

# Multidimensional Poverty in China: Findings Based on the CHNS

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**Abstract** This paper estimates multidimensional poverty in China by applying the Alkire-Foster methodology to the China Health and Nutrition Survey 2000–2009 data. Five dimensions are included: income, living standard, education, health and social security. Results suggest that rapid economic growth has resulted not only in a reduction in income poverty but also in a reduction in multidimensional poverty in the last decade, both in terms of its prevalence and intensity. However, many challenges remain. There are wide disparities across provinces and between urban and rural areas, with poverty being 1.5 times higher in rural areas than in urban ones in 2009. Moreover, rising deprivation in education in rural and less developed provinces should also be a policymaking concern.

**Keywords** Multidimensional poverty · Poverty measurement · Counting approach · China · CHNS

## 1 Introduction

Poverty has traditionally been seen as lacking income (or consumption). However, during the last three decades, thanks to the seminal works of Townsend (1979), Streeten (1981), and Sen (1981, 1985), this unidimensional concept of poverty has been challenged and poverty is now increasingly viewed as a multidimensional phenomenon. From this perspective, income is seen as an insufficient indicator of poverty. There are two main reasons for this. First, as demonstrated in many case studies, there are often high errors of inclusion and exclusion between those who are income poor and those who are deprived in other dimensions of human wellbeing (Baulch and Masset 2003; Ruggeri Laderchi et al. 2003). Second, the monetary-metric income approach may include inaccuracies because not all non-monetary attributes can be directly measured due to the lack of or imperfections in related markets, as is the case in many less-developed countries (Bourguignon and

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Chakravarty 2003). Therefore, although income is an important prerequisite for human development, when measuring human deprivation, income should be supplemented by some other key attributes or dimensions such as literacy, life expectancy, provision of public services, and access to clean water.

In Sen's (1976) pioneering paper, poverty measurement is conceptualized as involving two steps: *identifying* the poor and *aggregating* the poor into a society-wide measure. He also proposed an axiomatic approach to poverty measurement. Since then, more axioms have been introduced and a wide range of unidimensional poverty measures have been developed, one of them being the Foster, Greer, and Thorbecke (FGT) (1984) class of poverty measures.<sup>1</sup>

In a multidimensional context, the *identification* and *aggregation* of poverty are more complicated than in the unidimensional one. However, some of the axioms of the unidimensional context can be analogously extended to the multidimensional one and several axiomatic measures have been proposed by Tsui (2002), Bourguignon and Chakravarty (2003), Atkinson (2003), and Alkire and Foster (2007, 2011). This paper estimates multidimensional poverty in China by applying the Alkire-Foster (AF) methodology, which builds upon the FGT unidimensional measures.

The AF methodology has many attractive characteristics. First, it introduces a more inclusive approach for the *identification* of the poor, providing more choices than the two traditional approaches: the *intersection* approach and *union* approach. Second, the AF measures satisfy an array of convenient axioms. These include the possibility of decomposing the measure into population subgroups as well as breaking it down into dimension-specific contributions, allowing better identification of policy priorities and a wide range of practical applications.

Since the launch of the "Reform and Opening Up" in 1978, China has achieved high rates of economic growth, with its real GDP growing annually at an average rate of 9.8 % during the period 1978–2007. Benefiting from this phenomenal economic growth, China has also made outstanding progress in alleviating income poverty. The proportion of people living on less than \$1.08 per day at 1993 PPPs dropped from 65 % in 1981 to 4 % in 2007, and the absolute number of poor fell from 652 million to 54 million, a decline of over half a billion people (World Bank 2009). To some extent China's achievement in poverty alleviation reshaped the poverty status of the world (Chen and Ravallion 2007; Ravallion and Chen 2007). Taking a multidimensional perspective allows analysis of whether this outstanding performance in growth and income poverty reduction has also translated into improvements in other dimensions.

The data used in this paper corresponds to the China Health and Nutrition Survey (CHNS) (2000, 2004, 2006 and 2009). Nine out of the 31 provinces of mainland China are included in the CHNS: Heilongjiang, Liaoning, Shandong, Jiangsu, Henan, Hubei, Hunan, Guangxi and Guizhou.<sup>2</sup> Five dimensions are considered in estimating multidimensional poverty: income, living standard, education, health and social security. The living standard dimension consists of four sub-dimensions, including access to clean water, improved sanitation facilities, electricity and improved cooking fuel.

The rest of the paper is organized as follows. Section 2 introduces the data and samples used in this paper and explains the indicators, cutoffs and weighting approach used for the

<sup>1</sup> For a survey on poverty axioms and measures see Foster and Sen (1997).

<sup>2</sup> In mainland China, there are three kinds of provincial-level administrative regions: provinces, municipalities, and autonomous regions. Guangxi is one of five autonomous regions. For simplicity, we use the term 'province' for all sample regions.

identification of deprivation in specific dimensions. Section 3 decomposes the multidimensional poverty measure by province, as well as urban and rural areas, and breaks it down by dimension. Finally, Sect. 4 contains the conclusions of the paper.

## 2 Dataset and Indicators

### 2.1 Data and Sample

The dataset used in this paper is from the China Health and Nutrition Survey (CHNS), which is jointly conducted by the Carolina Population Center at the University of North Carolina at Chapel Hill and the Chinese Center for Disease Control and Prevention. The first round of CHNS was conducted in 1989, and seven additional waves were collected in 1991, 1993, 1997, 2000, 2004, 2006 and 2009. As stated above, CHNS covers the provinces of Heilongjiang, Liaoning, Jiangsu, Shandong, Henan, Hunan, Hubei, Guangxi and Guizhou (see Fig. 1). Among the nine provinces, Heilongjiang was not covered by CHNS in 1989, 1991 and 1993; and Liaoning was absent from the 1997 survey. Only waves during the period of 2000–2009 covered all nine provinces; thus, only these four waves are considered in the paper. The total population in the nine survey provinces amounted to 556 million, accounting for 41.66 % of the mainland's population.

