DISCUSSION PAPER

Estimating Sub-National Human Development Indices in the Presence of Limited Information

The Case of Bhutan

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Ramesh Gampat and Niranjan Sarangi

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Regional Centre for Asia Pacific, Colombo Office
Human Development Report Unit
23 Independence Avenue, Colombo 7, Sri Lanka
Tel.: +94 11 4526400
Fax: + 94 11 4526410
www.undprcc.lk
Email: rcc@undp.org

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Abstract

The human development index, or HDI as it is popularly called, measures progress in the human condition along three dimensions: a long and healthy life, knowledge and command over resources to enjoy a decent standard of living. But the HDI is not the same as the concept of human development. It does not, for example, capture the varied and multi-faceted dimensions of human development, including the range of freedoms, cultural diversity and many intangible choices that are difficult to quantify and measure. Unlike the GDP, which is a money metric that measures only the value of goods and services, the HDI goes beyond gauging material wellbeing. It is this broader perspective that makes the HDI a powerful advocacy tool to expand and deepen the debate about the state of human condition and to fine-tune national policies with human development concerns.

National HDIs, which are published in the UNDP global Human Development Reports (HDRs), present a broad picture of the state of people's lives in a particular country. To obtain a picture at the sub-national level (for example, among regions and population groups, such as gender or ethnicity), sub-national HDIs are required, which draw attention to local and localized disparities in human development. Among Asia-Pacific countries, India has used sub-national HDRs and sub-national HDIs (at the state and district levels) to influence decentralized, integrated planning by the central government; some states are even using the district level HDIs as an input for policy changes. Besides India, other Asia-Pacific countries, including Cambodia and Indonesia, have produced sub-national HDRs and HDIs.

Sub-national HDIs require more disaggregated data, which poses a huge challenge for the national accounts of many countries were not designed to collect such data. Further, indicators of health conditions, including deaths, at the sub-national level are often not available in many statistical systems. While proxy methods for generating the necessary data can always be found, it is crucially important that these alternative methods are robust and consistent.

This paper attempts innovative ways to estimate sub-national level life expectancy at birth and per capita GDP for Bhutan in order to calculate sub-national HDIs. The estimates, produced for all 20 dzongkhags (provinces), show that human development in all dzongkhags is in the medium range (0.500 to 0.799), but it is most advanced in Thimphu.

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While colleagues provided intellectual and logistical support, all errors in the paper are the responsibility of the authors.

Abbreviations

ACE	Annual Consumption Expenditure
ADLIT	Adult Literacy
ADPOP	Adult Population
ALR	Adult Literacy Rate
BLSS	Bhutan Living Standard Survey
CGENR	Combined Gross Enrolment Ratio
ENR	Enrolment Ratio
GDP	Gross Domestic Product
GER	Gross Enrolment Ratio
GNH	Gross National Happiness
GNHC	Gross National Happiness Commission
GNP	Gross National Product
HD	Human Development
HDI	Human Development Index
HDI-AM	HDI – Age-wise Method
HDI-CM	HDI – Chiang Method
HDR	Human Development Report
KRC	Knowledge Resources Committee
LE	Life Expectancy
MPCE	Monthly Per Capita Expenditure
NGO	Non-Governmental Organisation
NSB	National Statistics Bureau
PCGDP	Per Capita Gross Domestic Product
POPAG	Population Age Group
PPP	Purchasing Power Parity
SEPHO	South East England Public Health Observatory
UK ONS	UK Office of National Statistics

I. Introduction

The popularity of the human development index (HDI) as a rough indicator of the human condition, and possibly as a guide to resource allocation, has motivated many governments to calculate sub-national HDIs. Disaggregated data, indicators and indices, especially at the sub-national level, quickly draw attention to glaring human deficits, fuel advocacy and stimulate more effective planning and monitoring of socio-economic activities and results.Sub-national HDIs, could, ultimately, motivate policies that are more finely aligned with human development concerns.

In the Asia-Pacific region, Cambodia, India, Indonesia, Nepal, Pakistan and Thailand have prepared sub-national human development reports, including calculations of HDIs, at the state, provincial, district and even at the local levels. Several states in India have calculated HDIs at the district level and some have progressed further to calculate HDIs at the local level of the governance structure.

While the calculation of national and sub-national HDIs is a simple exercise that requires no particular set of mathematical skills, it does require a good dataset that is sufficiently disaggregated. This paper takes up the challenge of estimating HDIs for all 20 dzongkhags (provinces) of Bhutan in the presence of the lack of data on per capita gross domestic product (GDP) and life expectancy at the sub-national level.[1] An important reason for this exercise was to supplement the socio-economic profiles of the 20 dzongkhags, which the National Statistics Bureau (NSB) and Gross National Happiness Commission (GNHC) of the Royal Government of Bhutan were in the process of developing. The authorities were of the view that sub-national HDIs could be a powerful tool to guide policy formulation and planning, including resource allocation.

Data for the exercise was provided by government agencies. However, disaggregated data at the dzongkhag level has been a challenge for the HDI estimation exercise. These data gaps – especially for life expectancy and per capita GDP at the dzongkhag level – were surmounted by alternative approaches developed by the authors. This paper summarises the conceptual and measurement issues, provides a detailed account of the methodology used and discusses the results of the sub-national estimation exercise.

Section II of the paper briefly touches upon the concept of human development and its associated indicator, the HDI. Section III discusses the use of sub-national HDIs as a critical tool for measuring the state of human development at local level. Section IV identifies measurement challenges, especially data gaps, and discusses methodological issues: ways to calculate life expectancy for small populations and to estimate per capita GDP at the sub-national level. The requisite dataset for the estimation of HDIs for all 20 dzongkhags in Bhutan is compiled in Section V. The results of the estimation exercise are presented and discussed in Section VI. The paper closes in Section VII with an overall discussion and lessons learned.

II. Human Development and the Human Development Index

Human Development (HD) is a process of enhancing people's choices. In principle, these choices can be infinite and can change over time. But at all levels of development and for all societies, the three essential choices are for people to lead a long and healthy life, acquire knowledge and have command over the necessary resources for a decent standard of living. The unavailability of these essential choices could mean the loss of many other opportunities. Yet these three central choices do not comprise the sum-total of human development. Additional choices, highly valued by many, range from political, economic and social freedom to opportunities for creativity and productivity, and the enjoyment of human rights, dignity and self-respect.

Human development thus has two sides: the formation of human capabilities such as improved health, knowledge and skills on the one hand,

1 The mission comprised two staff members, Ramesh Gampat and Niranjan Sarangi, from the Human Development Report Unit of the UNDP Regional Centre for Asia Pacific, Colombo Office. The mission visited Bhutan from 28 June to 6 July 2008.

and the use people make of their acquired capabilities for leisure, productivity or cultural, social and political activity, on the other. Considerable human frustrations can result if the gap between capabilities and opportunities is not finely balanced.

Two key points may be noted here. First, human development is not the same as economic growth. The latter, taken as an expansion of output/income, is perhaps the most popular way of measuring the material progress of nations. But it is a means to an end, not an end in itself. For example, income could be used to purchase essential drugs, develop inter-continental ballistic missiles and plant land mines, fuel civil wars or even to land humans on the moon. But human well-being depends upon both the *level* of income and *how* that income is used – that is, the quality of growth is no less important than the quantity of growth. One of the founders of the Human Development Report (HDR), Mahbub ul Haq frames the issue in this manner: " … the use of income by a society is just as important as the generation of income itself, or that income expansion leads to much less human satisfaction in a virtual political prison or cultural void than in a more liberal political and economic environment" (Haq 1995: 14).

Second, high per capita income or rapid growth can coexist with stark human deprivations unless that growth 'lifts all boats'. For example, Brazil had a per capita income of US$8,402 (PPP US$) in 2005 and an HDI of 0.800, while Botswana had a higher per capita income of US$12,387 but an HDI of only 0.654. Equity thus becomes crucial and is particularly central to Asia in the context of rising inequality (as gauged by the Gini coefficient) despite robust and sustained growth. Clearly, growth does not automatically bring greater equality, including gender equality, which has direct implications for human development.

Finding a more appropriate paradigm to uplift the human condition does not mean that the work is done; it is only half of the 'great question' that has engaged the human mind for more than two millennia. Even after 20 years, the human development paradigm is yet to make a large presence in academia, where it is still seen as too 'soft' to equip freshly-minted PhDs with marketable skills. Moreover, while the central idea of human development revolves around choice, choice brings with it a paradox in some countries, especially the rich ones. For example, if one is confronted with a bewildering range of ice cream, as would be the case if one steps into a modern supermarket, one may be unable to choose or will probably make a choice that does not optimize one's welfare. The information on brand, price, expiry date, ingredients, nutritional content and so on is simply overwhelming to process so quickly. When one finally makes a choice, there is no guarantee that it is the best choice.

Another critique is that the various freedoms have not been well-integrated into the human development paradigm; the focus has been mostly on the three dimensions of the HDI that are easily quantifiable and thus measurable. Finally, there are conceptual issues: individual vs. societal, the apparent inconsistency between quantification, optimisation and the wider understanding of wellbeing, and the philosophical issue of the role of morality in the human development paradigm.

It is necessary to note that the HDI is not the same as human development. The latter is a multi-dimensional concept, a whole new paradigm of development, while the former is one possible way of measuring progress of the human condition in three dimensions (a new paradigm naturally requires a new measure, which was a powerful motivation for the creation of the HDI). The three dimensions of the HDI are:

- A long and healthy life as gauged by life expectancy at birth.
- Knowledge as gauged by adult literacy and combined gross enrolment ratio (GER).
- Command over resources to enjoy a decent standard of living as gauged by GDP per capita in PPP terms.

Clearly, the HDI does not capture the varied and multi-faceted dimensions of human development, including the range of freedoms, cultural diversity and many intangible choices that are difficult to measure. Consequently, *the HDI cannot be equated with human development* for it captures but a partial view of a holistic and multi-dimensional phenomenon. Yet, the HDI is a popular index, probably because of its power to chart the progress of nations in multi-dimensional terms and hence its appeal as an advocacy tool. The HDI quickly grabs the attention of policy makers, the media, academia, lobbying groups and NGOs. It can help to expand and deepen the debate about the state of the human condition (from global, to regional, to national, to sub-national) and to align policies with human development concerns. The fact that countries around the world so eagerly await the release of the yearly HDI attests to its popularity.

Why was there a need for a new index? Existing measures have not been designed to gauge the state human progress as envisaged by the new paradigm. But designing a new measure presented a considerable challenge. There were conceptual issues and were methodological and data issues that had to be surmounted.[2] Moreover, the new measure should be simple, easy to calculate and easy to understand. The compromise between technicality and simplicity meant that the new index could suffer the major shortcomings of existing measures, but it would convey a broader view of progress. Thus was born the HDI at the beginning of the 'revolution' that increasingly led people to look at development differently: not as a commodity, but as a means to human fulfillment. Just as per capita GDP/GNP is a way of representing the economic conditions of a given country, the HDI is shorthand for mapping the human condition. It is this a broader measure and more information-laden than GDP/GNP per capita. And yet it is simple to calculate and understand, which probably explains its popularity as a powerful advocacy tool.

