (Flegal et al., 2003).

Region

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[37] The classification of regions is based on the NFHS format

North India: Delhi, Haryana, Himachal Pradesh, Jammu and Kashmir, Punjab, Rajasthan

Central India: Madhya Pradesh

East India: Bihar, Orissa, West Bengal

North east India: Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim

West India: Goa, Gujarat, Maharashtra

South: Andhra Pradesh, Tamil Nadu, Kerala, Karnataka

India is divided into North, South, East, West, Northeast, and Central based on its geographical and culture related factors. For policy implications differential impact of regional political, policy oriented and cultural factors on health status can be extremely helpful to improve wellbeing of people. The regional dummies hence will prove which states are better in coping with malnutrition and which ones have higher simultaneous existence of malnutrition and obesity.

Place of residence and SLI compound variable

A compound variable for place of residence and SLI[38] is constructed which has 6 categories and will test hypothesis (1). This compound variable allowed to test whether there are differences in the likelihood of being underweight/overweight between socioeconomic groups both within urban and rural areas. As many researchers emphasised and reemphasised the role of urbanization (Popkin, 1993; Mendez et al., 2005), this compound variable throws direct light on urban rural differences in the occurrence of underweight/overweight between different categories of SLI.

Religion

For the logistic regression six categories (Hindu, Muslim, Christian, Jain, Sikh and others) of religion were used whereas for quantile regression only five categories (Hindu, Muslim, Christian, Jain, and others) were taken into consideration. Use of religion in our regression can help us to capture different food habits or cultural differences that cannot be captured by the other explanatory variables.

[38] SLI summary measure is calculated by adding the following scores for each household. More information related to the construction of this index is available in Chapter 3.
[38] Type of place of residence has rural and urban categories.

Ethnicity/Caste

This variable controls for caste differences in India. Women from the sample belong to 'Scheduled Caste', 'Scheduled Tribe' (have low socioeconomic status like Scheduled Caste), 'Other Backward Castes' (slightly lower in terms of social status), or higher castes.

The typical characteristics of tribes are simplicity of technology, geographical isolation, distinct culture, shyness to contact with the rest of society and economic backwardness. Scheduled caste and tribes have low socioeconomic status and were treated as untouchables till it was abolished in the second half of 20^{th} century. Moreover, they are deprived of education and many of them still are small and marginal farmers, and rural labourers.

Exposure to mass media

This variable can act as proxy for availability of leisure time and women's sedentary lifestyle to some extent. Women who read news paper, watch television, listen to radio, and watch movies regularly belong to 'exposure to all components of mass media' category. The other two categories are exposure to some components, and no exposure to mass media.

Employment

This variable comprises of women who do not work, who work without getting paid, who work for salary, and self-employed women. This will help us in assessing the impact of employment of women on their nutritional status.

Education of women and their husbands

This variable helps us to test whether the education of woman and her husband has any significant impact on her nutritional status as education comes out as a significant variable for deciding health by many researchers.

Height

Using height as an explanatory variable one can test using both logistic regression and quantile regression to see whether shorter people are more obese. Use of height as an explanatory variable of BMI is the first attempt to see if short people have higher BMI.

Number of household members

This variable can be used to study not only allocation within household but also the impact of the family size on the nutritional status of women.

5.4.3. Data analyses

Bivariate and multivariate techniques are used in this study to explore the nutritional status of women of different socioeconomic background. For showing the malnutrition levels chronic energy deficiency[39] is selected as an indicator which is usually indicated by a BMI of less than 18.5. In this paper, this six fold classification was used only for few bivariate analyses in order to have an overview of categories of malnutrition and overweight. For bivariate analyses all women are considered whereas for the binary logistic regression and the Quantile Regression (abbreviated as QR hereafter) only adults above age 20 were considered. Women that are below 20 were

[39] From now on a BMI less than 18.5, chronic energy deficiency and malnutrition terms are used as synonyms.

removed as their final height is still not determined and in the case of malnourished individuals growth can prolong till the age of 24 (Guntupalli and Baten, 2006). Moreover, extreme cases of BMI and height that seems implausible were removed from the data.

5.4.3.1. Binary Logistic regression

The first part of this section focuses on binary logistic regression, and later we shift to quantile regression. Binary logistic regression analysis (Table 5 and 6) is used to estimate the predicted probability of having nutritional problems. Moreover, using this methodology we can identify the probability of occurrence of underweight or overweight in the various socioeconomic, regional categories compared to the reference category. In total, 35 percent of the sample was malnourished and 11 percent are either overweight or obese. Two separate regressions were run for malnourishment, and overweight and obesity comparing to normal individuals. The binary logistic regression model for malnutrition takes women with a BMI below 18.5 as malnourished whereas the logistic regression model for overweight and obesity takes women with a BMI above 25.[40] In both the models, malnourished and overweight women were compared to normal women.

Models for malnutrition assessment

Variables included in the model for assessing malnutrition can be classified into four main categories: region, compound variable of rural/urban residence and standard of living, demographic variables, social variables, and economic variables.

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[40] BMI below 18.5 is classified as malnutrition and BMI above 25 is taken as overweight and obese category. Both the models have women with normal BMI as their reference category.

Model estimation for malnutrition

Malnutrition = a_0 + a_1(woman's age) + a_2(square of woman's age) + a_3(region) + a_4 (compound variable of standard of living and type of place of residence) + a_5(religion) +a_6(caste) + a_7(employment) + a_8(women's education) + a_9(husband's education) + a_{10}(stunting in childhood) + a_{10}(number of household members) + ϵ

Model estimation for overweight and obesity

Overweight and obesity = b_0 + b_1(woman's age) + b_2(square of woman's age) + b_3(region) + b_4(compound variable of standard of living and type of place of residence) + b_5(religion) + b_6(caste) + b_7(employment) + b_8(women's education) + b_9(husband's education) + b_{10}(number of household members) + ϵ

5.4.3.2. Quantile regression

In the logistic regression (Table 5 and 6) we consider categories of the BMI although we have individual BMI data available. In this way we lose information relating to the distribution of BMI as we divide the whole data into 2 categories only. Moreover, we cannot use OLS regression as it focuses on the mean of the distribution of BMI and this does not provide much information on other parts of the distribution (Buchinsky, 1998; Koenker and Hallock, 2001). Especially in terms of policy interventions exclusive emphasis on the mean may not provide accurate design. In specific, we cannot use the policy issues for addressing problems of malnourishment that occur at the lower tail of BMI by seeing OLS which focuses on the mean. To overcome this problem, QR is used to estimate the explanatory variables' effects on the BMI level over the whole distribution. Also why should we assume that BMI is affected in all groups in a similar way?

QR is an estimation method which allows the regression line to pass through different quantiles of the distribution of the dependent variable. In this way, QR gives more complete picture of relation between dependent variable and its covariates. QR is also efficient compared to the logistic regression model due to the fact that there is growing consensus about cut-off point (the BMI level that decides obesity or malnutrition status of a person) of BMI for Indians. We cannot asses health status of people based on too high and too low BMI by classifying them into malnutrition and obesity categories. Moreover, these cut-off values are referential rather than definitive and, malnutrition and obesity is more a matter of degree.