Among the nine sampled provinces, Heilongjiang and Liaoning, located in northeast China, are two of the provinces with the highest level of industrialization and urbanization. Shandong and Jiangsu, located in the coastal areas of eastern China, have been since 1978 two of the most successful provinces in terms of economic growth. Henan, Hubei and Hunan are representative provinces from central China. These three provinces have similar economic development levels, with a medium level of per capita GDP. Guizhou and Guangxi, located in western China, are characterized as the least developed areas in China. Due to the lack of economic opportunities in the western and central provinces, large amounts of rural out-migrant workers are moving to urban areas and the eastern provinces.<sup>3</sup> In 2009, the China National Bureau of Statistics estimated that there were 145 million rural out-migrant workers in China, of which 56.4 % were from western and central provinces, and 62.5 % worked in eastern provinces (NBS 2010a).<sup>4</sup>

CHNS has a multistage stratified cluster design. In each province, counties were first stratified into three grades (low, middle and high) by income and then one or two counties were randomly selected from each grade. A weighted sampling scheme was used to randomly select four counties in each province. In addition, two cities with higher and lower incomes were also selected; the higher income cities usually were provincial capitals. Villages and townships within the counties as well as urban and suburban neighbourhoods within the cities were randomly selected. For this study, the sizes of the valid sample in each wave are shown in Table 1.

<sup>3</sup> In China, migrant workers are defined as those registered as farmers and with rural residences but mainly making their livelihood from non-agricultural sectors. Migrant workers can be divided into two types of groups, local-migrant workers and out-migrant workers, depending on whether or not they are working within the township where they registered their residence.

<sup>4</sup> In 2008, out-migrant workers working in the eastern provinces accounted for 71 % of total out-migrant workers in China. As China's export-led sectors in coastal areas slowed down during the global financial crisis in 2009 and public transfer schemes in the less developed areas increased, more and more migrant workers chose to return to their own province rather than moving out.



**Fig. 1** Map of surveyed provinces. Source: CHNS website. [http://www.cpc.unc.edu/projects/china/proj\\_desc/chinamap.html](http://www.cpc.unc.edu/projects/china/proj_desc/chinamap.html). Areas in dark green are the provinces where CHNS were conducted

**Table 1** Size of valid household samples in CHNS 2000–2009

Years	Number of sample households	Attrition rate compared to the previous wave (%)
2000	3,959	–
2004	4,148	18.26
2006	4,176	14.37
2009	4,319	19.92

The CHNS dataset is one of a few panel datasets that has collected data every 2–4 years for nearly two decades in China. CHNS uses a wide range of indicators at the individual, household and community level, including income, employment, health and nutrition, consumption, water sources, sanitation, demographic variables of household members, and access to improved roads, among others. Such a wide range of indicators enables an estimation of multidimensional poverty.

Since 1993, in each wave of the CHNS survey, the sample has been composed of the households originally sampled in 1989 plus all new households formed from sample households who resided in sample areas. Additionally, households that dropped from the panel were replaced by new ones. In the four waves considered in this paper, 80–85 % of

households were kept from one wave to the next (see Table 1). However, there were also many dropped sample households that re-occurred in the later waves. In total there were 28.77 % of original sampled households who were present in the 2000 wave and were dropped in the 2009 wave.<sup>5</sup> We do not restrict the analysis to the households of the panel. However, the fact that the same survey has been consistently applied over different years allows the poverty estimates to be compared over time.

CHNS is actually the only large comprehensive dataset that is publicly available and for which there are successive rounds. In addition, CHNS includes samples in both rural and urban areas, allowing comparison of multidimensional poverty between them, which is of special importance for policy recommendations given the urban–rural dual structure of China’s economy and society.

CHNS has been mainly used to analyse health status, health inequality, as well as health habits and their determinants (e.g. Doak 2002; Kim et al. 2004; Popkin et al. 2006; Stookey et al. 2005; among others). There are, however, a few studies which use CHNS to analyse gender issues (de Brauw et al. 2008) and poverty and inequality (Zhu and Luo 2008; Wang and Alkire 2009; Gao 2012 etc.)

## 2.2 Dimensions, Indicators, Weights and Cutoffs

Selecting the dimensions, indicators, weights and cutoffs is always difficult and inevitably entails value judgements. In terms of the dimensions and indicators to be considered, this paper does not intend to be prescriptive nor exhaustive. We simply consider a set of possible dimensions and indicators based on previous work and the possibilities offered by the data.

In particular, we consider five dimensions and eight indicators which are listed in Table 2 alongside their corresponding deprivation cutoffs and weights. We first consider the income dimension. Although viewed as an insufficient standalone indicator of poverty, it is recognised as an important means to access valuable ends (Stiglitz et al. 2009; Narayan et al. 2000, among others). We also consider another material dimension, which is living standard as measured by four direct indicators rather than income. The four living standard indicators are access to clean water, improved sanitation facilities, electricity and improved cooking fuel. The reason for including this separate dimension is that with imperfect markets, income does not guarantee access to certain basic services. In addition, these basic services are also essential to other dimensions of human wellbeing and hence to the quality of life. Unsafe water is a direct cause of many diseases in developing countries, and access to clean water has been widely seen as a basic right (World Bank 2003; UNDP 2006). Access to improved sanitation facilities has significantly positive effects on reducing the contagion of various diseases like hepatitis, cholera and diarrhoea (WHO and UNICEF 2000; World Bank 2003). Without access to electricity, people are excluded from

<sup>5</sup> Further analysis on the attrition sample and newly added sample shows that, in rural areas, the households that left the panel had—on average—significantly better economic status than those who remained in the panel; however, in urban areas, the difference in the economic status between the households that left the panel and those which remained is less significant, and in some cases, like urban Heilongjiang, the households that left the panel between wave 2000 and 2004 actually had a worse economic status than those which remained. However, the households which were added to the sample in replacement of those which left, had better economic status than the average. Moreover, in most cases, the difference in per capita income between added households and those in the original sample is comparable to that between dropped sample and those in the original sample, when the income growth between the subsequent waves is considered. The size of dropped and added samples varied in different provinces and waves; thus here we do not provide a general comparison of them.