The global Human Development Report (HDR) produced by UNDP calculates the HDI at the national level for most countries of the world – 177 countries in the 2007/2008 HDR. The HDI has wide acceptability across countries as a measure of human wellbeing. It is also comparable across countries and over time. For example, Bhutan's HDI has improved over time and its gap with, say, Sri Lanka, has narrowed significantly (Limbu 2009). It is now only behind Maldives and Sri Lanka in South Asia, and ahead of India, Pakistan, Bangladesh and Nepal.

Interestingly, Bhutan has developed an independent measure of the human condition – the Gross National Happiness (GNH) index, which is not the same as the HDI or the concept of human development. Drawing heavily on non-material values, the GNH is intended to capture progress under Bhutan's model of development which rests on four core values: (1) respecting cultural traditions; (2) protecting the natural environment; (3) ensuring equitable distribution of wealth and resources; and (4) maintaining responsive governance. This is as fine an endeavor as any, for it shows that Bhutan clearly understands the limitation of measures that focus on means (not ends) and has developed a measure that is contextualized and tailored to its own values and philosophy.

III. Why Sub-National HDIs?

The HDI is based on three dimensions that roughly capture the state of people's lives in a country or a specific geographical area of the country in the case of the sub-national HDI. The tradition, as practiced in the UNDP global Human Development Reports, is to calculate the HDI at the national level, which means that macro-level data are used. But such data is highly aggregative and may hide variations at the sub-national level. For example, the adult literacy rate of Bhutan is 52.8 per cent, but there is considerable variation across provinces, varying from a low of 39.2 per cent in Gasa to a high of 68.9 per cent in Thimphu. Similarly, GDP per capita, or life expectancy, could mask significant differences across regions or groups within a country. For these reasons, national HDIs are not a substitute for sub-national ones (by state, province, community), nor are they very useful for comparative assessments of groups of people (by gender or by ethnicity, for example). Like per capita GDP, the HDI fails to capture variations at a more disaggregated level. Indeed, most macro-indicators (or indices) in a country's national accounts are averages that are too aggregative to be representative of all population groups or areas in a country.

While national averages are useful for cross-country comparison, more disaggregated data

2 Several principles guided the development of the new index, which became known as the Human Development Index. Such an index (1) must measure the central core of human development which is enlarging people's choices; (2) include only a limited number of variables to keep the index simple and manageable; (3) must be a composite index instead of several separate indices; (4) must cover both social and economic choices; (5) its coverage and methodology must be kept very flexible; (6) while the index can only be as good as the data fed into it, lack of reliable and up-to-date data should not be allowed in inhibit the emergence of the new index (Haq 1995).

are necessary if the focus is on in-country comparison (for example, among regions and population groups, such as gender or ethnic groups). If the necessary dataset is available, the HDI can be calculated at sub-national levels to convey a broader, more insightful and analytical view of living conditions as depicted by the three dimensions of the index: it is a graphic and insightful way to identify and draw attention to local and localised disparities in human development across both regions and different population groups. For this reason, sub-national HDIs can be an even more powerful tool than national HDIs in the hands of politicians and the media.

Small wonder, then, that many countries are now calculating the HDI at the sub-national level even if they do not produce a sub-national HDR. Among Asia-Pacific countries, India has used sub-national HDRs and sub-national HDIs (at the state and district levels) to influence decentralised, integrated planning by the central government; some states are even using the district level HDI as an input for policy changes. For example, the Government of Karnataka, a Southern Indian State, used social sector indicators, including those that go into the preparation of the HDI, for identifying backward regions in the State. The Government of Maharashtra launched a human development mission in three districts with low HDI values, and special budgetary support is being provided to these 'backward' regions. Besides India, other Asia-Pacific countries, including Cambodia and Indonesia, have produced sub-national HDRs and HDIs.

The downside of sub-national HDIs is that data requirements become progressively more difficult as the scope of the HDI is narrowed. There is thus a trade-off between the utility of the HDI and the costs of producing it.

IV. Estimating Sub-National HDIs: Issues and Challenges

Data and Indicators

The data requirements for the computation of the HDI, especially at the sub-national level, are, as noted, pose the most difficult challenge. In fact, data rather than conceptual issues are the chief constraint to the calculation of the HDI at the sub-national level. Many countries have the necessary data for the construction of education index, but not for GDP and life expectancy. Bhutan is a typical example of this problem, and we developed ways to estimate life expectancy (in addition to the standard method) and per capita GDP, both of which are discussed in this section of the paper.

To be feasible for inclusion in the sub-national HDI, an indicator must be:

- Comparable across sub-national units, which thus presumes a standard methodology
- Available for all sub-national units and over time, if a temporal comparison is desired
- Of reasonable quality in terms of accuracy and representativeness
- Valid or based on identifiable criteria that effectively captures what the indicator intended to measure. For example, adult literacy rate shows the percentage of literates in the age group of 15 and above in a population, and cannot be approximated by youth literacy
- Policy-relevant or based on criteria that can influence decision-makers and policies directly or indirectly.
- Based on data that is globally comparable, if calculation of national HDI is the goal, but this is not a strict requirement for sub-national HDIs.

Often, sub-national data are not available or are not of reasonable quality for two critical reasons. First, statistical systems in many countries are usually not geared towards the production of such disaggregated data. Second, small sample estimates are not reliable for sub-national data. For example, the *national* life expectancy estimate for Bhutan is reliable, but estimates at the dzongkhag-level may not be reliable because of small-sample bias, especially for populations below 5,000. Accuracy is also a concern for provincial GDP estimates owing to the difficulties of segregating output by location. The reason is a simple one: GDP does not count semi-finished goods produced by an industry that may be located in different regions/provinces/areas of the country. Instead, it counts only the *finished* products of the industry. So, for example, intermediate goods that are used to make bicycles or rickshaws are not counted in GDP regardless of where in the country they are produced; only the fully assembled bicycles and rickshaws are counted. Nevertheless, GDP estimate at the provincial or even lower level for calculating the HDI has been attempted in India, for example.[3] In many cases, however, the costs and risk of inaccuracy of such estimates are often unacceptable and proxy estimates are used instead for calculating sub-national HDIs.

Life Expectancy: Concept and Overview

Life expectancy [4] refers to the average number of years a person of a given age and sex can expect to live, if current age-specific and sex-specific death rates continue to apply *throughout* the person's lifetime. More technically, life expectancy is the mean expectation of life at birth, e_0, or at a particular age or age interval. Of course, prediction of death is rarely accurate and the range of uncertainty is very wide.

A number of factors affect a person's life span, including gender [5], genetics, state of health, lifestyle, accidents, disease, medical advances, natural disasters, conflict and war. Life expectancy is dependent heavily upon the criteria used to select the group[6] and life expectancy at birth is highly sensitive to the death rate in the first year of life. Nevertheless, it is possible to predict the number of survivors each year with a surprising degree of confidence–but this requires a relatively large group of people.

Life expectancy at birth, or the expected average life span of a person at birth, is sometimes used as an overall indicator of a country's (or geographical area) population overall health and physical well-being. Griffiths and Fitzpatrick (2001) observed that life expectancy " … is a summary measure of mortality at every age that allows comparisons to be made between areas and time periods without the need to assume a particular standard population." The UK Government (2001), for example, is apparently of the view that life expectancy is the best summary measure of health outcomes and uses it as an indicator of geographical inequalities in health (Toson and Baker 2003). Indeed, life expectancy at birth has been used as a measure of the health status of the population in England and Wales since the 1840s (*ibid*).

That said, it is important to note that life expectancy is an entirely hypothetical construct. Thus,

3 See technical notes on the HDI in Madhya Pradesh HDR 2007 (Government of Madhya Pradesh 2007: 139-144).

4 *Actuarial science* is the term used for the mathematics of mortality and life expectancy, named after the profession of actuaries that developed early life tables for commercial use. Life expectancy is a common term for the more technical one *expectation of life*, which is the average expected total years of life.

5 It is a known empirical fact that women tend to have higher life expectancies than men. At around 2007, the worldwide life expectancy of both males and females was 64.3 years. For males alone, it was 62.7 years and 66 years for females, a difference of more than three years (Rosenberg 2007). The sex difference in life expectancy ranges from about 4-6 years in North America and Europe to more than 13 years in Russia.

Sex differences in life expectancy are evident even before birth. In the womb, male fetuses have a higher mortality rate – males are conceived at a ratio of 124 males/100 females, but by birth the ratio is only 105 males/100 females. For premature babies (below two pounds), females have a higher survival rate. Interestingly, the sex ratio tends to equalise at around age 13, which is close to menarche, suggesting a potential reproductive-equilibrium explanation that is probably of evolutionary significance. Women are better able to cope with blood loss whether it is from periodic menstruation or trauma. By age 110, 90 per cent of the population is female; by age 112, the figure is 92 per cent.

Yet the reasons for the sex difference in life expectancy are still hotly debated and are far from settled. Standard arguments tend to favor environmental factors: men, on average, are employed in more dangerous occupations (factories, the military, etc), are more prone to accidents, more likely to partake in high-risk sports ('train surfing,' roller-board skating, skyscraper climbing, etc); they also tend to consume more tobacco, alcohol and dangerous drugs and are more likely to die from lung cancer, tuberculosis and cirrhosis of the liver. Men are also more likely to die from injuries, whether unintentional (for example, automotive accidents) or intentional (suicide, violence, war) (WHO 2004).

However, these arguments are not fully sufficient to explain observed differences in life expectancy between the sexes: even for known socio-environmental effects on mortality, females still have longer life expectancy. Some argue that women are biologically superior to men and thus live longer. Others, adopting a more evolutionary perspective, note that shorter male life expectancy is merely another manifestation of the general rule seen in all animal species: larger individuals tend to have shorter life spans (Stindl 2004; Samaras and Elrick 2002; Samaras *et al*. 2003); body size is a function of both nature (genetics) and nurture (environment, including nutrition). Yet, contrary to what some argue, people who are better nourished are taller and tend to live longer.

6 Provided that the requisite data is available, life expectancy can be calculated for specific sub-population by, for example, ethnicity, race or gender or a combination of these characteristics.

life expectancy at birth may not represent the age at which the average child born today is likely to die, since mortality probabilities are likely to change over time. By the time the child reaches 40, for example, the child born today might be more or less likely to die that year than a person aged 40 today is of dying this year. Like all summary statistics, life expectancy is an *average* and it does not measure the *distribution* of either mortality risk within one person's life, or between different sub-populations in a country. Clearly, two countries with the same life expectancy at birth may not necessarily have the same mortality probability at every age. Moreover, while life expectancy of the general population may appear quite high, it could mask considerable variations among sub-populations. Life expectancy at birth, moreover, does not give any direct indication of the effect of morbidity on overall health or physical well-being.