Chamukuttan et al. (2003) argued that the cut-off value for healthy urban Indian is less than 23 kg/m^2 (which is lower compared to WHO cut-off value 25). Their definition of cut-off value for normal BMI depends on identifying the risk association with diabetes which is strongly associated with BMI (Chamukuttan et al., 2003). Shetty (2002) also emphasized that BMI does not provide a good indicator of body fat for any given BMI among Indians. Increasing BMI is associated with central adiposity[41] and higher waist/hip ratios along with a risk of non communicable diseases appearing at much lower BMI ($<25 kg/m^2$) than any other population groups. Research of both Shetty and Chamukuttan et al. leads to the direction that the true problem of obesity using BMI <25 was not

[41] Adipose tissue is an anatomical term for loose connective tissue composed of adipocytes. Its main role is to store energy in the form of fat, although it also cushions and insulates the body. Adiposity causes an increase of body fat to more than twice the normal level.

exaggerated and is in fact understated by taking higher reference category. In this context where the cut off value is uncertain, QR is a good estimation method.

The OLS estimator is strongly influenced by outliers due to the fact that large squared residuals are generated. Median regression can be robust to outliers compared to OLS[42]. Least Absolute Deviation approach is used in quantile regression instead of Ordinary Least Square approach. For quantiles above the median, a higher weight is placed in the residuals above the quantile than on the residuals below the quantile.[43] This pushes the minimization up above the median and for quantiles below the median less weight is placed on residuals above the quantile. Unlike OLS, QR is robust to extreme observations. In case of the NFHS data, the BMI is not normally distributed (Figure 9) and this argument also supports use of the QR method.

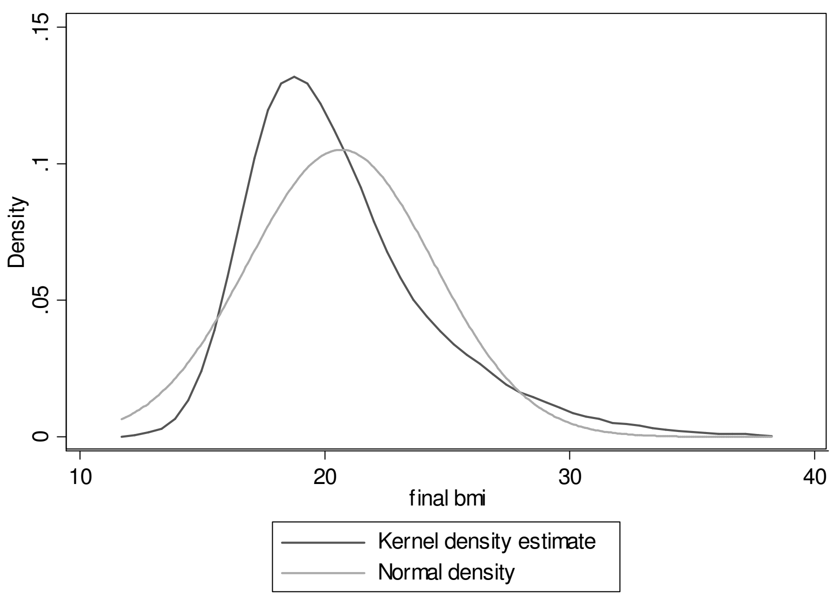

Figure 9: Test of normal distribution of the sample

[43] Chapter 3 provides more information about LAD approach and equations of Quantile Regression.

5.5. Prevalence of malnutrition, and overweight and obesity

Before doing the main analytical part it is interesting to see the percentage of women in all BMI categories by socio-economic characteristics.

5.5.1. Malnutrition

The nutritional status is appalling for the women belonging to low standard of living where half of the women suffer from chronic energy deficiency (Table 2). Little more than one-third of the women from medium standard of living households and nearly one fifth of the women from high standard of living households suffer from malnutrition. Summing up, the overall prevalence of nutritional deficiency is high among Indian adult women.

The Central region (Madhya Pradesh and Uttar Pradesh) has 38-40 percent of women with nutritional deficiency and the Eastern region has 42-46 percent of women with malnutrition problems. Among Northern states, Rajasthan has the highest number of women with chronic energy deficiency (38%). In the Southern region, Andhra Pradesh and Karnataka have $2/5^{th}$ of the women suffering from malnutrition. In addition, all the states mentioned above have high prevalence of malnutrition compared with the average malnutrition prevalence of India (Figure 7 & 8).

State level BMI categorical prevalence sates from the original data are shown in appendix.