**Table 2** Dimension, indicator and cutoff

Dimensions	Indicators	Deprivation cutoffs (the household is deprived if)	Weights
Income	Per capita income of household	Per capita income of the household less than CNY 2300 in rural areas and less than CNY 3014 in urban areas, at 2010 constant prices, adjusted according to prices in different waves and regions	1
Living standard	Access to clean water	No access to tap water in-house or in-yard	0.25
	Access to improved sanitation facilities	No access to toilet facilities, no access to private restroom, or using open earth pit as toilet	0.25
	Access to electricity	Not using electricity as a main energy source for lighting	0.25
	Access to improved cooking fuel	Using wood, stick/straw, charcoal, etc. as main fuels for cooking	0.25
Health	Body Mass Index (BMI)	At least one adult member of the household with BMI less than 18.5 kg/m <sup>2</sup>	1
Education	Completion of primary school	No household member has completed primary education	1
Social security	Medical insurance	No any household member has access to any kind of medical insurance	1

using a wide range of facilities like television, refrigerators, telephones, and computers. Finally, the type of cooking fuel is closely linked with indoor air pollution, deforestation and greenhouse gas emissions. Incomplete and inefficient combustion of solid fuels results in the emission of hundreds of compounds. In China, indoor air pollution caused by solid fuel use is responsible for more than 40,000 premature deaths annually (Zhang and Smith 2007).

We also consider health and education, which are widely agreed upon as being intrinsically valuable ends (Sen 1985; UNDP 1990; Stiglitz et al. 2009). Good health and education are also key aspects of human capability, understood in Sen's terms as a person's freedom to lead one type of life or another. Finally, we consider social security. The social security system provides a safety network for people to cushion the negative effects of social and economic risks (Sen 1999; China Development Research Foundation [CDRF] 2009). Moreover, this dimension seems particularly relevant in the case of China, given that the dismantling of the collective commune system in rural areas and the large-scale economic restructuring of the state and collective sector in urban areas completely overturned the foundations of the earlier social welfare and social security system (World Bank 2009).

In terms of the indicators and deprivation cutoffs, for the income dimension, we identify a rural household as deprived in income if the per capita income of the household is less than 2300 China Yuan (CNY) per year in 2010, or CNY 2227 in 2008. This is a recently updated official poverty line defined by the State Council Leading Group Office of Poverty Alleviation and Development, roughly equivalent to USD 1.8 per day at the 2005 PPP.<sup>6</sup>

<sup>6</sup> Traditionally the government used an official *absolute poverty line* to monitor rural poverty, and the line in 2007 was set at CNY 785 per person per year. However, the standard is widely criticized and is thought to be too low to reflect the real picture of China's rural poverty (CDRF 2007). In 2000, the government also introduced the *low income line* to monitor the situation of relative poverty of rural households, and the line was set at CNY 1027 in 2007. In 2008, the State Council Leading Group Office of Poverty Alleviation and Development announced the unification of the two lines and used CNY 1027 in 2007 as the only poverty line. In November 2011, the government further increased the rural official poverty line to CNY 2300 per person at 2010 prices. Considering the price inflation in rural areas, this new poverty standard in 2008 was CNY 2227 per person per year.

The urban income deprivation cutoff was CNY 3014 in 2010, or CNY 2944 in 2008. The urban poverty line is about \$2.4/day at the 2005 PPP.<sup>7</sup> This income deprivation cutoff was adjusted according to different provincial CPI deflators in the years concerned.

Regarding the living standard dimension, a household is considered deprived in access to clean water if it does not have access to piped water. This standard coincides with that of the Chinese government, but it is more demanding than the one considered in the Millennium Development Goals (MDGs).<sup>8</sup> As for sanitation, a household is considered deprived if it has no access to any toilet facilities or no access to a private restroom or uses an open earth pit as toilet. This standard coincides with that of the MDGs. We proxy access to electricity by the type of lighting, as lighting is the most basic use of electricity. Finally, a household is considered deprived in cooking fuel if it uses wood, stick/straw or charcoal, which also follows the MDGs.

Both the income and living standard indicators are constructed at the household level, assuming a sharing of resources. CHNS provides individual information on health, education and access to health insurance schemes. However, for the other three dimensions, we decided to construct indicators also at the household level, making similar assumptions of the sharing of advantages or disadvantages, and the impacts of these advantages or disadvantages, within the household. This is in line with the methodology used in the Multidimensional Poverty Index (MPI) (Alkire and Santos 2010; UNDP 2010, 2011).

The health dimension is measured with the Body Mass Index, defined as  $\text{weight}/\text{height}^2$ . BMI captures long-term nutrition status and thus it can reflect health deprivation. Additionally, it is widely used in different disciplines. In line with the World Health Organisation (WHO), if an adult's BMI is less than  $18.5 \text{ kg}/\text{m}^2$ , then the person is considered as being deprived in health.<sup>9</sup> If there is at least one adult (aged 18 or above) whose BMI is less than  $18.5 \text{ kg}/\text{m}^2$ , the household is defined as deprived in health and thus all its members are considered deprived in this dimension. The underlying assumption is that a malnourished person in the household has negative effects over all household members. For this paper we are considering only adults' malnutrition. The dataset offers information on children, but this would need adjustments and assumptions for households with no children.

<sup>7</sup> Urban poverty in China has not raised concerns widely until China accelerated the reform of state-owned enterprises in the late 1990s. Although many scholars and organizations made efforts to measure urban poverty since then, there is currently no widely accepted income poverty line in China's urban areas. However, in the late 1990s, China launched the Minimum Living Allowance System in urban areas and the standard of the system was used to identify whether the household should be provided with a certain allowance, so as to meet their basic needs. Hence the standard of Minimum Living Allowance could be seen as one kind of poverty line. Due to a huge diversity of economic development among different regions, the standards vary considerably. In 2010, the average standard of Minimum Living Allowance was CNY 251.2/month per person; thus we adopt this standard as urban poverty line. Using this standard of poverty could help improve poverty monitoring for government policymaking.

<sup>8</sup> According to the Chinese Ministry of Health, China launched the programs for improving access to clean water and improved sanitation facilities in the 1960s and scaled up these programs in 1980s. By the end of 2005, more than 95 % of the population had access to primarily improved water and 55 % of the population had improved sanitation facilities. Considering that the quality standard for this primarily improved water is still very low, the government decided to set universal access to piped water in rural areas as a policy target; hence, this paper chose having no access to piped water as the deprivation cutoff.