Several subtly different methods are available for the calculation of life expectancy. Two of the most commonly used are the Chiang method[7] (Chiang 1968; 1978), and the Silcocks method (Silcocks *et al*. 2001). To use actuarial notation, the probability of surviving from age x to age x+n is denoted by ${}_np_x$ and the probability of dying at age x (that is between ages x ad x+1) is denoted by q_x. Life expectancy at age x, denoted by e_x, is then the summation of the probabilities of surviving to every age. Algebraically:

$$e_x = \sum_{t=1}^{\infty} {}_t\rho_x = \sum_{t=0}^{\infty} t\,{}_tp_x q_{x+t}$$

t = years lived and ∞ is taken as the highest age achieved (ω). Because age is rounded down to the last birthday, on average people live half a year beyond their final birthday; so half a year is added to the life expectancy to come up with the 'full' life expectancy. Life expectancy can also be calculated by integrating the survival curve from ages 0 to positive infinity (the maximum lifespan, sometimes called omega (ω))[8].

To estimate life expectancy, it is necessary to construct a life table. The accuracy of the life table depends on the completeness of the data. Starting with a cohort of individuals of any given size (say, *N* newborns), it is possible to calculate how many would survive to each age, which paves the way for calculating life expectancy at any age. Data on the proportion of persons of each age who die is usually taken from national censuses and international sources. However, the vital registration systems that officially register birth and death in many poor countries are often weak and may be non-existent in geographically remote and mountainous areas. In such cases, many births and death go unrecorded. To fill the gap, different agencies use different techniques to correct for missing or non-existent data. The World Bank uses household surveys, which collects data on recent births and death, as well as demographic projections, to obtain a picture of the mortality structure of countries where the necessary data are missing.

Two sets of data are required to construct a life table. First, population by age bands: where mortality and population data are available on a yearly basis, *complete* life tables can be produced; otherwise, *abridged* life tables[9], with age intervals of 5 or 10 years, are commonly produced. Second, age-specific death rates: for example, if five per cent of the people alive at their 70th birthday die before their 71st birthday, then the age-specific death rate at age 70 is 5 per cent. All other columns in the table are computed from these two sets of data.

Life tables are of two kinds: cohort and current. A cohort life table captures the actual mortality experience of a cohort of persons from the birth (or other events such as brain tumor) of the first person, to the death of the last. But cohort life tables are not very useful for studying current life expectancies even though they are useful for other purposes, such as studying patient survival after treatment. For our purposes, cohort life tables suffer from two shortcomings. First, cohort life tables would require following members of the cohort until they are all dead – possibly as long as 100 years. Second, a cohort life table reflects historical conditions that are probably no longer valid.

A current life table provides a cross-sectional picture of the age-specific mortality experience of a population during a specified time period.

7 This is also discussed and illustrated in Newell (1994) and Shyrock and Siegel (1976).

8 The formula is: $e^0\ (0,t) = \int_0^{\omega} l(a,t)\, da$, where l (a,t) is the life table probability at time t of surviving from birth to age a, and ω is the highest age attained (Vaupel and Romo 2002).

9 *Abridged life tables* refer to life tables that contain data for age groups instead of single-year ages.

The age-specific mortality rates are applied to a hypothetical cohort of newborns to calculate their life expectancy. For other age bands, life expectancy is calculated in a similar manner. For example, life expectancy for the age band 25 is calculated by applying the age-specific mortality rate to the hypothetical cohort in this age interval. Complete life tables have life expectancies broken down by each year of life. In some cases, the breakdown could be even finer as in the under-one year of age interval where most infant deaths occur, with many deaths occurring during the first 28 days of life (Toson and Baker 2003). Abridged life tables have large age intervals, usually 3-5 or even 10-year age bands.

Estimating Life Expectancy: Small Populations

When the necessary data points required for the construction of life tables are relatively large, the estimates produced by the unadjusted (standard) Chiang methodology is accurate. However, the methodology breaks down when it is applied to small areas–where the population is small or the number of deaths are too few in a single year, and remain so even if the data are aggregated over a three-year period. So the critical issue is to find a method that produces reasonably accurate estimates for small populations.

Griffiths and Fitzpatrick (2001) produced life tables for local authorities for the UK, but excluded certain areas, including the Isle of Scilly and the City of London, which had populations of 2,100 and 7,100 respectively. They argued that 'there are too few deaths there in a three-year period to make analysis meaningful' at the ward level. Silcocks *et al*. (2001) used a population of 256,000 to study the sampling distribution and utility of life expectancy at the district level and below. In the UK, the Office for National Statistics, using a revised Chiang methodology, produces life expectancies for local authority and health authority areas.[10] Others employ the Silcocks methodology to produce life expectancies for small areas.[11]

According to SEPHO (2005), the Chiang methodology produces better estimate for life expectancy for small populations. Models that use 5-year age bands up to 85+ generated the best life expectancy estimates, which have a normal distribution even for small populations. The associated confidence intervals are also valid. Interestingly, zero deaths in one or more age bands do not have a significant effect on the standard error of the life expectancy estimate. " … the presence of age bands with no deaths is likely to have little impact on the calculation of standard errors for population of 5,000 and over" (Toson and Baker 2003: 17). However, a non-zero value in the final age band is required; otherwise, a zero value leads to an infinite life expectancy and the calculation of the variance, and thus the standard error fails. In this case-the final age band-it is recommended that the appropriate national mortality rate for this age band could be used. It was also shown that the adjusted Chiang method produces reliable life expectancy estimates for a population size 5,000 and above. 'As the population size decreases through, especially under 5,000 the standard error tends to be underestimated' (Toson and Baker 2003: 13), and life expectancy tends to be overestimated.

A more comprehensive review of methods for estimating life expectancy for small populations is beyond the scope of this paper. However, we will now provide an intuitive feel of the mechanics involved in the calculations by illustrating the adjusted Chiang method (Chiang 1968; Newell 1994), which is widely used, for example, by the UK Office of National Statistics to calculate life expectancies at the electoral ward level where the mean population is about 5,800 (Toson and Baker 2003).

The Chiang Method

Because of data problems and the size of population distribution in Bhutan by dzongkhag, this paper adopts two approaches to estimate life expectancy: small-area estimate employing the Chiang method and an Age-wise method developed by the authors. This section of the paper provides details on the adjusted Chiang method, and we draw liberally on Toson and Baker (2003) and SEPHO (2005). The adjusted Chiang

10 Based on their evaluation, Eayres and Williams (2004:248) concluded that 'LEs estimated using the Chiang and Silcocks methodologies showed good agreement,' but still recommended the Chiang methodology for calculating small areas life expectancies in England.Two reasons are offered: (a) it produces better estimates when compared to the Government Actuaries Department (GAD) figures; and (b) it is consistent with the methodology used by UK Office for National Statistics for larger populations.

11 More to the point, this study aimed to 'investigate the usefulness of life expectancy as a summary measure of mortality at health-authority level or below, and to derive a formula for the variance of life expectancy results' (Toson and Baker 2003: 7). The specific aim of this innovative study was thus to come up with a method to estimate life expectancy at the sub-national level.

method is best described by referring to the actual life expectancy table (Annex Table A.1).[12] There are several columns:

Age interval or age band: age in years between the lower and upper limit of the age interval. For example, 5-9 years is the 5-year age interval between the fifth and ninth birthdays. More formally, the age interval may be defined as:

$$x_i \leq x < x_{i+1} \quad \text{for } i = 0, 1, \ldots \omega -1$$

Here, each age interval is indicated by the subscript i = 0 to ω. The age at the beginning of the of the age interval i is denoted by x_i. The final age interval does not have an upper age limit and is thus open-ended:

$$x_i \leq x \text{ for } i = \omega$$

The choice of the final age band is crucial to the accuracy of the life expectancy estimates, which is increasingly overestimated as population size decreases. The effect is greatest when the final age band is 95+. Eayres and Williams (2004) propose that the final age band should be 85+ for small populations.

Interval width: the width in years of the age interval i, denoted by n_i.

Fraction of last age interval of life: individuals in a hypothetical cohort who die during the age intervals do not all die at either the start of the end of the interval. Instead, they die at different time during the age interval. Now, the fraction of the last age interval of life is the average fraction of the age interval that individuals live before they die. It is denoted by a_i. As deaths are usually assumed to be evenly distributed during the age interval, this column usually has the fraction 0.5. However, this is not a tenable assumption for individuals in <1 age group as most deaths in this age group occur in the perinatal and neonatal periods. In this case, the fraction is set to 0.1. Thus:

$$a_i = 0.1 \text{ for } i = 0 \text{ and } a_i = 0.5 \text{ for } a = 1, 2 \ldots\omega$$

Population years at risk, usually abbreviated to 'pop': this is in fact the study population for age interval i, denoted by P_i. In the case of Bhutan, the 2005 population in the 10-14 age-group was 77,007.

Number of deaths in the interval: the number of actual deaths recorded in the study population for the age interval i. Usually denoted by D_i.

Annual death rate in interval: the average annual age-specific mortality rate for age interval i, denoted by M_i.

$$M_i = D_i / P_i \quad \text{for } i = 0,1, \ldots \omega$$

Probability of dying/surviving in interval: the probability that a member of the cohort will die or survive during the age interval i. The probability of dying is denoted by q_i and the probability of surviving by p_i. Both the probability of dying or surviving is calculated from the mortality rate M_i. The life table can then be completed by applying either the probability of dying or surviving to the hypothetical cohort, as these are alternative but equivalent approaches:

$$p_i = 1 - q_i$$

Note that the probability of dying in the final age band = 1, so the probability of surviving = 0. That is:

$$p_i = 1,\ q_i = 0 \text{ for } i = \omega$$

Now there are many ways to estimate the probability of survival during an age interval, and this constitutes a significant difference among methodologies. The Chiang methodology postulates that for the hypothetical cohort deaths of members within an age interval are evenly distributed, which explains why this methodology is also known as the linear method. So if the number alive at the beginning of the age interval is l_i and the number of deaths during the interval is d_i, then the probability of death q_i is:

$$q_i = d_i / l_i$$

By manipulating and substituting terms, we get:

12 The discussion in this section draws heavily upon SEPHO (2005).

$$q_i = \frac{n_i M_i}{1+(1-a_i)\, n_i M_i}$$

The above formula is for *complete* life tables. The probability of dying for the *abridged* life table using the Chiang methodology is:

$$q_i = 2M_i /(2+M_i) \text{ for } i = 1,2 \dots \omega -1.$$

It should be obvious that $i = 1,2 \dots \omega -1$ suggests that the formula does not apply to the first age interval (i=0) where most of the deaths occur early in the interval.[13]