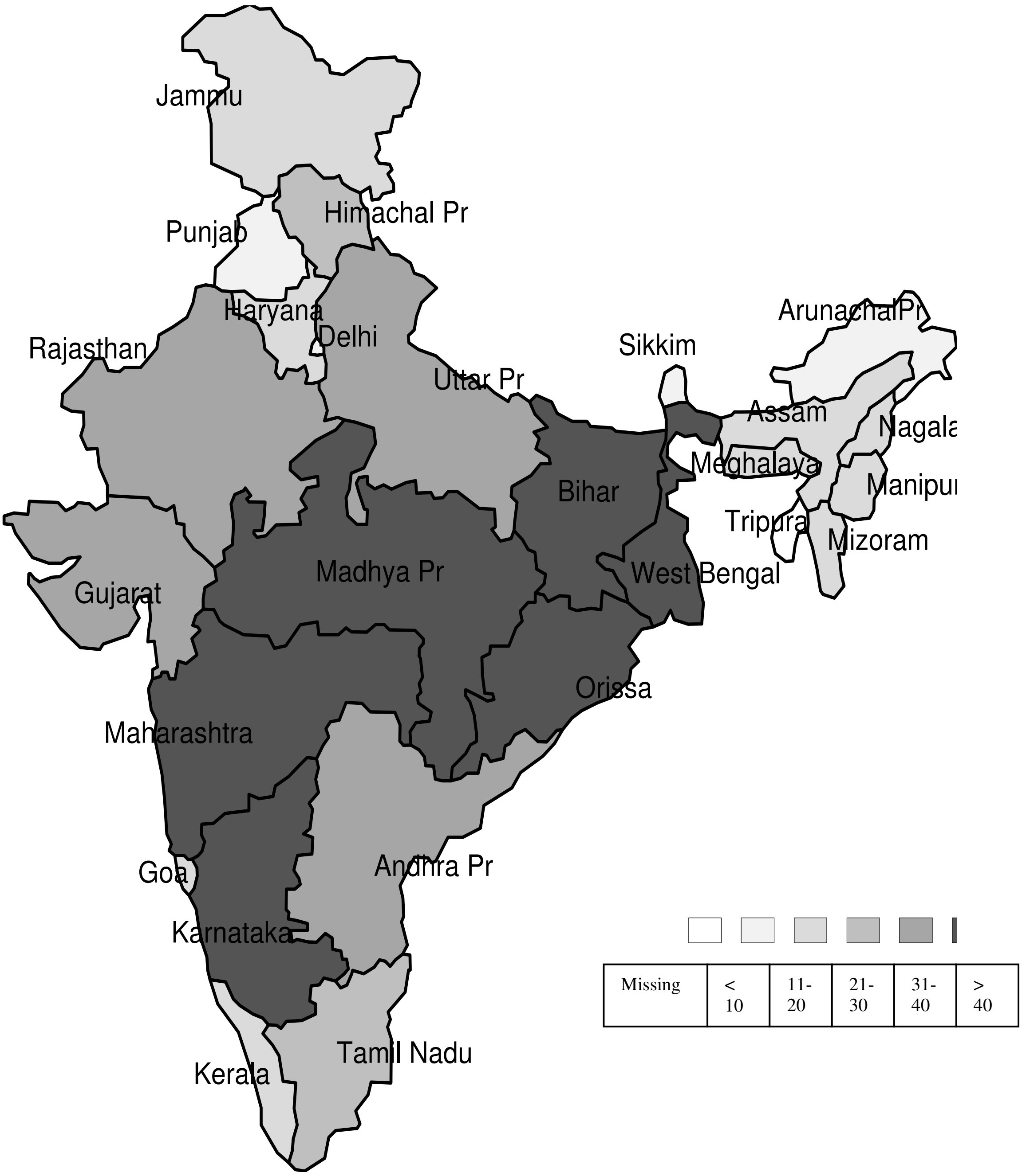

Figure 7: Map of Indian States with proportion of malnourished women

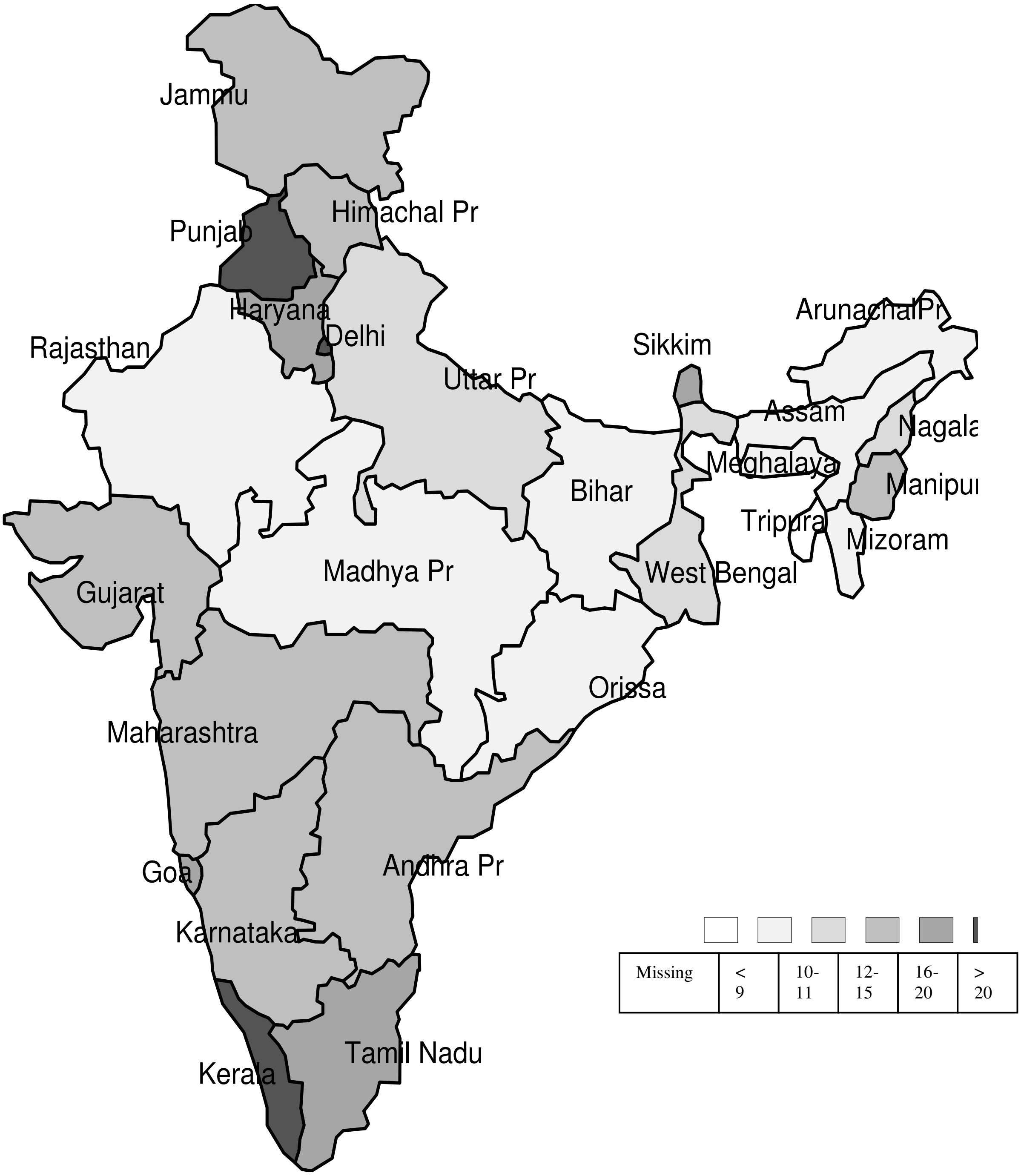

Figure 8: Map of Indian States with proportion of overweight women

Table 2: Among ever-married women, percentage with specified levels of BMI by selected background characteristics, India, 1998-99

Background characteristics	**Mean**	**Under weight**	**Normal**	**Over weight**	**Obese**
Age					
15-19	19.1	43.8	53.8	2.2	0.3
20-24	19.3	44.1	50.6	4.5	0.9
25-29	19.8	41.0	48.1	8.7	2.2
30-34	20.4	36.3	47.5	12.2	4.0
35-39	20.9	32.9	46.8	14.9	5.4
40-44	21.1	32.7	44.1	17.0	6.2
45-49	21.3	31.1	44.1	17.0	7.8
Standard of living					
Low	18.9	50.1	45.7	3.5	0.7
Medium	20.1	37.5	49.9	10.0	2.6
High	22.7	18.4	46.2	24.6	10.8
Residence					
Urban	22.1	23.7	45.2	22.0	9.1
Rural	19.6	42.6	48.7	6.9	1.7
Education					
Illiterate	19.4	44.6	47.6	6.3	1.6
Literate, < middle school complete	20.6	34.2	47.9	13.2	4.6
Middle school complete	21.1	29.6	49.1	15.9	5.4
High school complete and above	22.6	18.7	47.3	23.9	10.1
Religion					
Hindu	20.1	38.7	47.8	10.1	3.4
Muslim	20.5	35.7	47.6	12.4	4.3
Christian	21.4	26.0	50.8	17.5	5.7
Sikh	23.0	17.8	44.5	26.2	11.5
Jain	23.5	16.5	41.0	28.8	13.7
Buddhist/Neo-Buddhist	20.3	35.6	49.2	10.9	4.2
Other	18.8	58.9	34.0	5.7	1.4
Caste/Tribe					
Scheduled caste	19.5	44.1	47.1	7.1	1.7
Scheduled tribe	19.1	48.1	46.4	4.5	0.9
Other backward class	20.1	37.5	49.2	10.2	3.1
Other	21.0	32.1	47.2	14.8	5.9
Work status					
Work for Family	19.4	44.0	48.2	6.3	1.6
Employed by someone else	19.7	46.1	44.6	7.1	2.1
Self-employed	20.4	36.8	46.0	12.9	4.3
Not worked in the past 12 months	20.7	33.3	48.9	13.1	4.7

Source: National Family Health Survey-2

Table 3: Among ever-married women, percentage with specified levels of BMI by place of residence and standard of living (SLI), India, 1998-99

BMI	Total	Rural			Urban		
		Low SLI	MediumSli	HighSli	Low Sli	MediumSli	HighSli
<16	6.8	10.2	6.9	3.5	9.8	5.4	1.6
16-16.99	8.5	12.0	9.2	5.6	10.0	5.9	2.8
17-18.49	19.6	25.8	21.9	13.7	22.4	14.3	7.2
18.5-24.99	53.9	49.8	55.9	58.8	51.5	56.7	52.4
25.0-29.99	8.8	2.0	5.3	14.9	5.3	14.2	26.2
>30	2.3	0.3	0.9	3.6	1.1	3.5	9.8
Total (n)	74541	21535	25375	7244	2530	9202	8655

Source: National Family Health Survey-2

Table 4: Among ever-married women, percentage with specified levels of BMI major regions of India, 1998-99