<sup>9</sup> Compared to the international normal range 18.5–24.99, Asians' range of normal BMI is lower, between 18.5 and  $22.9 \text{ kg}/\text{m}^2$ . Asians with a  $\text{BMI} \geq 23.0$  are considered to be overweight. Thus the international cutoff for censoring overweight and obesity is not applicable to China (Zhou 2002), but the cutoff for identifying the underweight is still applicable to China and has been widely used to analyse the health status of the Chinese people (see, e. g., Zhou 2002; Tang et al. 2007; Zhang et al. 2005).

In terms of education, ideally, we should define illiteracy in a functional sense, for example, whether people can recognize a certain number of words and can do basic arithmetic. However, such information is not available. In China, prior to the mid-1980s, primary school lasted 5 years and since then was extended to 6 years. Because of the change in the primary education system, the schooling years of individuals might differ when they completed their primary education. Hence in this paper we use the completion of primary school instead of years of schooling as the indicator, and a household is considered as being deprived in education if no household member has completed primary education. Reaching universal access to primary school is the second MDG. Thus, although less demanding, our indicator is related to the MDGs and similar to the one used in the MPI. We could have defined an individual-level indicator of education, but we have chosen this milder requirement following Basu and Foster (1998), who state that the literacy abilities of one household member can be shared and enjoyed by other members so that the effective literacy (or educational level) of the household is higher than the individual educational levels.

Finally, for the social security dimension, ideally, we should include an array of indicators to reflect how people are secured by social safety network. Unfortunately, the only available indicator is health insurance. Other indicators such as access to unemployment insurance, minimum living allowance, work injury insurance or old-age pension are not available. We consider that access to health insurance is an incomplete indicator but that it reasonably proxies access to social security. In China, about one-third of poor families fell into poverty just because of economic shocks caused by diseases and disabilities in 2005 (CDRF 2007). Having access to health insurance, for any member of the family is of significant importance in reducing the vulnerability of a household. Thus, we define a household, and therefore all its members, as being deprived in social security if no member of the household is covered by any kind of health insurance program.

In terms of the weighting for each dimension and indicator, we follow a nested weighting approach such that each dimension is given a weight of 1 and each indicator of the living standard dimension is given a weight of 0.25, as shown in Table 2.<sup>10</sup>

It is necessary to investigate the bivariate correlations across indicators chosen for measuring multidimensional deprivation when a multidimensional perspective is being applied. Table 3 reports the Spearman coefficients between the indicators in 2009. Results show that most of the correlation coefficients between the different pairs of indicators were quite low, no higher than 0.22. Thus it is reasonable to include all eight indicators suggested above. Correlation analyses of other waves show similar results.

### 3 Results

#### 3.1 Headcount Ratios by Dimension and Number of Deprivations

First, we present in Table 4 the deprivation rates by dimension in each wave. These are expressed in the proportion of households which are experiencing deprivations in each dimension.

In Table 4 it can be seen that deprivation in social security is the highest among all considered indicators in the first three waves. Nearly two-thirds of Chinese households had

<sup>10</sup> For further discussion on the nested weighting structure see Alkire and Foster (2007, 2011) and for a discussion on the meaning of weights see Decaneq and Lugo (2012).



**Table 3** Spearman correlation coefficient between selected indicators (2009)

	Income pc	Education	Health	Security	Water	Sanitation	Electricity	Fuel
Income pc	1	-0.160** (0.000)	-0.044** (0.004)	-0.101** (0.000)	-0.144** (0.000)	-0.176** (0.000)	-0.009 (0.554)	-0.086** (0.000)
Education		1	0.005 (0.731)	0.110** (0.000)	0.029 (0.061)	0.096** (0.000)	-0.009 (0.548)	0.077** (0.000)
Health			1	0.014 (0.344)	-0.005 (0.759)	-0.002 (0.875)	-0.01 (0.528)	0.025 (0.094)
Security				1	-0.010 (0.517)	0.038* (0.012)	-0.012 (0.445)	-0.005 (0.751)
Water					1	0.219** (0.000)	0.024 (0.121)	0.212** (0.000)
Sanitation						1	0.020 (0.191)	0.102** (0.000)
Electricity							1	0.007 (0.625)
Fuel								1

The valid number of sample households is 4319. Significance of coefficients are reflected in parentheses

\*\* Correlation is significant at the 0.01 level (2-tailed)

\* Correlation is significant at the 0.05 level (2-tailed)

no member with access to any kind of health insurance in 2000. In 2006, about 40 % of the surveyed households were still not covered by any kind of health insurance. However, this decreased over time, associated to a (a) a scaling up of the New Cooperative Medical Scheme (NCMS) in rural areas since 2003 and (b) a new urban residents' basic medical insurance scheme which was introduced in 2007 to expand urban health insurance to urban unemployed residents, students and children. Additionally, there has been a rapid roll out of the Medical Assistance scheme in rural and urban areas to provide poor and vulnerable groups with financial help with their health insurance contributions and payments. By the end of 2009, there were 1.2 billion Chinese covered by NCMS, Urban Employee's Medical Insurance or Urban Residents' Basic Medical Insurance, accounting for 90 % of the total

**Table 4** Percentage of deprived households in each dimension (2000–2009, %)

Dimensions	2000	2004	2006	2009
Income	26.95	22.93	21.98	12.83
Living standard				
Water	30.59	24.57	22.87	19.36
Sanitation	29.07	25.84	20.26	15.84
Electricity	0.88	0.34	0.34	0.32
Cooking fuel	28.32	25.82	22.10	16.58
Education	7.96	10.49	13.58	12.43
Health	13.24	12.42	11.76	12.76
Social security	66.38	59.43	39.70	3.98
Total Number of Sample Households	3,959	4,148	4,176	4,319

population (CDRF 2010). Owing to the rapid expansion of basic medical insurance, in 2009 the proportion of households without any health insurance had declined to less than 4 %.