Numbers alive at the start of interval: the number of individuals of the hypothetical cohort alive at the start of the age interval is usually denoted by l_i. The hypothetical cohort is normally and arbitrarily set to 100,000. There are two equivalent ways for finding the number of persons alive at the start of the subsequent age interval. These are: (1) apply the probability of surviving the previous age interval to the numbers alive at the start of this (the previous) age interval, and (2) subtract the numbers of persons who died during the previous age interval from the number alive at the start of this (the previous) age interval. Algebraically, this can be written:

$$l_i = 100{,}000 \text{ for } i = 0$$

$$l_i = l_{i-1}P_{i-I} \text{ or}$$

$$l_i = l_{i-1} - d_{i-1} \text{ for } i = 1, 2, \dots\omega$$

Numbers dying in the interval: this is the number of persons in the hypothetical cohort dying in the age interval i, denoted by d_i. As with the numbers surviving, there are two alternative but equivalent ways of arriving at the numbers dying in the interval: (1) apply the probability of dying in the interval to the number of persons alive at the start of the age interval; and (2) subtract the number of persons alive at the beginning of the age interval from the number alive at the start of the next age interval. Since the final age interval has no upper limit, all persons alive at the start of the interval will die during it. Algebraically:

$$d_i = l_i - l_{i+1} \text{ or } d_i = l_i q_i \text{ for } i = 0,1, \dots\omega - 1$$

$$d_i = l_i \text{ for } i = \omega$$

Number of years lived in the interval: equals the product of the number of person-years lived during the interval i times the number of people in the hypothetical cohort who are alive at the start of the interval, symbolized by L_i. However, this is not valid for the final age interval, since it is open-ended. The Chiang method assumes that the probability of survival in the final age band is zero, which, by definition, leads to a zero variance for this age group. If the variance is important, as it is in small populations, then the Chiang assumption of zero survival for the final age group is not valid. In fact, Silcocks *et al* (2001) argued that life expectancy for the final age band is not dependent upon the probability of survival, but on the mean length of survival. The UK ONS methodology, which we have used for the calculation of life expectancy in Bhutan, assumes that survival in this age band is exponential. In other words, the number of survivors decreases each year at the age-specific mortality rate (M_i, $i = \omega$). This assumption, it may be noted, affects only the estimate of the standard error for this age interval and not life expectancy itself.[14]

Algebraically, the above can be written as:

$$L_i = n_i(l_i-d_i) + a_i n_i d_i \text{ or}$$

$$L_i = n_i(l_{i+1}+a_i d_i) \text{ for } i = 0, 1, 2, \dots \omega$$

$$L_i = l_i/M_i \text{ for } i = \omega$$

Total number of years lived beyond the start of interval: the total number of person years that will be lived by people of the hypothetical cohort who are alive at the start of the age interval i, denoted by T_i. In other words, it is the summation of the number of years lived in the given age interval and all subsequent age intervals. That is:

13 Silcocks's methodology for estimating the probability of survival during an age interval differs from that of Chiang. While Chiang uses a linear method, Silcocks assumes that the mortality rate is constant throughout the age interval. The result is that survival is exponential. That is, the probability of survival is: $p_i = \exp(-ni\ Mi)$, where Mi is the average annual mortality rate: Mi = Di /Pi . For a complete life table, the Silcocks method is less accurate than the Chiang method. This is because the assumption of a constant mortality rate throughout the age interval is not valid for human populations. In such populations, mortality risks for age intervals after childhood increases slowly, but at a rate that is consistent with the linear method. In fact, the Chiang method generated more accurate estimates of life expectancy than the Silcocks method (SEPHO 2005).

14 The UK ONS refers to this as the Chiang II methodology (Toson and Baker 2003).

$$T_i = L_i + L_{i+1} + \ldots + L_\omega \text{ or}$$

$$T_i = T_{i+1} + L_i \text{ for } i = 0, 1,2, \ldots \omega$$

Observed expectation of life at the start of interval: the average number of years that each member of the cohort alive at the start of the interval can expect to live, denoted by e_i. It is, in other words, the quotient of the total number of years lived beyond the start of the interval and the number of persons alive at the start of the interval. That is:

$$e_i = T_i/l_i \text{ for } i = 0, 1, 2, \ldots \omega$$

The 95 per cent confidence interval: the calculation of confidence intervals is not usually a standard practice when estimating life expectancy. However, it is helpful to have confidence intervals given the problems of estimating life expectancy for small populations, especially those below 5,000. If the estimate of life expectancy is normally distributed, the confidence interval can be calculated in the usual way:

$$e_i \pm 1.96 S_{ei}$$

where S_{ei} is the standard error of e_i given by $\sqrt{S^2_{e_i}}$.

In age bands where there are no deaths, the standard error will be underestimated because the contribution to the variance for those intervals with zero deaths will be zero. As the population becomes increasingly small, zero deaths in some age intervals is a real possibility. However, Toson and Baker (2003) demonstrated that the presence of age intervals with zero deaths is not likely to have a significant effect on the calculation of the standard error for populations 5,000 and above. For populations smaller than this, even a very small value (0.03) tends to overestimate the standard error, while leaving age bands with zero deaths leads to an underestimation of the standard error. Note, too, that zero deaths in the final age band causes the Chiang method for calculating the variance to fail. If no correction is done for the final age interval, the result would be 'an infinite LE' (Eayres and Williams 2004: 248).

For estimating life expectancy by dzongkhag, we have used the spreadsheet[15] used by the British Office for National Statistics (ONS) to estimate life expectancy at the electoral ward level. Because the mean population at the ward level is less than 6,000, the spreadsheet enables the calculation expectancy at birth with a 95 per cent confidence interval.

The Age-wise Method

This is a rather simple method, perhaps less robust than the Chiang method, that was used to generate quick estimates of life expectancy for Bhutan by dzongkhags. This method, which we have dubbed the Age-wise method, is, in effect, a three-step procedure that requires two pieces of data: (a) national life expectancy at birth, and (b) the proportion of Bhutan's population by dzongkhag (or geographical area, more generally) that is above national life expectancy at birth. A simple assumption is at the basis of the Age-wise method: dzongkhags with a *higher* share of their population above the national life expectancy at birth tend to have a higher life expectancy than dzongkhags with a *lower* share of their population above national life expectancy.

The three steps involved in the Age-wise method are as follows:

1. Calculate the proportion of population aged 66 (Bhutan's 2005 life expectancy at birth) and above in each dzongkhag (X_{di}) to obtain the percentage of the population in each dzongkhag that is above the national life expectancy at birth, which was 66 years.

2. Take the median value (m) of the results from step one (20 data points, one for each dzongkhag), which is the average of the 10th and 11th values in the ordered distribution.

3. Adjust X_{di} for each dzongkhag if they are above or below the median value (m) to obtain life expectancy at birth for that dzongkhag. The adjustment procedure is:

   • If $X_{di} > m$ (a higher proportion of population

15 Available at [http://www.statistics.gov.uk/statbase/Product.asp?vlnk=10626] (last accessed on 7 April 2009). The workbook contains five sheets. The first contains a brief introduction to the estimating exercise. The second and third contain life tables constructed according to the Chiang methodology – Chiang (I) and the adjusted Chiang or Chiang (II) – and are identical in their calculation of life expectancy. However, they differ in their computation of the standard error, as may be seen in the different formula for Var(qx). The calculation of the standard error in the Chiang (I) method fails if there are zero deaths in any of the age intervals – because the calculation of Var(qx) involves dividing by the number of deaths. The Chiang (II) adjusts for this shortcoming in Chiang (I) by allowing for the computation of the standard error when there is zero death in any age band. It does this by requiring the components of var(qx) to be multiplied by the mortality rate. The fourth sheet has a life table constructed according to the Silcocks methodology, while the final sheet contains the life table developed for ONS, which is essentially the same as the Chiang II method.

aged 66 and above the median value), use the following equation:

$$\text{If } X_{di} > m, \text{ then } LE_{di} = 66[1+(X_{di}/100)]$$

- If $X_{di} < m$ (a lower proportion of population aged 66 and above the median value), use the following equation:

$$\text{If } X_{di} < m, \text{ then } LE_{di} = 66[1-(X_{di}/100)]$$

- If $X_{di} = m$, no adjustment is made.

The theoretical justification for the Age-wise method rests on the underlying assumption as stated above. If a larger percentage of people in province Y live longer than the national life expectancy at birth than people in province Z, then people in province Y will have a longer life expectancy than people in province Z. This is a reasonable assumption, but why use the median value, or any value for that matter, of the distribution (which comprises the percentage of people in each province above national life expectancy – the X_{di}) to adjust life expectancy for a given province? An adjustment is necessary since it is highly probable that a certain percentage of the people in each province will have (provincial) life expectancy greater than the national life expectancy. If this is in fact the case, then the national life expectancy will have to be higher than the value used to arrive at the X_{di} for each dzongkhag, which creates a vicious trap. So the issue is not if an adjustment factor has to be used, but what the adjustment factor should be. We settled on the median of the X_{di} distribution because it is more representative of the distribution.

Estimating Per Capita GDP

GDP per capita at the dzongkhag level is not available from the national accounts. The estimate we employ for per capita GDP by dzongkhag is based on three indicators: (1) monthly per capita consumption expenditure (MPCE) for each dzongkhag as given by BLSS 2007; (2) population (POP) for each dzongkhag taken from the Population Census of 2005; and (3) GDP of Bhutan at the national level as per the National Accounts data.

The steps for estimating per capita GDP for the 20 dzongkhags are given below:

1. Calculate total annual consumption expenditure (ACE) of each dzongkhag:

$$ACE_{di} = 12 * MPCE_{di} * POP_{di}$$

where di refers to i^{th} dzongkhang and i =1 to 20.

2. Calculate annual consumption expenditure of each dzongkhag (S_{di}) as a share of total consumption for all dzongkhags:

$$S_{di} = ACE_{di} / \sum ACE_{di}$$

3. Apply these shares (S_{di}) to the GDP of Bhutan (GDP_B) to obtain GDP for each dzongkhag (GDP_{di}):

$$GDP_{di} = S_{di} * GDP_B$$

4. Obtain per capita GDP for each dzongkhag ($PCGDP_{di}$) by dividing the GDP_{di} by the population of each dzongkhag (POP_{di}):

$$PCGDP_{di} = GDP_{di} / POP_{di}$$

V. Sub-National HDIs for Bhutan: The Dataset

Bhutan is a landlocked country nestled at the foothills of the Himalayas, but also positioned between India and China, the two economic powerhouses of Asia. Its population, estimated at around 0.6 million in 2005, is scattered across the 20 dzongkhags (provinces) that comprises the country. About 16 per cent of the country's population live in the most populous and developed dzongkhag (Thimphu), while less than one per cent live in the least populous dzongkhag (Gasa). The four most populous dzongkhags – Thimphu, Chhukha, Samtse and Trashigang

– accounted for 45 per cent of the country's population, while combined shares of 10 other dzongkhags amounted to 23 per cent of the total population (less than three per cent of the population in each of these 10 dzongkhags). It is thus reasonable to say that, besides the four most populous dzongkhags, the population of Bhutan is thinly distributed over the other 16 dzongkhags (Table 1).

The majority of Bhutanese live in rural areas and earn their livelihood mainly from agriculture. The driving force of Bhutan's economy so far is hydropower and related activities, such as construction and energy-intensive industries. The country's GDP grew at an average rate of seven per cent per annum in the quarter-century leading to 2004, while per capita income rose at about four per cent during this time (Osmani *et al*. 2006). Poverty remains a major challenge and it is more severe in rural than urban areas. According to Bhutan's *Living Standard Survey* report of 2007, income poverty was 23.2 per cent in 2006, which is considerably less than the 31.7 per cent in 2003 (cited in Alkire *et al*. n.d.). Average life expectancy (at birth) for Bhutan as a whole was 66.25 years in 2005 (UNDP 2007a), but life expectancy by dzongkhags does not exist.