BMI	Total	North	Central	East	NorthEast	West	South
<16	6.8	4.0	5.8	8.5	4.2	9.0	6.3
16-16.99	8.6	6.4	8.6	10.2	5.1	9.5	8.1
17-18.49	19.6	16.3	21.7	23.5	16.4	18.8	17.0
18.5-24.99	54.0	56.7	56.4	52.0	68.8	49.0	53.4
25.0-29.99	8.8	12.3	6.0	5.0	4.6	10.2	12.2
>30	2.3	4.3	1.5	0.8	0.9	3.5	2.9
Total (n)	75324	9504	14525	17147	2680	11594	19874

Source: National Family Health Survey-2

The proportion of severely thin and moderately thin women is higher from rural and urban low standard of living households (Table 4). Eastern and Western India have the highest proportion of severely and moderately thin women (Table 4). In summary, nutritional problems are particularly serious for rural, illiterate, and working women that are not self-employed. Scheduled caste and scheduled tribe women also seem to suffer from the lack of nutrition which is expected due to their lower socioeconomic status. This research strongly supports the view that the social structural factors in India predispose certain groups to long-term poverty, discrimination and deprivation. As expected, women who live in households with a low standard of living seem to suffer from malnutrition.

The percentage of women having malnutrition problems decreases when one moves from age 20 to age 49 which is not surprising based on previous literature women (Table 2). Chronic energy deficiency is also prevalent among the rural women (43 %) compared with the urban women (24 %). Nearly two fifth of Hindu women, two thirds of Muslim women and one fourth of Christian women have a low BMI. Furthermore, malnutrition is prevalent among women from scheduled caste (44 %) and scheduled tribe (48 %) compared to women belonging to other backward castes (38 %) and higher castes (32 %) (Table 2).

Literacy and malnutrition seem to have a very strong negative relation. Malnutrition is substantially prevalent among illiterate women (44.6%) and this gradually decreases steadily with increasing education. The working status of women seems to play a very important role in deciding BMI where working women seem to be on the unfavourable side. Chronic energy deficiency is considerably prevalent among women who are currently working (44.3%) as compared to women who have not worked in the past twelve months (33.3%). Among working women, the prevalence of malnutrition is low among self-employed women (36.8 %) compared to women who are employed by someone else (44%) (Table 2).

5.5.1.1. Determinants of Malnutrition

The results of the logistic regression model comparing underweight women with those of normal BMI are shown in Table 5. Odd ratios are given in the table with 95 % confidence intervals. Women from Western and Eastern regions have the highest odds of being malnourished whereas women from the North-east India have the lowest probabilities of being malnourished. Women from rural and low standard of living have the highest odds of being malnourished. Among the demographic variables, age as expected played a significant role in determining the malnutrition and younger women have higher odds of being malnourished compared to the older women. This result is similar compared to previous studies.

The religion variable shows that the probability of being underweight is low among women belonging to Christian and Sikh women compared to other women. Scheduled caste and scheduled tribes have high odds of being malnourished compared to the women belonging to higher castes. Economic variables have a significant impact on determining malnutrition. Women who have paid jobs have higher odds of being malnourished compared with the women who are employed but unpaid. The probability of being malnourished is lowest for women who do not work and it showing that women that are having enough household income enjoy better nutritional status.

Table 5: Effect of socioeconomic and demographic factors on malnutrition

Variables	Coefficient	Variables	Coefficient
Age	0.963***	**Schooling**	1.003
Age square	1.000***	**Husband's education**	
Region		No	0.915***
North	0.905**	Yes (ref)	
Central	1.017	**Number of household members**	1.002***
East	1.180***	**Height**	
NorthEast	0.588***	Not stunted	
West	1.433***	Stunted (ref)	0.957*
South (ref)			
SLI and Place			
Urban Low	1.579***		
Urban Middle	1.048		
Urban High	0.687***		
Rural Low	1.700***		
Rural Middle	1.448***		
Rural High (ref)			
Religion			
Hindu	1.089		
Muslim	1.068		
Christian	0.814*		
Sikh	0.820*		
Jain	0.898		
Other (ref)			
Caste			
Scheduled caste	1.070*		
Scheduled tribe	1.118*		
Backward caste	0.963		
High caste (ref)			
Employment			
No job	0.907*		
Paid	1.086*		
Self employed	0.969		
Unpaid (ref)			
Media exposure			
No exposure	1.055		
Some components	1.026		
All components (ref)			

* $p < 0.05$ ** $p < 0.01$ *** $p = 0.00$

The numbers reported in this table are Odds ratios

The media exposure variable does not play a significant role in deciding malnutrition. Surprisingly woman's education turns out insignificant whereas her husband education significantly decreases Indian woman's probability of malnourishment occurrence. Shorter women have lower odds of being malnourished compared to taller women.

5.5.2. Overweight and Obesity

The first two parts of this sub-section will focus on the results of the bivariate analyses and third one –determinants of obesity- will focus on regression results.

5.5.2.1. Overweight

Nearly 11 percent of Indian women according to the WHO classification belong to the overweight category. Nearly 25% of the women from high standard of living households (24.6%) belong to the overweight category compared to women with a low standard of living (3.5%) (Table 2 and 3 in the previous section). The proportion of women belonging to the overweight category is high among women belonging to Southern states, Western states, Northern states (except Rajasthan) and women belonging to the states of Sikkim and Manipur compared with the Indian average value. The age of women has a strong positive relation with overweight.

Urban women have a relatively disadvantageous position in terms of overweight compared with rural women. Seven percent of rural women and 22 percent of urban women are overweight. The percentage of women belonging to the overweight category is higher among women from Sikh (26.2%) and Jain (28.8%) religions.

Higher caste (15%) and other backward caste (10.2%) women are more over-weight compared with scheduled caste (7.1%) and scheduled tribe women (4.5%). Literacy has a strong positive relation with overweight, and work status shows a negative relation with overweight. Literate and working women are more likely to fall into this overweight category compared with their complementary group.

5.5.2.2. Obesity

Southern states, Western states and Northern states (except Rajasthan) have a higher percentage of women falling into the obesity category compared with the Indian average value. Obesity has strong positive relation with the age of the woman, her standard of living and her education. Elderly women, educated women and working women are more likely to become obese. Sikh and Jain women are more obese compared with women belonging to other religions. The impact of religion on obesity is interesting due to the fact that the food habits of these groups are decided by culture. Moreover, they belong to economically elite groups. In addition to being relatively tall, Sikh and Jain women are more likely than women in any other groups to be obese.

In sum, overweight and obesity are becoming a substantial problem among several groups of women in India, particularly women living in urban areas, women who are well educated, and women from households with a high standard of living. Approximately one-quarter of women in each of these groups have a BMI of 25 or more and 6–7 percent have a BMI of 30 or more.

5.5.2.3. Determinants of overweight and obesity using logistic regression

The results of logistic regression for overweight and obesity are shown in Table 6. The outcome of the regression compares overweight and obese women with those of normal weight women. Results are presented as odds with 95% confidence. Women from the South have the highest odds of being overweight and obese. Urban women with a high standard of living have the highest odds of being overweight and obese and urban women with middle standard of living follow them.

Rural women with high standard of living took the third position confirming the conviction that being urban positively influences the probability of being overweight and obese. This confirms the popular conception that urban areas play an important role in deciding nutritional status. The demographic variable, age, is also playing a significant role in determining individual BMI, where older women have the highest odds for being overweight and obese.