Although significant achievements were made in alleviating deprivation related to access to water, improved sanitation facilities and improved cooking fuel, as part of the Integrated Village Development Program, more than 15 % of the sample households were deprived in these sub-dimensions in 2009. This may be linked to the fact that more than half of the poor live outside the villages designated to participate in the program (World Bank 2009, p. 83). Expansion of the electricity service, especially through the Poverty Reduction Plan, allowed virtually all Chinese households to have access to electricity after 2000.

According to Table 4, more than 10 % of the sampled households were still deprived in terms of income, education and health in 2009. However, the trends of three dimensions evolved in very different manners. Deprivation in income declined continuously during the period of 2000–2009, with a 14 % decrease in the income deprivation rate. Deprivation in health exhibited a very small reduction from the beginning to the end of the period and deprivation in education exhibited an increase. The trends evidenced by deprivation in health and education are associated to the fact that panel data is being used and thus household members migrate out over time. It therefore deserves a closer look.

The increase in deprivation in education between 2000 and 2006 is actually due to the migration of household members. In fact, among the 3,818 households with education information included in both waves of 2000 and 2004, there were 112 households which were not originally deprived in education in 2000 but were deprived in 2004 because the educated household member left the household during the period. During 2004–2006, this kind of educational outflow was even more severe: 160 out of 3,490 households became deprived. However, since the 2006 wave, the trend was reversed: only 23 households became deprived in education, and 32 households were no longer deprived because a new member joined or/and there was an increase in the education attainment levels of older family members.

Reasons for this education outflow across survey households may vary from migration, marriage, to death of family member. It is noteworthy that this type of education outflow occurred mainly in rural and least developed areas. In the sample, about 84 % of households that were deprived in education because of education outflow were living in rural areas between 2000 and 2004, and 70 % of such households were living in five central and western provinces. This phenomenon may reflect the trend of population migration from rural to urban areas and from relatively less developed provinces to coastal provinces in China. Rural migrant workers, in particular those who were able to settle in urban areas were, on average, are better educated than the family members they left behind (NBS 2010a). Interestingly, the education flow situation coincided with the trend of population migration in China. The number of rural out-migrant workers increased steadily after 1999, from about 52.4 million in 1999 to 145.3 million in 2009 (Lu 2011). However, due to the impacts of the global financial crisis and increasing public investment in western and central regions, the number of out-migrant workers working in coastal areas declined in about 8.9 million in 2009. In the meantime, the amount of out-migrant workers working in western and central provinces increased about 14 million (NBS 2010a). This reverse in the direction of migration might help to reduce the education outflow in less developed areas.

Our estimates show that there were only slight changes in household health deprivation during the survey period, which is contrary to China's significant improvement in food security and health status during the period. Even taking the food price inflation into

**Table 5** Distribution of the number of deprivation dimensions

Weighted number of deprivation dimensions (c)	Percentage of the poor in 2000	Percentage of the poor in 2004	Percentage of the poor in 2006	Percentage of the poor in 2009
0	18.01 %	21.46 %	26.75 %	43.37 %
(0–1)	7.73 %	9.59 %	15.11 %	22.57 %
[1–2)	41.42 %	39.59 %	35.23 %	27.11 %
[2–3)	25.92 %	23.02 %	17.41 %	5.95 %
[3–4)	6.11 %	5.67 %	4.96 %	0.95 %
[4–5)	0.76 %	0.65 %	0.55 %	0.05 %
5	0.05 %	0.02 %	0 %	0 %
Valid Sample	3,959	4,148	4,176	4,319

account, Chinese people's expenditure in food more than doubled between 2000 and 2009. In addition, China's the life expectancy at birth increased from 71.40 to 74.83 years in 2010, according to the results of sixth China National Population Census (NBS 2012). The insignificant change of health status may be suggesting that poorly nourished members were often left behind.

The above statistics provide an idea of the dimension-specific deprivation levels. We now move to the multidimensional approach, which evaluates simultaneous deprivations. Table 5 presents the percentage of households deprived in different numbers of weighted dimensions.<sup>11</sup> The percentage of non-deprived households increased from 18.01 % in 2000 to 43.37 % in 2009, which reflects the overall decreasing poverty trend in the country. Also note that, in the first three waves, about 75 % of the households were deprived in less than the equivalent of two dimensions and only about 5 % of households had the equivalent of three or more weighted deprivations. In the 2009 wave, about 94 % of people were deprived in less than the equivalent of two dimensions, and only 1 % of households had the equivalent of three or more weighted deprivations. This suggests that not only has there been a decreasing trend in multidimensional poverty in the study period, but also that the level of *simultaneous* deprivations is not so acute. In addition, 27–48 % of the households were deprived in at least one dimension but less than two during the survey years. These are households deprived in one of the income, education, health, and social security dimensions (weighted at one each) and in some component/s of the living standard dimension (weighted at 0.25 each).

### 3.2 Multidimensional Poverty Estimates

In constructing a measure of multidimensional poverty, one critical step is to choose the number of dimensions in which someone has to be deprived so as to be considered multidimensionally poor; in the AF terminology this is the poverty cutoff  $k$ . Under the nested weighting approach adopted in this paper, the value of  $k$  can vary from 0.25 to 5. The selection of the specific  $k$  value depends on the preference of the researcher or policymakers, the specific context of a society and the purpose of the exercise at hand. Clearly, if  $k$  is too low, there will be a large proportion of the population that is identified as poor, which might cause confusion and even arouse political displeasure. On the other

<sup>11</sup> Note that results in Table 5 are not weighted by the population in the provinces concerned.

hand, if the value of poverty cutoff  $k$  is set too high, only a small proportion of people will be identified as multidimensionally poor, which could also mislead policymaking. Based on the results of Table 4, we select a poverty cutoff of  $k = 2$ .