Bhutan has reasonably good national account statistics, published every year by the National Statistics Bureau, Royal Government of Bhutan. GDP per capita is available for the country as a whole but not by dzongkhags. Similarly, life expectancy at birth data is available for the country as a whole but not for the dzongkhags. The Population Census done in 2005 contains a wealth of data on population, literacy and enrolment figures for all 20 dzongkhags and these were used

Table 1. Chiang and Age-wise Methods: Estimates of Life Expectancy at Birth by Dzongkhag

Dzongkhags	Population 2005	Percentage of population aged 66 and above 2005	Life expectancy at birth(years) 2005 (Chiang method)	Life expectancy at birth (years) 2005 (Age-wise method)	Chiang method		
					Lower 95% confidence interval	Upper 95% confidence interval	Width of confidence interval
Bumthang	16,116	5.8	69.7	69.8	66.65	72.70	6.05
Chhukha	74,387	2.4	62.6	64.5	61.12	64.15	3.03
Dagana	18,222	4.2	65.9	63.3	62.96	68.77	5.81
Gasa	3,116	5.0	59.3	69.3	53.19	65.35	12.16
Haa	11,648	4.6	66.1	69.0	62.56	69.53	6.97
Lhuentse	15,395	6.1	65.3	70.0	61.85	68.72	6.87
Mongar	37,069	5.1	66.5	69.4	64.23	68.76	4.53
Paro	36,433	4.8	68.0	62.9	66.07	69.77	3.70
Pemagatshel	13,864	7.3	68.8	70.8	65.37	72.17	6.80
Punakha	17,715	4.9	65.9	62.8	63.35	68.54	5.19
Samdrup Jongkhar	39,961	4.4	69.0	63.1	66.93	71.08	4.15
Samtse	60,100	4.2	64.9	63.2	63.33	66.41	3.08
Sarpang	41,549	3.3	69.4	63.9	67.24	71.47	4.23
Thimphu	98,676	2.7	65.7	64.2	64.44	69.98	5.54
Trashigang	51,134	5.1	63.4	69.4	61.48	65.39	3.91
Trashiyangtse	17,740	5.0	64.0	62.7	61.32	66.72	5.40
Trongsa	13,419	6.4	69.1	70.2	65.84	72.33	6.49
Tsirang	18,667	5.0	69.4	69.3	66.70	72.11	5.41
Wangdue	31,135	5.2	65.8	69.5	63.51	68.11	4.60
Zhemgang	18,636	5.9	70.4	69.9	67.34	73.41	6.07
Average		4.2	66.5	66.9	63.77	69.27	5.50
BHUTAN	**634,982**	**4.2**	**66.2**	**64.7**	**65.66**	**66.66**	**1.00**

Source: Based on Population Census of Bhutan 2005, data provided by NSB, Royal Government of Bhutan.

to calculate literacy and enrolment rates.

As explained in the previous section, two methods were used to calculate life expectancy and one for GDP per capita for all dzongkhags. This section of the paper employs these methods to assemble the requisite dataset for the estimation of sub-national HDIs in Bhutan.

Estimate of Life Expectancy

The results of the adjusted Chiang and Age-wise methods of estimating life expectancy (at birth and by other age bands) for all dzongkhags of Bhutan are shown in Table 1.[16] Consider the simple arithmetic mean and standard deviations of these estimates, respectively: Chiang method: 66.5 and 2.8; Age-wise method: 66.7 and 3.3. Clearly, the mean of the two estimates of life expectancy are not far off from that of Bhutan as a whole: 66.25 years, but the estimate generated by the Chiang method for small areas comes closer than that of the Age-wise method. However, the difference (range) between the highest and lowest estimates by the Chiang method (11.1) is larger than that of the Age-wise method (8.1). Since the upper limits of the two estimates are 70.4 (Zhemgang) and 70.8 (Pemagatshel) respectively, the difference stems mainly from the value of the lower bound. Neither of these provinces has the lowest mortality rate in the country – that distinction belonged to Sarpang, which has a mortality rate of 0.56 in 2005. However, consistent with the importance of mortality rates in the estimation of life expectancy, the Chiang method seems more credible: Zhemgang has a lower mortality rate (0.64) than Pemagatshel (0.79) and thus a higher life expectancy.

Of the 20 provinces, Gasa has the highest mortality rate (1.16) and, according to the Chiang method, has the lowest life expectancy (59.3 years). On the other hand, Trashiyangtse, with a mortality rate of 0.92, has the lowest life expectancy (62.7 years) by the Age-wise method. Sarpang recorded the lowest mortality rate (0.57) in the country, which is only just above Thimphu's (0.58), but neither method accorded it the highest life expectancy, even though the estimate by Chiang is considerably higher than that of the Age-wise method (69.4 years against 63.9 years). By way of comparison, the national mortality rate in 2005 was 0.79.

The 95 per cent confidence intervals have also been estimated for the Chiang method (Table 1). These demonstrate that the estimate of life expectancy at birth is most robust for Chhukha (with a width of 3.03 years) and lowest for Gasa (with a width of 12.16 years). Interestingly, estimates for some dzongkhags, including Chhukha, Monggar, Paro and Samtse, appear to be more robust than that of the most developed dzongkhag, Thimphu, the country's capital, which has a confidence interval width of 5.54.

Which of the two estimates of life expectancy by dzongkhag is more accurate? At least two sets of issues need to be considered: methodological and consistency (Table 2). The arguments presented in this table suggest that the Chiang method produces estimates that are more robust and thus more accurate. As noted earlier, the average of the estimates of the 20 dzongkhags produced by the Age-wise method is not significantly different from that of the Chiang method, but there are significant differences between the two distributions (greater variability). The Chiang method is tested and is robust for populations above 5,000, while the Age-wise method is untested and still requires a sound theoretical justification. The appeal of the Age-wise method is that is it less data-demanding than the Chiang method, and may be used to produce a quick and tentative estimate of life expectancy possibly even for populations of less than 5,000 even if mortality data is non-existent.

Education: Adult Literacy Rate (ALR)

Adult Literacy Rate (ALR) is the proportion of the adult population aged 15 years and older that is literate (ADLIT), expressed as a percentage of the respective population (ADPOP) in each dzongkhag. The necessary data is taken from the 2005 Census, which provides, among other things, age and literacy distribution by the 20 dzongkhags. The equation below was used to generate the results shown in Table 3.

16 The authors discovered that a UNICEF consultant, Dirk Westloaf, also produced life expectancy estimate by dzongkhag for Bhutan, but his methodology is not available. His estimates show large variation across dzongkhags and the mean is 64.43 years, which is far below the national average of 66.25 in 2005. For these reasons, we have not used his estimate of life expectancy in calculating sub-national HDIs for Bhutan.

Table 2. Chiang and Age-wise Methods of Life Expectancy: Issues of Robustness

Estimate	Methodological	Bhutan Dataset	
		Strengths	Weakness
Chiang method (adjusted)	Methodologically robust, tried and tested; for example, used by the British Office for National Statistics, to generate life expectancy estimates at the electoral ward level, which has a mean population of 5,800 (Toson and Baker 2003). The adjusted Chiang method also produces 95 per cent confidence intervals, which enhances the value of its estimates.	Estimates consistent with mortality conditions in dzongkhag. Indeed, the correlation coefficient between mortality rate and life expectancy estimate by dzongkhag = - 0.72. All columns of the life table are automatically calculated once data on age distribution of the population and the appropriate age-specific data (by individual years or age interval, depending upon whether complete or abridged life tables are being done) on mortality (death) rates are available. Width of confidence interval consistent with population size and mortality conditions. Lower variability of estimate by dzongkhag (SD = 2.82). Mean of estimates closest to value for Bhutan as a whole.	Produces inaccurate life expectancy for populations below 5,000. Even no available method produces accurate life expectancy estimates for population below 5,000.
Age-wise method	Adjusts national life expectancy for each dzongkhag by the median of the proportion of population in all 20 dzongkhags above the national life expectancy of 66 years. To our knowledge, this method has not been used before.	Less data-demanding than the Chiang method. Only two pieces of data are necessary: national life expectancy and percentage of population in each province above national life expectancy. No mortality data is required. May be used to produce quick and tentative estimates for small areas with populations of less than 5,000. Mean value for 20 dzongkhags very close to national value.	Correlation between life expectancy and mortality rates in the wrong direction, albeit weakly correlated (correlation coefficient = 0.25). Higher variability of estimates than the Chiang method. Still needs a strong theoretical justification.

Source: Authors' write-up.

$$ALR_{di}=(ADLIT_{di}/ADPOP_{di})*100$$

According to available data, just about half of Bhutan's adult population is literate. It is less than this figure in 12 of the 20 dzongkhags and greater than 55 per cent in only four of them. Adult literacy rate is highest in the most developed dzongkhag, Thimphu (68.9 per cent), and lowest in Gasa (39.2 per cent). It is perhaps noteworthy to observe that adult literacy rate in Chhukha (59 per cent), the dzongkhag placed second on this indicator, is still 10 per cent below that of Thimphu. As a general statement, it can be said that the ALRs for all but four dzongkhags are about 45 per cent, and, with a standard deviation of 7.2, there does seems to be considerable variations across dzongkhags.

Education: Combined Gross Enrolment Ratio (CGENR)

The combined gross enrolment ratio is calculated by expressing the total number of pupils/ students enroled in primary, lower secondary, middle secondary and higher secondary education (ENR) as a percentage of the population in the theoretical age group[17] of 6 to 18 years for the same level of education (POPAG) in each dzongkhag. The necessary data comes from the population Census of 2005. The equation below was used to generate the results shown in Table 4.

$$CGENR_{di}=(ENR_{di}/POPAG_{di})*100$$

The data in Table 4 demonstrates that only about two-thirds of the country's population between 6-18 years is enroled in educational institutions. Three dzongkhags - Gasa, Dagana and Samtse - have combined gross enrolment ratios that are less than 50 per cent. This statistic is highest in Thimphu (78.8 per cent) and lowest in Gasa (43.8 per cent), but Dagana is only marginally better off than Gasa in this respect. On the other hand, the combined gross enrolment ratios for five dzongkhags are higher than 70 per cent: Thimphu, Paro, Pemagatshel, Bumthang and Punakha. In sum, Bhutan's combined gross enrolment ratio ranges from 78.8 per cent in Thimphu to 43.8 per cent in Gasa. The SD of 10.7 suggests that there is significant variability around the average enrolment ratio of 62.1 per cent, but it's variability is concentrated mainly in the lower and upper ends of the distribution.