The probability of having overweight and obesity problems is high among Sikh women. Women from high castes have the highest odds of being overweight and obese. Economic variables play a significant role in determining the problems of overweight and obesity. Women who are jobless and women who are self-employed are more likely to be overweight and obese than women who are in unpaid jobs. Women from higher castes have the highest odds of being overweight and obese, and vice versa.

Table 6: Effect of socioeconomic and demographic factors on overweight and obesity

Variables	Coefficient	Variables	Coefficient
Age	1.350***	**Media exposure**	
Age square	0.997***	No	0.725***
Region		Some components	0.997
North	0.780***	**All components** (ref)	
Central	0.591***	**Years of schooling**	1.032***
East	0.545***	**Husband's education**	
Northeast	0.396***	No	0.812***
West	0.854***	Yes (ref)	
South (ref)		**Number of household members**	0.991*
SLI and Place		**Height**	
Urban Low	0.843	Not stunted	0.999***
Urban Middle	1.248***	Stunted (ref)	
Urban High	1.929***		
Rural Low	0.399***	**Number of observations**	72336
Rural Middle	0.614***		
Rural High (ref)			
Religion			
Hindu	1.030		
Muslim	1.249		
Christian	1.121		
Sikh	1.967***		
Jain	1.306		
Other (ref)			
Caste			
Scheduled caste	0.822***		
Scheduled tribe	0.805***		
Backward caste	0.886***		
High caste (ref)			
Employment			
No job	1.607***		
Paid	1.073		
Self employed	1.472***		
Unpaid (ref)			

* $p < 0.05$ ** $p < 0.01$ *** $p = 0.00$

The numbers reported in this table are Odds ratios

Women with media exposure seem to have higher odds of being obese and overweight. This confirms the view that women with more leisure time to watch television, to listen to the radio or to watch movies regularly have more odds of having problems of overweight and obesity due to their sedentary nature. Education of both woman and her husband increases her odds of being overweight and obese. Compared to stunted women, taller women have the higher probability of being overweight and obese. This implies that the hypothesis of stunted people having more probability for being overweight can be rejected.

5.6. Determinants of the BMI using QR

Using binary logistic regression, we are losing information relating to the distribution of the BMI as we divide the sample into two categories only. However, we cannot use OLS regression as it focuses on the mean of the distribution of the BMI and this does not provide much information on other parts of the distribution (Buchinsky, 1998; Koenker and Hallock, 2001). To overcome this problem, QR[44] was used to estimate the explanatory variables' effects on the BMI level over the whole distribution.

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[44] sqreg estimates simultaneous-quantile regression for various quantiles simultaneously. It produces the same coefficients as qreg for each quantile. sqreg command has robust standard errors like normal quantile regression using variance-covariance matrix. Also simultaneous quantile regression (sqreg) obtains robust standard errors via bootstrapping. For bootstrapping number of 100 replications were considered in the model as the 20 replications that are used in the sqreg model by default are not sufficient.

Breusch-Pagan/Cook-Weisberg test for normal OLS regression showed heteroskedasticity issue and using robust standard errors we control for this problem.

Table 7 shows the results obtained from estimation of the BMI using QR for 10th, 20th, 40th, 60th, 80th and 90th percentile (Q=0.1, 0.2, 0.4, 0.6, 0.8, 0.9) Regional differences cannot only be observed within one quantile but also over different quantiles of the distribution that is pivotal in the view of policy. Interestingly, one can see that BMI of the North Eastern women is decreasing severely when we move to higher quartiles of the distribution whereas in the lower quartiles of the distribution they are performing better which support the fact the they have the highest incidence of normal weight. Southern women have the highest BMI in the 80th and 90th percentile showing that women in upper quartiles in Southern India are undergoing nutritional transition. (q=0.8 and 0.9).

As expected, women from urban areas with a high SLI have the highest BMI throughout the distribution and their BMI increases steadily when we move from lowest to highest quantile. Rural women with a low SLI have the lowest BMI compared to their urban counterparts. Rural women with medium SLI follow rural women with low SLI. QR analysis confirms that it is more important to be urban than to have high standard of living as urban women with both middle and high standard of living have higher BMI compared to the rural high standard of living women. For all q values, Hindus have the lowest BMI and Sikhs have the highest BMI (except for 10th percentile). Being a Muslim exerts no impact on the BMI for the 10th percentile. The impact of ethnicity on the BMI increases when we move to higher quintiles. Nevertheless, being a Scheduled Caste or Scheduled Tribe lowers BMI in all parts of distribution.

BMI elasticity seems to increase with increasing quantile for women who do not work and BMI is higher in this group of women when q is 0.4, 0.6, .0.8, and 0.9. The

BMI of self employed women decreased with increasing quantile and they have the lowest BMI in all parts of the distribution. Media exposure does not have any significant impact on BMI of lowest half of the distribution. The impact of mass media on BMI of women with no exposure to mass media decreases steadily from 20th percentile to 90th percentile. QR reconfirmed the results that were obtained from binary logistic regression that showed that women who watch TV, read news papers, listen to radio and watch movies regularly have higher odds of being obese compared to women with no mass media exposure.

The impact of years of woman's education on her BMI on BMI increases steadily from lowest quantile to highest quintile of the distribution (except for the 90th percentile or Q=0.9). Education of husband has the highest impact on BMI of woman when Q=0.9 unlike the impact of her own education. QR shows that stunting of women does not lead to obesity in all quartiles of the distribution and the BMI of taller women increases with each quartile of the distribution compared to the stunted women. This result confirms the logistic regression analysis.

5.7. Conclusion

NFHS-2 data shows that more than one third of women aged 15-49 have chronic energy deficiency and 25 percent of urban women are either overweight or obese. The analyses presented in this paper provide evidence of increasing inequality and socioeconomic differences in nutritional status. Caste, employment and regional factors were associated with the occurrence of underweight and overweight.

Table 7: Estimation of impact of socio economic and demographic variables on BMI using Quantile Regression

Variables	Q(10)	Q(20)	Q(40)	Q(60)	Q(80)	Q(90)
Age	0.08***	0.11***	0.12***	0.16***	0.25***	0.32***
Age square	-0.001**	-0.001***	-0.001***	-0.001***	-0.002***	-0.003***
Region						
North	0.13*	0.85*	-0.05	-0.16**	-0.25*	-0.33
Central	-0.06	-0.11*	-0.30***	-0.51***	-0.70***	-0.88***
East	-0.24*	-0.29***	-0.49***	-0.74***	-1.03***	-1.20***
NorthEast	0.34**	0.38***	0.14**	-0.17**	-0.57***	-0.92***
West	-0.55***	-0.52***	-0.53***	-0.52***	-0.51***	-0.52***
South (ref)						
SLI and Place						
Urban Low	-0.74***	-0.83***	-1.07***	-1.30***	-1.59***	-1.49***
Urban Middle	-0.18**	-0.12	-0.09	0.02	0.12	0.24*
Urban High	0.96***	1.27***	1.68***	1.92***	2.06***	2.20***
Rural Low	-0.69***	-0.85***	-1.17***	-1.54***	-2.01***	-2.39***
Rural Middle	-0.48***	-0.61***	-0.89***	-1.19***	-1.59***	-1.85***
Rural High (ref)						
Religion						
Muslim	0.07	0.15***	0.24***	0.40***	0.50***	0.70***
Christian	0.49***	0.46***	0.45***	0.39***	0.35***	0.56***
Sikh	0.40**	0.79***	1.13***	1.37***	1.68***	2.07***
Other	0.27	0.45*	0.81***	1.13***	1.35***	1.22**
Hindu (ref)						
Caste						
Scheduled caste	-0.14**	-0.17***	-0.29***	-0.31***	-0.37***	-0.42***
Scheduled tribe	0.01	-0.12	-0.21***	-0.26***	-0.40***	-0.45**
Backward caste	-0.05	-0.07*	-0.10**	-0.12**	-0.18**	-0.26*
High caste (ref)						
Employment						
No job	0.01	0.05	0.18***	0.25***	0.45***	0.60***
Paid	0.09	0.08	0.13*	0.13	0.30*	0.39*
Self employed	-0.14*	-0.11*	-0.10*	-0.20***	-0.14*	-0.13
Unpaid (ref)						
Media exposure						
No	-0.12	-0.25**	-0.27**	-0.39***	-0.63**	-0.69**
Some components	-0.04	-0.15*	-0.13	-0.20*	-0.27*	0.21
All (ref)						