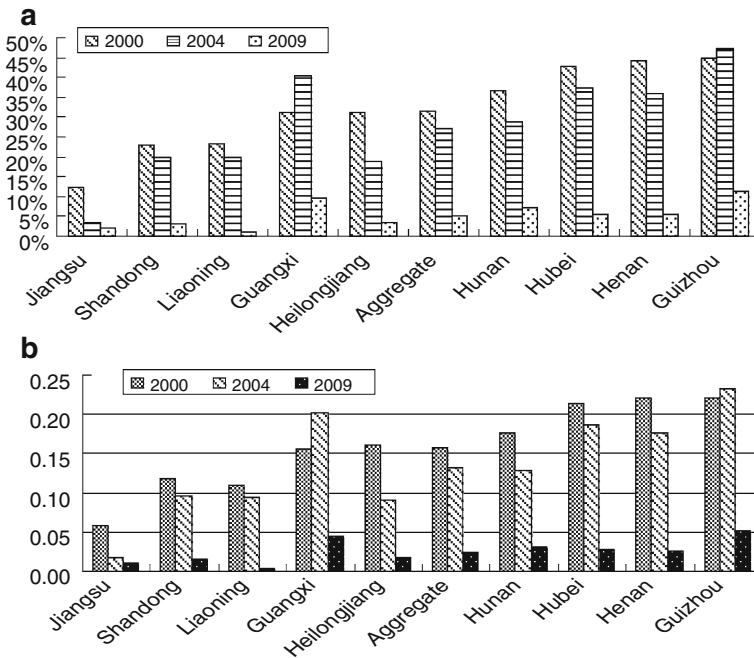
Figure 2a presents the multidimensional poverty headcount ratio ( $H_0$ ) at the aggregate level (considering the nine provinces) and by province using the poverty cutoff of  $k = 2$ . Figure 2b presents the  $M_0$  measure (adjusted headcount ratio) also using a cutoff of  $k = 2$ . In both cases, households have been weighted by their size, so these measures are population-based. As Fig. 2a depicts, the proportion of multidimensionally poor people at the aggregate level declined substantially between 2000 and 2009: from 31.65 to 5 %.  $M_0$  also decreased from 0.157 to 0.024. This suggests that while in 2000 the average poor person was deprived in 49.6 % of the weighted dimensions, in 2009 she was deprived in 46.4 % of the weighted dimensions.<sup>12</sup> Both the incidence and intensity of poverty were reduced. In addition, comparing income poverty with multidimensional poverty in 2000 and 2009 reveals the changing pattern of poverty in China. In 2000, 31.65 % of people were multidimensionally poor, while the proportion of people who were deprived in income was only 27.26 %. However, in 2009, the situation reversed, and only 5 % of people were deprived in two or more weighted dimensions, but the proportion of income-poor people was as high as 13 %. In this sense, China's poverty pattern has been changed substantially in the last decade. This change in the poverty pattern probably could be related to the shift in China's development policies after 2003, which aimed to coordinate urban-rural and regional development, economic and social development, and human development with environmental sustainability. Under the slogan of "building a harmonious society," the government accelerated its establishment of a universal social safety network, increasing investment in rural infrastructure, education, health and transfers to most remote areas.

However, it is worth noting that because China is such a populous country, even when there has been a reduction in the incidence and intensity of multidimensional poverty, in absolute numbers there is still a huge number of people in poverty. Specifically, assuming that the aggregate estimate is nationally representative, it implies that in 2009 there were about 68 million multidimensionally poor people.

Comparing the relative performance of the nine provinces, we can see in Fig. 2a that all survey provinces experienced a reduction both in the proportion of poor as well as in  $M_0$ . Among them, Henan achieved the most outstanding progress in reducing both  $H_0$  and  $M_0$  between 2000 and 2009 in absolute terms, which indicates that not only the proportion of multidimensionally poor was reduced, with a decrease of 39 %, but also the intensity of deprivations the poor experience. Hubei and Guizhou also experienced an impressive reduction in  $H_0$ , with a decrease of 37 and 33 %, correspondingly. They also reduced the intensity, as reflected in the reduction of  $M_0$ .

Though all surveyed provinces made significant progress in reducing multidimensional poverty, their achievements were uneven, as argued also by Ravallion and Chen (2007). All surveyed provinces reduced the incidence of multidimensional poverty to less than 10 % by 2009, except Guizhou, which had an  $H_0$  of 11.24 %. Following Guizhou, Guangxi was the second most-deprived province in 2009, with its  $H_0$  close to 10 %. However, in Liaoning province, the incidence of multidimensional poverty was successfully reduced to less than 1 %, the lowest level among surveyed provinces by 2009. Thus, the poverty incidence rates in Guizhou and Guangxi in 2009 were about 10 times of that in Liaoning, and 5 times of that in Jiangsu.

<sup>12</sup> Poverty intensity is obtained as  $M_0/H_0$ .



**Fig. 2** a Evolution of  $H_0$  between 2000 and 2009 (%) \* ( $k = 2$ ). b Evolution of  $M_0$  between 2000 and 2009\* ( $k = 2$ ) \* Both a and b are sorted by  $H_0$  and  $M_0$  in 2000, respectively

Table 6 shows the ranking of provincial poverty status according to  $H_0$  and  $M_0$  from richest to poorest throughout the survey years. Some cases are interesting. For example, in 2000 Shandong ranked second and Liaoning ranked third, as measured by  $H_0$ . However, if the breadth of poverty is included and we use  $M_0$ , the ranking is reversed, showing that although Shandong had a smaller proportion of people who were multidimensionally poor, on average they had more deprived dimensions than those in Liaoning. However, in 2009, there was no difference between the ranks of  $H_0$  and  $M_0$ .

The best performer—Henan—and the worst performer—Guangxi—throughout the study period, had the most dramatic change of their rank position: Guangxi moved from fourth in 2000 to eighth in 2009, in terms of  $H_0$  and  $M_0$ , whereas Henan moved in the opposite direction, from eighth to fifth.

### 3.3 Comparing Multidimensional Poverty with Income Poverty, HDI and GDP

Table 7 presents the sampled provinces ranked by  $M_0$  alongside their ranking by the Human Development Index (HDI), income poverty and per capita GDP. In all cases, countries are sorted from best to worse. It can be seen that some provinces experience changes in their rank positions when using  $M_0$  rather than alternative wellbeing indicators. For example, Guangxi ranked sixth according to the headcount ratio of income poverty, but it ranked eighth according to  $M_0$ . In addition, Hubei ranked fourth according to per capita GDP, while it only ranked sixth according to  $M_0$ . These provinces also have differences with their rankings according to the Human Development Index. Such differences suggest that the multidimensional measure adds valuable information to the income-alone perspective.