The fact that CGENR > ALR is not necessarily a cause for concern at this point in time, since the former includes only students in the age group 15-18 years, while ALR refers to the share of the entire population 15 years and above. It is not possible to say from the available data if dropout rates are high or low, but perhaps it is

Table 3. Bhutan: Adult Literacy Rate by Dzongkhag

Dzongkhag	Population (Adults 15 and above) 2005	Literates (Adults 15 and above) 2005	Adult literacy rate (% aged 15 and above) 2005
Bumthang	11,150	6,531	58.6
Chhukha	51,655	30,495	59.0
Dagana	11,162	4,907	44.0
Gasa	2,097	823	39.2
Ha	7,943	4,325	54.5
Lhuentse	9,940	4,495	45.2
Monggar	24,122	10,010	41.5
Paro	25,601	14,883	58.1
Pemagatshel	9,192	4,454	48.5
Punakha	11,854	6,254	52.8
Samdrup jongkhar	25,917	11,994	46.3
Samtse	39,763	17,690	44.5
Sarpang	27,300	14,182	51.9
Thimphu	68,984	47,514	68.9
Trashigang	33,257	15,444	46.4
Trashi yangtse	11,299	4,955	43.9
Trongsa	8,835	4,449	50.4
Tsirang	12,324	6,074	49.3
Wangdue	20,584	9,309	45.2
Zhemgang	12,044	5,685	47.2
BHUTAN	**425,023**	**224,473**	**49.8**

Source: Calculations based on Population Census of Bhutan 2005 and data provided by NSB, Royal Government of Bhutan.

17 In the context of Bhutan, the theoretical age group for primary school going children is 6 to 12 years, for lower secondary 13 to 14 years, for middle secondary 15 to 16 years and for higher secondary 17 to 18 years (BLSS 2007).

something that needs to be flagged.

GDP Per Capita by Dzongkhag

GDP data for Bhutan at the national level is available only for the period 1980 to 2006; no breakdown by dzongkhag is available. Since reliable population data (taken from the first Population Census in Bhutan, 2005) is available for only 2005 and 2006, reliable per capita GDP for the country can be calculated only for these two years.

The latest Bhutan Living Standard Survey (BLSS) 2007 contains data on monthly per capita consumption expenditure (MPCE) at both the national and sub-national levels. Consumption can, of course, be used as a proxy for income but could be a biased proxy if consumption is greater than income for more than a short period, which is in fact what the data shows for many poor countries. One reason for this is that people do not reveal their entire income in these surveys because they are afraid of taxes. This does not appear to be the case with Bhutan: its consumption expenditure in 2007 was about half the size of its GDP in 2006.

The estimate we employ for per capita GDP by dzongkhags is based on three indicators. These are: (1) monthly per capita consumption expenditure (MPCE) for each dzongkhag as given by BLSS 2007; (2) population (POP) for each dzongkhag as given by Census 2005; and (3) GDP at the national level as per the National Accounts data.

According to our estimate, per capita income in Thimphu was the highest in the country (Nu 109,749), while it was lowest in Lhuentse (Nu 31,881) (Table 5). That is, per capita GDP in Thimphu was 3.4 times that of the poorest dzongkhag. About 16 per cent of the country's population lives in Thimphu, while a little over two per cent lives in Lhuentse. Per capita income was less than Nu 50,000 in 9 of the 20 dzongkhags; only in Paro was it greater than Nu

Table 4. Bhutan: Combined Gross Enrolment Ratio by Dzongkhag

Dzongkhags	No of pupils enroled in primary education 2005	No of pupils enroled in lower secondary education 2005	No of pupils enroled in middle secondary education 2005	No of pupils enroled in higher secondary education 2005	Total number of pupils enroled 2005	Total population in the specified age group (6-18) 2005	Combined gross enrolment ratio (CGENR) 2005
Bumthang	2,392	507	381	259	3,539	4,865	72.7
Chhukha	8,737	1977	1,749	961	13,424	20,659	65.0
Dagana	2,228	423	178	20	2,849	6,476	44.0
Gasa	352	24	1	2	379	866	43.8
Ha	1,683	557	335	106	2,681	3,726	72.0
Lhuentse	2,281	437	210	30	2,958	5,077	58.3
Monggar	4,979	1,081	691	285	7,036	12,228	57.5
Paro	4,912	1,361	1,214	730	8,217	10,620	77.4
Pemagatshel	2,324	636	389	133	3,482	4,550	76.5
Punakha	2,398	667	702	461	4,228	5,921	71.4
Samdrup jongkhar	5,922	1,073	263	104	7,362	12,642	58.2
Samtse	6,403	1,038	427	281	8,149	18,341	44.4
Sarpang	5,211	1,078	541	106	6,936	12,825	54.1
Thimphu	12,391	3,307	3,080	2,736	21,514	27,298	78.8
Trashigang	7,394	1,664	1,245	433	10,736	17,118	62.7
Trashi yangtse	2,738	519	371	178	3,806	5,859	65.0
Trongsa	1,980	421	237	25	2,663	4,245	62.7
Tsirang	2,301	436	346	105	3,188	5,751	55.4
Wangdue	3,999	904	508	277	5,688	9,648	59.0
Zhemgang	2,838	591	447	202	4,078	6,432	63.4
BHUTAN	**83,463**	**18,701**	**13,315**	**7,434**	**122,913**	**195,147**	**62.1**

Source: Based on Population Census of Bhutan, 2005 and data provided by NSB, Royal Government of Bhutan.

70,000, aside from Thimphu. This considerable degree of variability across dzongkhags is reflected in a standard deviation that is more than a third of the average per capita GDP.

Once there is clarity about the indicators for the three dimensions of HDI, the next step is to make the indicators scale-free or unit-free in order to make them additive and easy to perform arithmetical operations on. UNDP uses the range equalization method to make the indicators scale-free:

Table 5. Bhutan: GDP Per Capita by Dzongkhag

Dzongkhag	Per capita consumption expenditure (monthly) (Nu.) 2007	Total consumption expenditure (annual) (Million Nu.) 2007	Share of total annual consumption expenditure	GDP per capita (annual) (Nu.) 2005
Bumthang	3,070	593.7	0.028	63,024.6
Chhukha	2,945	2,628.8	0.123	60,458.4
Dagana	1,962	429.0	0.020	40,278.3
Gasa	3,227	120.7	0.006	66,247.7
Haa	2,573	359.6	0.017	52,821.6
Lhuentse	1,553	286.9	0.013	31,881.8
Mongar	1,769	786.9	0.037	36,316.1
Paro	3,734	1,632.5	0.076	76,656.0
Pemagatshel	1,900	316.1	0.015	39,005.4
Punakha	2,790	593.1	0.028	57,276.4
Samdrup Jongkhar	1,980	949.5	0.044	40,647.8
Samtse	1,668	1,203.0	0.056	34,242.7
Sarpang	2,181	1,087.4	0.051	44,774.1
Thimphu	5,346	6,330.3	0.296	109,749.0
Trashigang	1,936	1,187.9	0.056	39,744.5
Trashiyangtse	2,302	490.0	0.023	47,258.2
Trongsa	2,552	410.9	0.019	52,390.5
Tsirang	2,570	575.7	0.027	52,760.0
Wangdue	2,709	1,012.1	0.047	55,613.6
Zhemgang	1,738	388.7	0.018	35,679.7
BHUTAN	**2,755**	**21,382.9**	**1.000**	**3,413 (PPP US$)**

Note: Nu. = Currency of Bhutan

Source: Calculations based on BLSS 2007 and National Accounts and data provided by NSB, Royal Government of Bhutan.

The equation below was used to generate the results shown in Table 5, following the four steps outlined in Section VI.

$$\text{Scale-free indicator} = \frac{\text{Actual value} - \text{Minimum value}}{\text{Maximum value} - \text{Minimum value}}$$

VI. Sub-National HDIs for Bhutan: Results

The methodology for calculating sub-national HDIs is the same as that for calculating national HDIs, as noted previously. The same indicators are also required for both levels of calculations, but they are more disaggregated: for sub-national HDIs. Indeed, the latter require a disaggregated dataset for which the national accounts of many countries, especially the poorer ones, were not designed to collect, process and disseminate.

Globally, the maximum and minimum values, called 'goalposts' for life expectancy rates, are set at 85 years and 25 years respectively. For both the education indicators (Adult Literacy Rate, and combined Gross Enrolment Rate), the lowest and highest attainment rates are set at 0 and 100 per cent respectively. The maximum and minimum for GDP per capita are set at 40,000 (PPP US$) and 100 (PPP US$). Sub-national HDRs have not used these goalposts and have derived alternative ones that are more relevant to the local context. First, PPP US$ are not necessary, and local currency can be used, since no cross-country comparison is involved. Second, the maximum GDP goalpost is not a target that provinces and small geographical areas in many poor countries can aspire to reach in the next 50 years or so. A poor country as a whole may be able to pull this feat off, but not some of its isolated, remote and direly poor provinces and communities. Third, provincial price levels are often not available for PPP conversion purposes. Fourth, goalposts should be set within the national development context (UNDP 2007b) so that they are more realistic, relevant and appropriate.

The calculation of the three dimension indices and the aggregate HDIs for dzongkhags are discussed in this section.

Life Expectancy Index

The life expectancy index measures the relative achievement of a dzongkhag on life expectancy at birth (LE_{di}). It comprises one indicator, life expectancy, and the life expectancy dimension index is calculated by using the UNDP standard methodology of Range Equalization (which will be used for all dimensions indices):

$$\text{Life expectancy index} = (LE_{di} - 25)/(85 - 25)$$

where LE_{di} refers to the life expectancy at birth for the i^{th} dzongkhag. The results are shown in Table 6.

Education Index

The education index measures a dzongkhag's relative achievement in both adult literacy and combined primary, secondary and higher secondary enrolment. The steps are given below:

1. Calculate the index for adult literacy by using the UNDP standard methodology of Range Equalization. The maximum and minimum values are the same as those used by the UNDP (UNDP 2007a): Maximum =100, Minimum= 0. Thus:

$$\text{Adult literacy index} = (ALR_{di} - 0)/(100 - 0)$$

where ALR_{di} refers to the actual adult literacy rate of i^{th} dzongkhag.

2. Calculate the index for combined gross enrolment by using the UNDP standard methodology. The maximum and minimum goalposts are the same as those used by the UNDP (UNDP 2007a): Maximum =100, Minimum=0.

$$\text{Combined gross enrolment index} = (CGENR_{di} - 0)/(100 - 0)$$

where $CGENR_{di}$ refers to the actual combined gross enrolment rate of i^{th} dzongkhag.

3. Sum the two indices by applying two-thirds weight to the adult literacy index and one-third weight to the combined gross enrolment index. That is,

$$\text{Education index} = 2/3\ (\text{adult literacy index}) + 1/3\ (\text{combined gross enrolment index})$$

Table 6 gives the result of this exercise.

GDP Index

The GDP index measures a dzongkhag's relative command over resources to enjoy a decent standard of living. The steps are given below:

1. Fix the goalposts for maximum ($PCGDP_{max}$) and minimum ($PCGDP_{min}$).

2. Transform GDP per capita into their logarithm values and then apply the UNDP standard methodology of range equalization to make the indicator scale-free. Log transformation of GDP per capita is used to account for the diminishing returns of utility derived from income.

Fixing the goalposts

Maximum: The maximum goalpost is fixed by projecting the per capita GDP of each dzongkhag for the next 25 years. The projection uses Thimphu's per capita GDP, which is currently the highest among the 20 dzongkhags. The other piece of data required for projection is, of course, per capita GDP growth rate. The problem here is that a time series of per capita GDP by dzongkhags is unavailable. Indeed, we have per capita GDP by dzongkhag only for 2005.