Variables	Q(10)	Q(20)	Q(40)	Q(60)	Q(80)	Q(90)
Schooling years	0.04***	0.05***	0.07***	0.09***	0.10***	0.01***
Husband's education						
No	0.16***	0.15***	0.17***	0.16**	0.20**	0.29***
Yes(ref)						
No. of house members	-0.01	-0.02***	-0.02***	-0.03***	-0.05***	-0.05***
Height						
Not stunted	0.24***	0.21***	0.23***	0.24***	0.41***	0.50***
Stunted (ref)						
Constant	15.50	16.07	17.14	18.10	18.54	18.68
Number of observations	72336	72336	72336	72336	72336	72336

* p < 0.05 ** p <0.01 *** p =0.00
The reported values are coefficients.

Women from an urban high standard of living and rural high standard of living, who are educated above high school, who are either not working or self employed, or who have exposure to media (television, cinema, news papers or radio) are more likely to be overweight or obese. These factors are significantly inversely related to the likelihood of malnutrition. The results of this study are similar to other studies in some developing countries where women from a low standard of living suffer from malnutrition and women from high standard of living have overweight and obesity problems (Monterio et al., 2000; Martorell et al., 2000). Moreover, this study shows a higher significance of the standard of living. Age was also a significant factor where older women are more likely to be obese or overweight whereas younger women are having the higher probability of being malnourished. These findings are consistent with the findings of other studies (Dhurandhar et al., 1992; Gopinath et al., 1994; Seidell, 1995; Laurier et al., 1992).

Sikh women have the highest probability of being overweight and obese. This might be related to lower participation in the workforce, which leads to a sedentary lifestyle and a high consumption of fat. Even though the standard of living is playing a dominant role for deciding the nutritional status, by the compound variable of place of residence and standard of living we can confirm that rural and urban place of residence still play an important role in deciding BMI of a woman. Urban women have higher probability of being overweight and obese compared to rural women in all standard of living categories. Moreover, women from an urban low standard of living have higher odds of being overweight and obese compared with rural middle and rural low standard of living women. Urban area of living plays a significant role in deciding the obesity status of the population, which is a threat to India in the context where urban population is increasing dramatically (Diwaker and Qureshi, 1992). At the same time, the rural poor are worse affected in terms of malnutrition and urban poor follow them.

This paper not only shows the relation between malnutrition and poverty levels of different states but also the relation between the State Domestic Product, and overweight and obesity. Policy makers should take into consideration also regional differences in malnutrition and obesity. It is very important to focus on different regions of India in different way based on the target group we aim. For instance, QR estimation results show that different regions follow differently in different parts of the distribution. For instance, we see from quantile regression that South India has the highest BMI in the upper quantiles whereas in the lower quantiles North and North East India perform better compared to the South. Another striking result is the result that in the lower quantiles urban women from low standard of living are worse compared to the rural poor. The rural-urban disparity increases only in the higher quantiles.

Another point that needs attention is the hypothesis that population with higher rates of stunting and low birth weight will have an increased risk of obesity related to chronic diseases in the adulthood (Byers and Marshall, 1995; Scrimshaw, 1995; Popkin et al., 1996; Barker 1998; Darton and Coyne, 1998; Himes, 2000). This study shows that taller women are prone to obesity problems and this might be due to the fact that they have the higher access to food. It might be possible that in the later phases of nutritional transition we can see shorter women being obese. If this will happen, for Indian policy makers this is going to be a huge challenge in the future as children who are stunted will become overweight in adult stage. Moreover, India will also have to face high levels of malnutrition related problems. Both malnutrition and overweight will decrease the health status of the population which will have a negative impact on the development of country.

Rural poor and urban poor women should get more information regarding healthy diet and different components of health whereas urban and rural rich women should get more information about improving their diet and exercise to prevent overweight and obesity.

Appendix G

Table G1: Among ever-married women, percentage with specified levels of BMI by state, India, 1998-99

States of India	**Body Mass Index of women**				
	Mean	**Under weight**	**Normal**	**Over weight**	**Obese**
India	20.3	37.6	47.8	10.9	3.7
North					
Delhi	23.7	12.9	44.4	27.6	15.2
Haryana	21.2	27.9	50.5	15.6	6.0
Himachal Pradesh	20.8	31.4	50.9	13.6	4.2
Jammu and Kashmir	21.0	28.0	53.0	14.0	5.0
Punjab	23.0	17.9	44.4	24.8	12.9
Rajasthan	19.9	38.0	52.2	7.4	2.4
Central					
Madhya Pradesh	19.8	39.9	51.0	6.7	2.3
Uttar Pradesh	20.0	37.7	51.3	8.5	2.5
East					
Bihar	19.4	41.5	52.5	4.9	1.1
Orissa	19.1	49.7	43.6	5.5	1.2
West Bengal	19.7	45.7	42.4	9.4	2.6
Northeast					
Arunachal Pradesh	21.0	11.6	81.2	5.8	1.4
Assam	20.0	28.6	64.3	5.9	1.2
Manipur	21.1	20.9	62.6	13.7	2.9
Meghayala	20.3	27.3	63.3	7.0	2.3
Mizoram	20.4	24.1	66.7	7.4	1.9
Nagaland	20.9	19.6	67.6	10.8	2.0
Sikkim	22.0	12.1	66.7	18.2	3.0
West					
Goa	21.6	29.0	44.1	19.4	7.5
Gujarat	20.7	38.7	40.4	14.5	6.4
Maharastra	20.2	41.8	41.6	12.3	4.4
South					
Andhra Pradesh	20.3	39.1	44.6	12.2	4.1
Karnataka	20.3	40.9	41.2	13.1	4.7
Kerala	22.1	19.8	51.9	21.8	6.5
Tamil Nadu	21.0	30.4	48.9	16.0	4.7

6. Concluding remarks

My dissertation focused on the following key questions regarding welfare and inequality from 1915-75:

1. What are the possible ways to assess the individual well-being?
2. How to aggregate the individual indicators of well-being into a measure?
3. How to assess the inequality in well-being?
4. What were the major determinants of heights in India?
5. What is the best way to capture the regional and gender welfare and inequality?

All the chapters of my thesis focused on the use of anthropometric data to assess individual well-being. Using mean heights and coefficients of variation in height – of various groups – defined by region, caste and religion - welfare and inequality were investigated. Moreover, to study contemporary welfare, the body mass index was also used in the final chapter. I found that heights were improving very little in the first half of the 20th century (0.7 cm) and in the second half a very modest improvement (about 0.8 cm) took place until 1974. Based on this, I can conclude that overall welfare of Indians did not change considerably from 1914-74. Furthermore, inequality of heights existed in India both between genders and castes. Finally, gender inequality in India was worse compared to other parts of the world pointing to the role of cultural factors like son preference. The following sections presents detailed summary of the major findings of my thesis.