**Table 6** Ranking of provincial poverty status from the richest to the poorest using  $H_o$  and  $M_o$  ( $k = 2$ )

	$H_o$		$M_o$	
	2000	2009	2000	2009
Jiangsu	1	2	1	2
Shandong	2	3	3	3
Liaoning	3	1	2	1
Guangxi	4	8	4	8
Heilongjiang	5	4	5	4
Hunan	6	7	6	7
Hubei	7	6	7	6
Henan	8	5	8	5
Guizhou	9	9	9	9

### 3.4 Analysing Multidimensional Poverty's Composition

#### 3.4.1 Decomposing $M_o$ by Dimension

One convenient property of the AF family of measures is that it allows identifying the contribution of the poor's deprivation in each dimension to overall multidimensional poverty. Figure 3 presents such decompositions in each of the 4 years.

In the first three waves, deprivation in social security was the largest contributor to overall  $M_o$ , accounting for nearly 40 % in 2000 and more than one-third in 2006. However, in 2009, income deprivation replaced the social security deprivation as the largest contributor to  $M_o$ , and the latter fell to the fourth largest contributor. The dramatic reduction in the contribution of social security deprivation should be attributed to China's accelerating pace in establishing a health insurance system in both rural and urban areas after 2003.

**Table 7** Comparing multidimensional poverty ( $M_o$ ) with income poverty, HDI and per capita GDP in 2009

	Multidimensional poverty ( $M_o$ ; ( $k = 2$ ))	Headcount ratio of income poverty (%)	HDI 2008 <sup>b</sup>	Per capita GDP 2009 (RMB) <sup>c</sup>
Aggregate	0.024	12.97	0.82	25,575
Liaoning	0.004 (1) <sup>a</sup>	5.76 (2)	0.861 (2)	35,239 (3)
Jiangsu	0.009 (2)	4.35 (1)	0.862 (1)	44,744 (1)
Shandong	0.016 (3)	10.46 (4)	0.845 (3)	35,894 (2)
Heilongjiang	0.017 (4)	6.67 (3)	0.807 (6)	22,447 (5)
Henan	0.026 (5)	23.2 (9)	0.798 (7)	20,597 (6)
Hubei	0.027 (6)	12.1 (5)	0.815 (4)	22,677 (4)
Hunan	0.031 (7)	15.92 (7)	0.812 (5)	20,428 (7)
Guangxi	0.045 (8)	15.79 (6)	0.797(8)	16,045 (8)
Guizhou	0.051 (9)	18.54 (8)	0.698 (9)	10,309 (9)

<sup>a</sup> Rankings of the provinces in terms of each indicator are shown in brackets

<sup>b</sup> HDI in 2008 is from CDRF, *China Development Report 2010*

<sup>c</sup> At current prices, data is from NBS (2010b), *China Statistical Yearbook 2010*

Interestingly, though both the absolute value of  $M_0$  and incidence rate of income deprivation decreased continuously and significantly between 2000 and 2009, the contribution of income deprivation to overall  $M_0$  was relatively stable during the survey period, accounting for about one-third. Contrary to the income dimension, the incidence rate of health deprivation remained relatively stable, with only a minor decrease during the survey period, and its contribution to overall  $M_0$  nearly doubled, from 11.83 % in 2000 to 21.62 % in 2009.

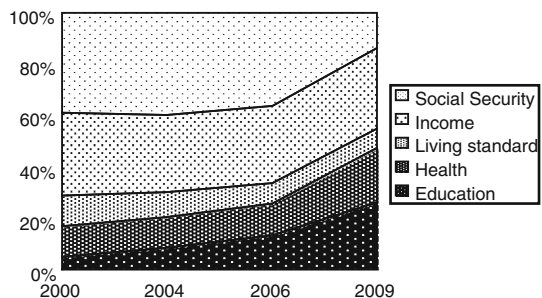
Education was the only dimension that experienced a rapid increase in the rate of deprivation; its contribution to the overall  $M_0$  also increased dramatically. From only 5 % in 2000 to 26 % in 2009. As discussed above, this dramatic increase in education deprivation and its contribution to  $M_0$  is related to changes in the household structure caused by migration. Conversely, all components of the living standard dimension declined continuously between 2000 and 2009, and their contribution to the overall  $M_0$  decreased in a similar manner.

It is interesting to compare the censored headcount ratios, measured by the proportion of people who are multidimensionally poor and deprived in a specific dimension simultaneously, with the raw headcount ratios in specific dimension, given by the proportion of people deprived in each dimension. Figure 4 depicts the two kinds of headcount ratios in selected dimensions in 2009. As shown in Fig. 4, the raw headcount ratio in the social security dimension was 3.68 % whereas the censored one was 1.61 %, which means about 42 % of social security deprived people were also deprived in at least another dimension.

The ratio of censored to raw headcount ratios reveals to what extent deprivation in one dimension overlaps with others. For example, the ratio was only 2 % in living standard whereas it was almost 50 % in the case of social security and 23–29 % in the case of health, education and income. This suggests that most of those who are deprived in living standard indicators are only deprived in those whereas significant fractions of the deprived in the other dimensions also experience some other deprivation.

Decomposing the contribution rate of each dimension to the reduction of  $M_0$  also provides some insights. As indicated by Table 8, in all surveyed provinces, the increase in access to social security had the largest contribution to the reduction of  $M_0$ , which on average contributed to more than 40 % of the total reduction in  $M_0$ . Reduction in income deprivation also had a substantial contribution to the reduction in provincial  $M_0$ —on average accounting for one-third of the reduction in  $M_0$ . Generally, the contribution of the education dimension to the reduction of overall  $M_0$  in each province was very limited, and there were three provinces, Guangxi, Guizhou, and Heilongjiang, that had a negative contribution rate in the education dimension.