Why not use the growth rate of Bhutan's per capita GDP? While time series data for Bhutan's GDP is available from 1980 onwards, population data is not (the first Census has population data only for 2005). The use of per capita GDP growth rate at the national level is therefore ruled out. Our solution to this dilemma is to use the trend growth rate of national GDP (from 1980 to 2005) to estimate per capita GDP of the current richest dzongkhag in 2030.

The steps involved in arriving at the maximum goalpost for dzongkhag GDP are:

1. Calculate the trend growth rate [18] (r) of GDP of Bhutan from 1980 to 2005.

2. Use r to estimate the per capita GDP of the current richest dzongkhag (Thimphu) in 2030 by using the formula $PCGDP_{2030}=PCGDP_{2005}(1+r)^t$ where t=25.

The estimated per capita GDP of Thimphu in 2030 is Nu 586,263, which is rounded up to 590,000 Nu. So the maximum goalpost per capita GDP ($PCGDP_{max}$) for calculating sub-national HDIs in Bhutan is set at Nu 590,000.

Minimum: The minimum per capita GDP ($PCGDP_{min}$) for any dzongkhag is set as Nu 100. The idea of Nu 100 is borrowed from the global HDR, which uses US $100 (PPP) per capita as the minimum goalpost. In India, sub-national HDRs have used Rupees 100 as the minimum goalpost. Note that Nu 100 is not the equivalent of US $100 (PPP), but it probably represents a hypothetical minimum situation that would permit a Bhutanese a mere existence. Most likely, however, no Bhutanese actually lives on Nu 100 during a given year.

The next step is to transform the values of GDP per capita into logarithm values and apply the range equalization method as below:

$$\text{GDP index} = \frac{[\text{Log}(PCGDP_{di}) - \text{Log}(100)]}{[\log(590{,}000) - \log(100)]}$$

where $PCGDP_{di}$ refers to the actual per capita GDP of ith dzongkhag.

Table 6 gives the result of this exercise.

HDIs for All Dzongkhags

All the necessary data for the calculation of HDIs by dzongkhag are now available. The HDI is simply an equally-weighted average of its three dimension indices, viz:

HDI = 1/3 (life expectancy index) + 1/3 (education index) + 1/3(GDP index)

Because of its underlying methodology, the value of the HDI ranges from 0 to 1. Higher values show higher human development; lower values, lower human development.

It will be recalled that two estimates of life expectancy have been produced, and that the estimates generated by the Chiang method is superior than those obtained by the Age-wise method. HDIs based on life expectancy generated by the Chiang method will be denoted by HDI-CM, and those produced by the Age-wise method by HDI-AM (Table 7 and Figure 1). Since GDP per capita and education are common to both estimates of the HDI, the difference between the estimates is due to life expectancy at birth.

Both estimates of the HDIs are in the range 0.500 – 0.800, which means that Bhutan's 20 dzongkhags are all in the medium range of hu-

18 The formula for computing the trend growth rate: $Y_t=Y_0(1+r)^t$ where Y_t and Y_0 refer to the terminal and base points and r refers to the rate of growth. Taking log on both sides we obtain $\log(Y_t)=\text{Log}(Y_0)+t*\log(1+r)$. Or $y=\alpha+\beta t$ where $y=\log(Y_t)$; $\alpha=\log(Y_0)$ and $\beta=\log(1+r)$. Regressing y on t we obtain the coefficient β. Then r=antilog (β) - 1. So r is the trend annual growth rate.

Table 6. Bhutan: HDI Dimension Indices for All 20 Dzongkhags

Dzongkhags	GDP index	Education index	Life expectancy index (Chiang method)	Life expectancy index (Age-wise method)
Bumthang	0.742	0.633	0.745	0.747
Chhukha	0.738	0.610	0.627	0.657
Dagana	0.691	0.440	0.681	0.638
Gasa	0.748	0.408	0.571	0.739
Haa	0.722	0.603	0.684	0.733
Lhuentse	0.664	0.496	0.672	0.750
Mongar	0.679	0.468	0.692	0.740
Paro	0.765	0.645	0.717	0.631
Pemagatshel	0.687	0.578	0.730	0.764
Punakha	0.731	0.590	0.682	0.629
Samdrup Jongkhar	0.692	0.503	0.734	0.635
Samtse	0.672	0.445	0.665	0.637
Sarpang	0.703	0.527	0.740	0.648
Thimphu	0.806	0.722	0.679	0.654
Trashigang	0.689	0.519	0.641	0.739
Trashiyangtse	0.709	0.509	0.650	0.629
Trongsa	0.721	0.545	0.735	0.753
Tsirang	0.722	0.513	0.740	0.738
Wangdue	0.728	0.498	0.680	0.741
Zhemgang	0.677	0.526	0.756	0.749
Average	0.732	0.562	0.691	0.698
BHUTAN	**0.589**	**0.485**	**0.662**	**0.662**

Source: Authors' calculation.

Table 7. Bhutan: Estimates of HDIs for All 20 Dzongkhags

Dzongkhag	HDI-CM (with life expectancy based on the Chiang method)	HDI-CM Rank	HDI-AM (with life expectancy based on the Age-wise method)	HDI-AM Rank	HDI-CM minus HDI-AM
Bumthang	0.707	3	0.707	2	0.000
Chhukha	0.658	9	0.668	7	-0.010
Dagana	0.604	18	0.589	19	0.015
Gasa	0.576	20	0.631	14	-0.055
Haa	0.670	4	0.686	3	-0.016
Lhuentse	0.610	17	0.637	13	-0.027
Mongar	0.613	16	0.629	15	-0.016
Paro	0.709	2	0.681	4	0.028
Pemagatshel	0.665	7	0.676	5	-0.011
Punakha	0.668	5	0.650	11	0.018
Samdrup Jongkhar	0.643	12	0.610	18	0.033
Samtse	0.594	19	0.585	20	0.009
Sarpang	0.656	10	0.626	16	0.030
Thimphu	0.736	1	0.727	1	0.009
Trashigang	0.616	15	0.649	12	-0.033
Trashiyangtse	0.623	14	0.616	17	0.007
Trongsa	0.667	6	0.673	6	0.000
Tsirang	0.658	8	0.658	8	-0.021
Wangdue	0.635	13	0.656	9	0.002
Zhemgang	0.653	11	0.651	10	-0.002

Source: Authors' calculation.

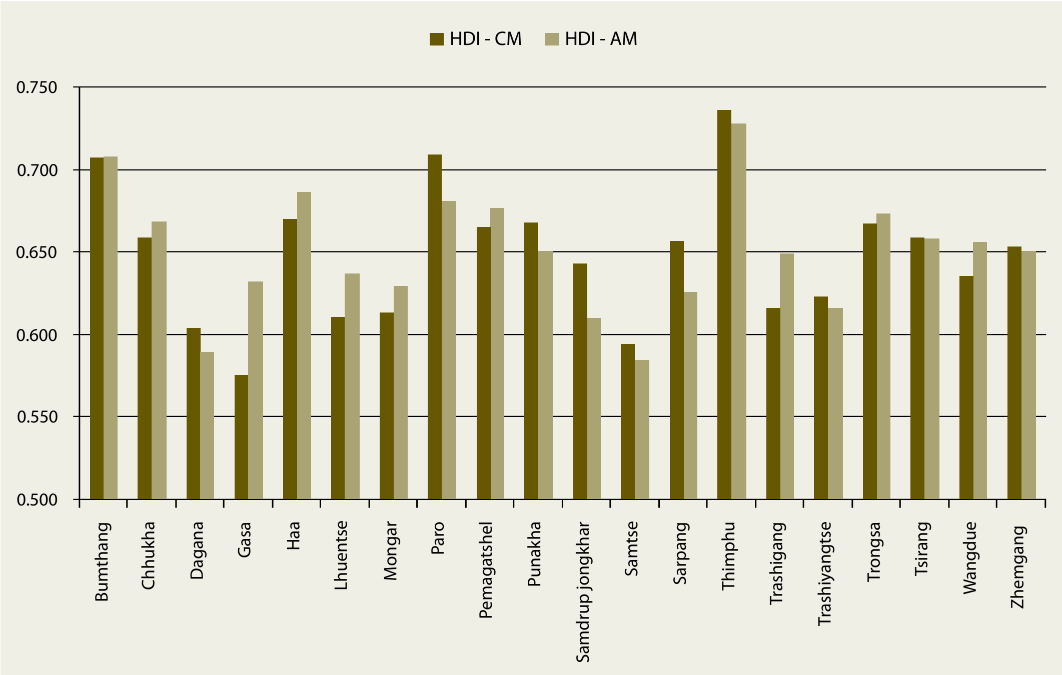

Figure 1. Bhutan: Estimates of HDIs for All 20 Dzongkhags

Source: Authors' calculation.

man development. Both estimates also reveal that the citizens living in the most developed dzongkhag, Thimphu, enjoy the highest level of human development in the country. Using life expectancy from the Chiang method to calculate the HDIs, three dzongkhags obtained HDI values greater than 0.700: Thimphu, Paro and Bumthang in that order. On the other hand, life expectancy estimates from the Age-wise method show that two dzongkhags scored an HDI greater than 0.700: Thimphu and Bumthang.

Paro is the second most developed dzongkhag in Bhutan, with greater access to health and educational facilities than any other dzongkhag besides Thimphu. It obtained the second highest HDI value if life expectancy is calculated by the Chiang method, and the fourth highest if this datapoint is generated by the Age-wise method. HDI-CM shows that Gasa has the lowest human development (HDI = 0.576) followed by Samtse (HDI = 0.594). On the other hand, HDI-AM allocates the lowest position to Samtse (HDI = 0.585), followed by Dagana (HDI = 0.589). Even so, the fact remains that the four poorest dzongkhags (i.e., with lowest level of human development conditions) in Bhutan are Gasa, Samtse and Dagana, not necessarily in that order. The overall difference in average HDI values (between HDI-CM and HDI-AM) is marginal, with HDI-AM greater by only 0.002. For nine dzongkhags, HDI-CM > HDI-AM; for another nine HDI-CM < HDI-AM; and for two, HDI-CM = HDI-AM. These differences, it will

Table 8. Ranking Difference Between Estimates of HDIs for Dzongkhags

Ranking difference	No difference (in rank)	Difference by 1-2 positions	Difference by 3-5 positions	Difference by more than 5 positions
Number of dzongkhags	3	9	4	4

Source: Authors' calculation.

be recalled, derive from a single dimension used for the calculation of the HDI values: life expectancy.

The differences in HDI ranking accorded to dzongkhags by HDI-CM and HDI-AG are shown in Table 8. Evidently, these differences are significant (greater by three or more steps) for eight of the 20 dzongkhags. For planning purposes and possibly the allocation of resources, it is HDI ranking of dzongkhags that is crucial and not necessarily the absolute values of the HDI. From this standpoint, it is desirable to have one estimate of the HDI. We have shown that the estimate of HDI using life expectancy generated by the Chiang method is more accurate.