6.1. The biological welfare of Indians in the pre-1950 period

6.1.1. Welfare before independence

Williamson (2000) argued that in the interwar period real wages of unskilled workers rose, whereas GDP data showed a downward trend. In my thesis, Williamson's real wage pattern was rejected using heights as a biological welfare indicator. Based on 26,154 observations of individuals in North, East and West India, I can conclude that Indian welfare was more or less stagnating from 1915 to 1944. Moreover, I did not find continuous convergence neither between castes and religious groups nor between occupational groups. A modest regional convergence among the three large regions did not lead to a general decline in height inequality in India. Though Indian welfare using biological welfare for this period was studied earlier, my thesis revolved around aspects of inequality that have been neglected before. Moreover, the relation between height and economic growth for India was barely studied.

6.1.2. Influenza and famine period

The effects of the 1918-1920 influenza epidemic on inequality are one of the most interesting results of my study. During the influenza and famine period 1918-20, I observed relatively low height inequality in India. Traders and landlords suffered more compared to the middle and lower status groups. I argued that the egalitarian effects of the influenza pandemic were the driving force for the low inequality of the 1918-20 period. Other factors that contributed to a lower extent of inequality were religious taboos especially related to food and the lower advantage of well-educated and metropolitan groups during "closed" phases of world trade.

6.1.3. The role of caste and religion in India

The caste system clearly played a significant role in determining stature of individuals. It was only the Indian substitute for income and educational differences that were at work in other countries. Upper caste Indians were about 2.9 cm taller than scheduled tribe men. Sikhs were even taller, but they lived in a region with high protein proximity advantages. In comparison, height differentials in Europe, North and South America were of a similar dimension (between 2.5 and nearly 5 cm between extreme groups). Interestingly, Indian pastoralists, who belonged to low caste and social status, were taller compared to the higher caste people - because of the milk proximity advantage mentioned above -, which is also an argument against an omnipotent determinism by caste.

6.1.4. Overall pessimism or optimism?

The hypothesis of Brennan, McDonald and Shlomowitz (1994) that heights increased modestly during the early 20th century was confirmed. Between 1915 and 1944, the increase in stature was only about 0.7 cm, which is much lower than in Europe. Perhaps the cheap rice imports did offset the detrimental nutritional effects of declining food production in India, and the declining GDP per capita as discussed in my thesis and previously by Brennan et al. (1994). The slightly improving disease environment over the 20th century might have played an additional role, certainly after the disastrous influenza pandemic during the period 1918-20.

6.2. Inequality and welfare in the independent India

Most of the studies on Indian welfare for the post 1950's revolve around poverty and malnutrition. This was a first attempt to study welfare and inequality in India linking macroeconomic data and stature information of 14 major states of India.

6.2.1. Growth of non-agricultural sector and welfare

Improvement in the non-agricultural state net domestic product improved welfare of people. Though the agricultural sector is predominant in India, improvement of this sector did not provide extra employment opportunities, whereas improvement in non-agricultural sector created jobs for surplus working people in the agricultural sector. Hence, I can argue that contemporary Indian welfare can also be improved by providing more employment opportunities for the surplus labour that depends on the agricultural sector. Moreover, the fact that only the middle and upper parts of the height distribution benefited from the growth of the non-agricultural sector provides information about the groups that enjoyed this growth, namely rural semi-skilled and skilled workers.

6.2.2. Caste, religion and region

The Indian caste system created particularly high inequality and did not disappear after independence. India is a huge country with high regional diversity. I could prove that women belonging to upper castes were tall in both rural and urban areas. The hypothesis of overall Hindu-Muslim inequality was not strongly evident except for rural areas in the lower parts of the distribution. In sum, the hypothesis that the caste system created inequality in welfare can be accepted completely, whereas religious inequality could be rejected (partially) due to the fact that only for the 25th percentile of the height distribution welfare of Muslims were lower compared to Hindus. Regional divergence is also evident in both welfare and inequality.

6.2.3. Adverse period of 1964-66

The period 1964-66 exhibited declining economic growth rates that were worsened further with droughts. The effect of this disastrous period on biological welfare was seldom discussed, and I addressed it for the first time in my thesis. Interestingly, I did not find enough evidence for the negative impact of disastrous period on the overall welfare of Indians. Interestingly, urban women in the tallest height percentile (90th) showed decline in their heights. Moreover, using quantile regression uncovers that the biological welfare of rural Indians in the lower quartiles of the distribution did not decline as expected in this period.

6.2.4. Inequality in heights

Using the coefficient of variation in heights to study inequality provided new insights. Deviation in rain increased inequality concluding that a negative impact on agriculture worsened inequality. Any improvement in the rural-urban gap in average per capita consumption reduced inequality. The relation between monetary measures of poverty and anthropometric inequality was not significant. Interestingly, Tamil Nadu and Uttar Pradesh showed higher inequality compared to Andhra Pradesh.

6.3. Gender inequality of Indians, 1950-75

Gender discrimination has been studied intensively by using various indicators such as nutrition, calorie intake, and mortality. In this study, I used a new measure ‘gender dimorphism in stature’ and argued that this could be used as an indicator for measuring gender discrimination by taking various data sources. This was the first attempt to look at gender differences in stature in a detailed way for India and Indians abroad.

6.3.1. Use of height as an indicator for measuring gender inequality

Most of the previous research on anthropometric gender inequality used height differences between men and women by default - overlooking completely the latest biological and evolutionary research on sexual differences in stature. Rensch started the debate in the 1950’s that stature of men improves faster compared to women as women are robust compared to men. This was tested with the hypothesis that larger stature dimorphism would not occur among groups that were relatively taller. Rejection of this hypothesis supported the use of gender dimorphism as an indicator for measuring gender inequality.

6.3.2. India a negative outlier in gender inequality

The first attempt of comparing Indian anthropometric gender inequality to other parts of the world was done in my thesis. I concluded that India had a quite high gender inequality, compared to other parts of the world, such as African and other Asian countries. Gender difference in child malnutrition – meaning bias against females – was higher in India in terms of stunting, wasting and underweight. Thus, I can conclude that gender inequality is induced not only by economic conditions - but also by the cultural bias against girls.

6.3.3. Major determinants of gender inequality

Both OLS and panel fixed effects regressions in chapter 4 proved that rainfall – a proxy for food production – is an important determinant of gender inequality. Good monsoon rain would decrease gender inequality, as an improvement in agricultural production might also “allow” more food allocation to women. At the same time, I found that deviation in rainfall, harvests, and food supply increases gender discrimination. Contrarily, higher development expenditures showed improvement in gender inequality.

The debate if participation of women in agriculture is beneficial to their health or not was further extended by the finding that rice cultivation did not improve biological welfare of women relative to men. Women in rice cultivating areas have to work hard in their rice fields, taking care of animals – for eggs, milk and ploughing – along with their regular household chores. Though work status improves the welfare of women in general along with their autonomy, the time available for taking care of kids might be limited resulting in better care for boy child compared to the girl child.

6.3.4. Dimorphism and famine period

Most of the studies related to gender differences in mortality during natural disasters, famine and near-famine periods overlooked some important aspects. A special focus was the issue of ‘female robustness’ leading to the hypothesis that dimorphism in stature would increase during natural disasters. By taking into consideration all the important disasters that happened during 1950-75, I could accept the hypothesis that during bad periods like natural calamities and disasters, females suffered more than males. This negative impact of disasters stayed significant even after controlling for economic and agricultural factors.