VII. Discussion and Lessons Learned

The initial estimation of HDIs by dzongkhags was actually done in Bhutan in July 2008, using estimate of life expectancy generated by the Age-wise method. Later, a more rigorous method was employed to estimate life expectancy.[19]

Life expectancy estimate: the two methods used in this paper to estimate life expectancy for the 20 dzongkhags of Bhutan are the adjusted Chiang method and the Age-wise method. The former is tested, robust and widely used; the latter, devised by the authors, is experimental, untested and requires a more robust theoretical justification. The adjusted Chiang method is superior to the Age-wise method for the following reasons:

- The Chiang method has been rigorously tested and widely used; it produces accurate estimates of life expectancy for populations of 5,000 and above. Zero deaths in any but the last age interval do not compromise accuracy, and even in the latter case, only the standard error, not the life expectancy of this age-band, is affected

- As the Age-wise method is not correlated with mortality rates, it does not necessarily follow that areas with high mortality rates will tend to have low life expectancy. The central point of the Age-wise method is that it ties life expectancy around the national average and then adjusts it by the percentage of people in each province who are older than the national life expectancy. In this way, it adds or subtracts x years to national life expectancy at birth in order to arrive at provincial life expectancy. Hence, the latter is thus a two-natured figure: expectation (national life expectancy at birth) plus/minus lived experience (percentage of people older than national life expectancy). The method fails if the national life expectancy is not available and thus in a way it requires national life expectancy to estimate sub-national life expectancy.

Per capita GDP estimate: as official data sources in Bhutan do not provide per capita GDP data by dzongkhags, the share of consumption expenditure by dzongkhag was used as a proxy to arrive at dzongkhag GDPs. This method of estimating per capita GDP suffers from a critical disadvantage; it assumes that the share of consumption expenditure across dzongkhags is the same as the share of income across dzongkhags. This may not be the case. For example, consumption does not capture many production activities including the hydro-electricity industries that may be present in some of the dzongkhags such as Pemagatshel. It is also possible that consumption expenditure in some dzongkhags may be higher than income – this is particularly true when people do not report actual income in an effort to avoid taxes.

The use of the more accurate Chiang method to generate estimates of life expectancy means that there are now two different estimates of this dimension. These were used to calculate two sets of sub-national HDIs. But two estimates of HDIs do raise an issue: which is more robust and thus could be used by policy makers, the media and other stakeholders involved in advocacy? We have seen that, while overall differences are not very significant, there are in fact significant differences when one drills down to the level of dzongkhags. While an accurate answer cannot be given in the absence of a rigorous evaluation of the Age-wise methodology

19 The methodology and results were presented to the representatives of GNHC, NSB, UN staff and national consultants of the Royal Government of Bhutan on 4 July 2008. The presentation was very much well received by the audience. In particular, government officials appreciated the results, the innovative methods employed to approximate missing data, the spreadsheet developed for the calculation of HDI (which can be used for further refinement of the estimates by merely entering the data into the appropriate cells of the spreadsheet) and the detailed documentation of the methodology used for estimation. Authors express their sincere thanks to all participants.

and results, we suggest that the HDI-CM results should be used as estimates of life expectancy as it produces robust estimates for populations of 5,000 and above.

There is now a debate as to whether sub-national HDIs could be used as a tool for resource allocation. On the 'for' side, there is the argument that, because the HDI is one of the most critical indices of human development concerns, it should be used for resource allocation. The HDI undoubtedly shows achievements at the sub-national level in three critical areas (health in terms of longevity, education, and purchasing power in terms of per capita GDP), but it omits many other dimensions of human development that are less susceptible to rigorous measurement.

On the 'against' side, a central position is that the HDI does not explicitly capture many aspects of human development, including poverty. Hence, using HDI as the *sole* criterion for resource allocation would be inappropriate. Then there is the issue of the politicization of the HDI: would casting the HDI as an instrument of resource allocation open it up to political meandering, which could undermine its legitimacy and advocacy power? Further, in the case of Bhutan, if the HDI is the only indicator for resource allocation to dzongkhags, a perverse situation could result: dzongkhags with high levels of human development (as measured by the HDI) would not have any incentive for improvement. This is because low HDIs will reward low-performing dzongkhags and punish high-performing ones at least until an equilibrium situation is reached – where the HDIs of all provinces are more or less equal. The danger is that this perversity could lead to a low-level HDI equilibrium trap.

We believe that the HDI should continue to be used to expose human development deficits; it is here that its advocacy power lies. The ability of the HDI to reveal discrepancies in the human condition is unsurpassed, and thus its power to influence decisions that takes these deficits into consideration. Nevertheless, while the national HDI was not intended to be used as the criterion for resource allocation, this is probably not the case with sub-national HDIs. Perhaps a stronger case could be made for using sub-national HDIs as *one* of the criteria in the formula for resource allocation.

In terms of lessons, the following may be of relevance:

- There will always be data issues, which will vary depending upon the country and the geographical scope to be covered (state, province, community, district, etc). However, proxy methods for generating the necessary data for estimating sub-national HDIs can always be found, but it is crucially important that these alternative methods are robust and consistent, and rigorously applied across all sub-national areas. The credibility of the estimation procedure is import for comparison across sub-national areas.

- It is not necessary to use per capita GDP in PPP dollar for the estimation of sub-national HDIs, since the aim is intra-country comparison, not comparison with other countries. Besides the use of local currency, the goalposts for the GDP indicator will also need to be estimated – it is likely that the global 'posts' are impossible targets for sub-national areas even in the next 50 years.

- Meet the appropriate government officials, including officials from the Ministries of Planning, Economic Development, Finance and Health, and the Statistical Bureau as soon as possible to discuss methodology, data requirements and any possible follow-up action. Give officials a spreadsheet (template) with the exact disaggregated data requirements. Keep them informed of progress and do not spring surprises upon them. Results of the estimates should be discussed with these officials before presenting them to a broader audience.

- Present the results to a broad cross-section of stakeholders, including government officials, NGOs, academia and donors. This can result in extensive and insightful feedback covering data, methodology, results and advocacy. Just as importantly, it can result in buy-in, that sense of shared involvement in the creation of statistics with advocacy power and the potential to influence policies.

- Conduct a training session for the estimation of HDI for diverse stakeholders, especially those who will provide and use the estimates, including government officials, the media, academia, NGOs and donors. This will facilitate a better understanding of human development and the HDI. It will also strengthen local capacity to estimate the HDI.

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Annex

Table A.1. Bhutan: Estimate of Life Expectancy for Thimphu using the Adjusted Chiang Method

Age band	x	n	a_x	pop	death	M_x	q_x	p_x	l_x	d_x	L_x	T_x	e_x	$var(q_x)$	$l_x^2[(1-a_x) n_1+e_{x+1}]^2 var(q_x)^2$	$sum(l_x^2[(1-a_x) n_1+e_{x+1}]^2 var(q_x)^2)$	Var(ex)	SE	Lower 95% confid. intvl	Upper 95% confid. intvl
<1	0	1	0.1	2,003	56	0.0280	0.0273	0.9727	100000	2727	97546	6571049	65.71	0.000013	587754519.001	4170934421.598	0.41709	0.6458	64.44	66.98
1-4	1	4	0.5	7,460	26	0.0035	0.0138	0.9862	97273	1347	386398	6473503	66.55	0.000007	294721555.841	3583179902.597	0.37869	0.6154		
5-9	5	5	0.5	9,424	20	0.0021	0.0106	0.9894	95926	1013	477099	6087106	63.46	0.000006	192495674.211	3288458346.755	0.35737	0.5978		
10-14	10	5	0.5	10,805	11	0.0010	0.0051	0.9949	94914	482	473363	5610006	59.11	0.000002	67994649.335	3095962672.545	0.34367	0.5862		
15-19	15	5	0.5	11,470	9	0.0008	0.0039	0.9961	94432	370	471234	5136643	54.40	0.000002	41072339.208	3027968023.210	0.33956	0.5827		
20-24	20	5	0.5	15,121	16	0.0011	0.0053	0.9947	94062	496	469069	4665409	49.60	0.000002	34336756.267	2986895684.001	0.33759	0.5810		
25-29	25	5	0.5	11,208	17	0.0015	0.0076	0.9924	93566	707	466061	4196340	44.85	0.000003	53120391.557	2952558927.734	0.33726	0.5807		
30-34	30	5	0.5	7,802	17	0.0022	0.0108	0.9892	92859	1006	461778	3730279	40.17	0.000007	85440238.761	2899438536.177	0.33626	0.5799		
35-39	35	5	0.5	6,764	31	0.0046	0.0227	0.9773	91853	2081	454060	3268501	35.58	0.000016	156450072.345	2813998297.416	0.33354	0.5775		
40-44	40	5	0.5	4,528	21	0.0046	0.0229	0.9771	89772	2058	443713	2814441	31.35	0.000024	171794221.493	2657548225.071	0.32976	0.5743		
45-49	45	5	0.5	3,575	40	0.0112	0.0544	0.9456	87714	4774	426634	2370728	27.03	0.000070	362449908.485	2485754003.578	0.32309	0.5684		
50-54	50	5	0.5	2,485	33	0.0133	0.0643	0.9357	82940	5330	401375	1944094	23.44	0.000117	403414462.605	2123304095.093	0.30866	0.5556		
55-59	55	5	0.5	1,647	36	0.0219	0.1036	0.8964	77610	8042	367944	1542719	19.88	0.000267	605313878.899	1719889632.488	0.28554	0.5344		
60-64	60	5	0.5	1,423	36	0.0253	0.1190	0.8810	69568	8276	327147	1174775	16.89	0.000346	447009376.419	1114575753.589	0.23030	0.4799		
65-69	65	5	0.5	1,102	40	0.0363	0.1664	0.8336	61291	10198	280960	847628	13.83	0.000577	400357214.258	667566377.170	0.17770	0.4216		
70-74	70	5	0.5	855	40	0.0468	0.2094	0.7906	51093	10700	228714	566668	11.09	0.000867	267209162.912	267209162.912	0.10236	0.3199		
75+	**75**	**17**	**0.5**	**1,004**	**120**	**0.1195**	**1.0000**	**0.0000**	**40393**	**40393**	**337954**	**337954**	**8.37**	**0.000000**	**0.000**	**0.000**	**0.00000**	**0.0000**		

Source: Template adapted from Toson and Baker (2003).

Note: This spreadsheet employs the adjusted Chiang method to calculate life expectancy. The user needs to enter only population and deaths (two columns) by age group. The other columns are then calculated automatically. This spreadsheet could be made available upon request. We also have estimates by age group for all 20 dzongkhags of Bhutan; the spreadsheets could be made available upon request. Please contact Ramesh Gampat at ramesh.gampat@undp.org or Niranjan Sarangi at niranjan.sarangi@undp.org.

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Human Development Report Unit
UNDP Regional Centre for Asia Pacific
Colombo Office
23 Independence Avenue
Colombo 7
Sri Lanka
Telephone: +94 11 4526 400
Fax: +94 11 4526 410
E-mail: asiapacific.hdru@undp.org
Web: www.undprcc.lk