6.3.5. Cultural explanation of gender dimorphism

Though the cultural argument for female discrimination in India was used by some development economists and scholars, special analysis was not done to test the cultural aspect. For the first time, cultural aspect of Indian gender discrimination was tested by studying Indians living in South Africa during 1948-75. Hence, I was able to separate regional aspects and cultural determinants of gender inequality. The most interesting finding that gender dimorphism among Indians in South Africa was higher compared to other racial groups concluded major role of cultural factors that might have been carried from India to South Africa.

6.4. Simultaneous existence of malnutrition and obesity in India

The first three quarters of the 20th century showed no tremendous improvement in the Indian economy whereas the last decade of the 20th century underwent drastic change in the life style and living standards of rich urban Indians creating a clear nutritional inequality. Looking at simultaneous existence of obesity and malnutrition in India was never done for India except for a couple of region specific studies. In this context, the findings from the chapter that exclusively focuses on body mass index instead of heights led to results that are very important from a policy perspective. Moreover, the thesis shifted to welfare of contemporary Indian women in this chapter.

6.4.1. Urbanization and obesity

Previous research hypothesised that urban residence plays an important role in determining obesity due to diet with higher fat content of food, animal products, sugar, and polished grains, along with more sedentary life style. At the same time, standard of living was debated as one of the important determinants of body mass index. However, most of the previous research focused on obesity and urban areas and obesity and rich people. The contrast between urban and rural area of residence was not studied. The analysis using interaction of SLI and rural/urban place of residence on the determinants of malnutrition and obesity provided new insights. Urban residence turned out to be major determinant of overweight and obesity compared to standard of living affiliating this to food and lifestyle.

6.4.2. Stunting and obesity

Previous research for some developing countries proved that stunting in childhood continues into adulthood, and results in adults of short stature. Short stature in the end might increases the risk of obesity. This was tested for India for the first time. It turned out that taller people are likely to be overweight and obese compared to shorter women. Nevertheless, it highlights that nutritional transition occurred only in the beginning phase and at later stages – where poor people become obese – the probability of obesity among short people might increase.

6.4.3. Quantile regression compared to logistic models

The most common methods used for studying this phenomenon are binary and multi-nominal logit regressions. However, I argued in the last chapter that especially in countries with nutritional transition, quantile regressions represent a more efficient way of uncovering the partial impact of socioeconomic factors. The method of quantile regression analysis is not focused on the average observation as in OLS regressions – but I incorporate more information using the distribution of the body mass index. Moreover, I can use individual information in a better way instead of classifying them all into three categories especially when the international standards are debated continuously.

6.5. Further research ideas

6.5.1. North-South divide: A new evidence in gender inequality

The World Health Survey (WHS) conducted in six states of India namely Assam, Karnataka, Maharashtra, Rajasthan, Uttar Pradesh and West Bengal showed interesting results that might open new research avenues related to the North-South divide in gender inequality. The WHS survey covered a combined random sample of 10,279 households and 9,994 adults above the age of 18 with nearly equal proportion of male and female respondents (WHS, 2006). Some interesting findings based on preliminary analysis (Figure 1) underline that the South Indian state of Karnataka has lower dimorphism compared to North Indian and East Indian states. Also Assam, North East Indian state showed very high gender differences; thus, this phenomenon is worth analyzing.[45] To use this data for investigating gender differences, I have to make sure that misreporting of heights is similar among males and females and across different regions.

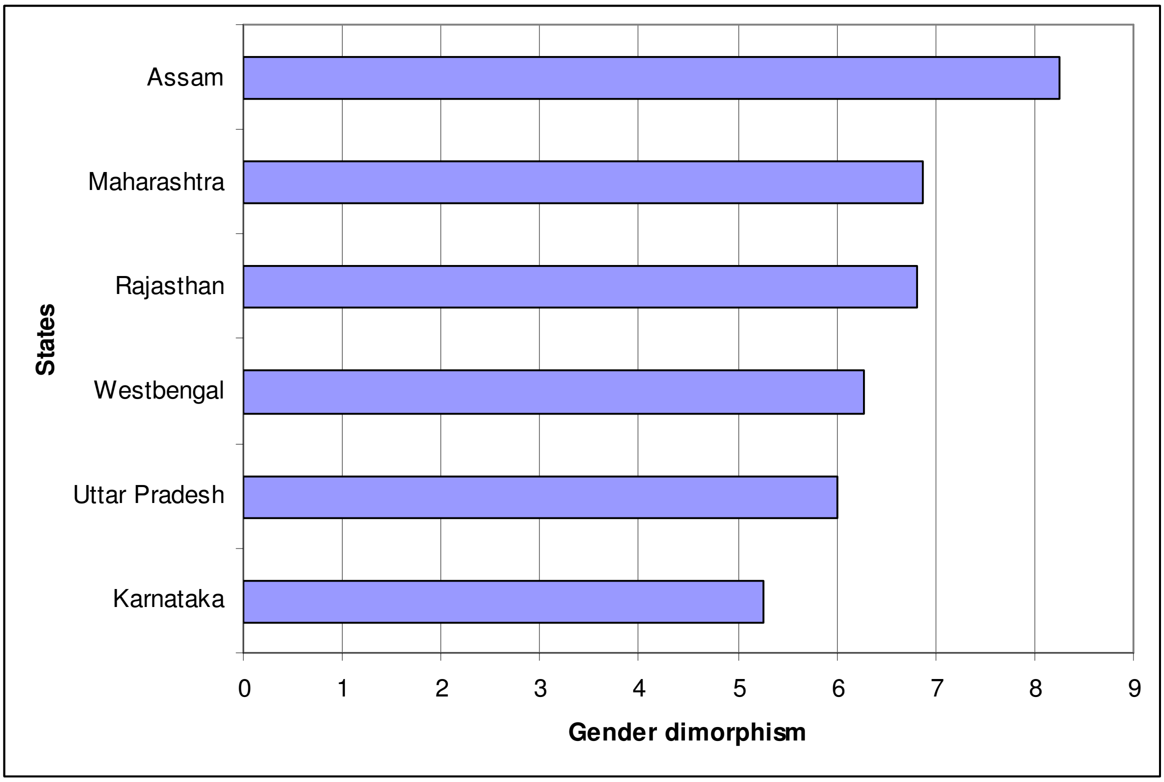

Figure 1: Gender dimorphism in stature. Source: WHS 2006

There is still space for innovative ideas like what happened to welfare of states that are ruled by the communist party like West Bengal and Kerala compared to other states? Also one can construct a broad database of all the disasters in India by year and region to study the impact of welfare and inequality. As my thesis focused only on 25

[45] The only caution we need to take it is that the stature data is self reported height. We might end up having over estimated heights due to misreporting. Also we have only one South Indian state in the sample that is Karnataka. Nevertheless, Maharashtra cannot be included in the northern sample.

years and few states, extending the time horizon might be interesting to analyze the short and long-term consequences of natural disasters. In sum, the whole idea of this research was to contribute new ideas and insights to the area of welfare and inequality of Indians from 1900 to 2000, and I hope to make my message clear: Indian inequality by caste existed from 1900 and there is no tremendous improvement in the welfare in the first part of 20^{th} century. The second part of the 20^{th} century (1950-75) also showed a negligible improvement in heights and caste inequality did not decline in India after independence. Moreover, my thesis provided evidence and determinants of gender inequality in India using anthropometric data highlighting the fact that bad periods like natural disasters increases gender inequality further. In sum the welfare of Indians from 1914-74 followed an “everything is constant except slight change” pattern. The last years of the 20^{th} century showed huge transition in lifestyle and living standards of Indians (especially urban and rich). Hence the contemporary India has a large stagnating proportion of malnourished and increasing proportion of obese and overweight people.

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