**Fig. 3** Contribution of each dimension to  $M_0$  ( $k = 2$ )



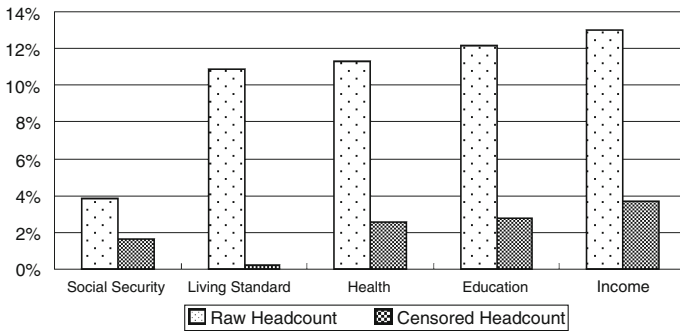


Fig. 4 Censored headcount ratios ( $k = 2$ ) and raw headcount ratios in specific dimensions (2009)

Table 8 Contribution of each dimension to the reduction of  $M_0$  in each province (2000–2009) (%)

	Income	Education	Health	Social security	Living standard	$\Delta M_0$
Liaoning	33.19	0.39	16.61	42.13	7.68	-0.106
Heilongjiang	32.38	-0.23	7.90	41.20	18.76	-0.144
Jiangsu	29.26	8.20	10.23	41.63	10.67	-0.049
Shandong	32.51	4.67	7.20	41.27	14.35	-0.102
Henan	35.42	0.15	6.77	42.96	14.70	-0.195
Hubei	32.12	0.76	10.35	42.97	13.81	-0.187
Hunan	33.63	2.17	9.27	46.29	8.64	-0.145
Guangxi	24.68	-1.09	18.22	44.28	13.91	-0.110
Guizhou	27.81	-0.29	15.97	48.73	7.77	-0.171

3.4.2 Decomposing  $M_0$  by Province

To further compare the contribution of each province to the overall  $M_0$ , we decompose  $M_0$  by province in 2000, 2004 and 2009. Results are shown in Fig. 5.

It is worth noting that in the 3 years under analysis, Henan was the province making the largest contribution to overall  $M_0$ , accounting for about one quarter in 2000 and 2004 and

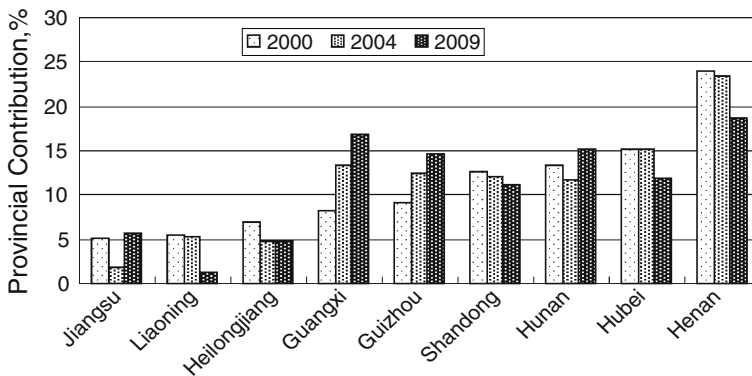
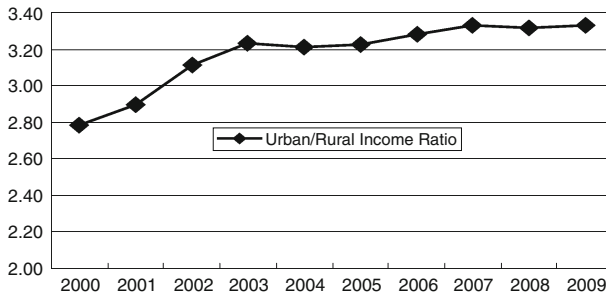


Fig. 5 Contribution rate of each province to overall  $M_0$  ( $k = 2$ )





**Fig. 6** Trend of Urban/rural income inequality during 2000–2009. *Data source: NBS (2010b), China Statistical Yearbook 2010*

exceeding its population contribution by 8–10 percentage points. Not until 2009 did Henan's contribution to the overall  $M_0$  decrease to less than 20 %. In addition, five out of the nine provinces, Liaoning, Heilongjiang, Shandong, Hubei and Henan, saw a decrease in their contribution to the national  $M_0$  between 2000 and 2009. On the contrary, Guangxi, Guizhou, Hunan and Jiangsu witnessed an increase in their contribution to aggregate  $M_0$  between 2000 and 2009. In 2009, Guangxi and Hunan were the second and third largest contributors to the aggregate  $M_0$ , respectively, because of their relatively higher provincial  $M_0$  as well as a larger population share in the sample. In addition, although Guizhou had the highest provincial  $M_0$  in 2009, its contribution to the aggregate  $M_0$  ranked sixth because of its small population share.

### 3.5 Decomposing $M_0$ by Rural and Urban Areas

The Chinese economy is characterized by a typical dual economic structure between urban and rural areas. For a long time, the Chinese government had adopted an urban-biased development policy, placing strict controls on the agricultural products market and the migration of rural labourers and investing much more in urban areas than in rural areas, so as to support the development of urban and industrial sectors. As a result, China has experienced a widening income disparity between urban and rural areas since the mid-1980s, even though the regulations on agricultural products and labour mobility have largely been relaxed.

Figure 6 shows the trend of the urban/rural mean income ratio in the first decade of the twenty first century. In the first 4 years of the century, China witnessed a rapid increase in the urban/rural income ratio, from 2.79 in 2000 to 3.23 in 2003. After 2003, following the transition of development policy in China, the urban–rural income gap increased at a relatively slower pace and it hit the historical record, 3.33, by the end of 2009.<sup>13</sup>

Our estimates also reflect this strong rural–urban asymmetry. Table 9 presents the ratio of rural to urban multidimensional poverty in the four considered years, measured by  $H_0$  and  $M_0$ . As the table illustrates, multidimensional poverty is much more prevalent in rural areas than in urban areas. Rural poverty was about 1.7 times more prevalent than urban poverty in 2004 and 1.5 times in 2009. It is also interesting to note that  $M_0$  indicates a higher urban–rural disparity than  $H_0$ , suggesting that rural households were more severely

<sup>13</sup> According to recent statistics, the urban/rural mean income ratio has decreased from 3.33 in 2009 to 3.23 in 2010, and it decreased to 3.13 in 2011, which was close the level of 2002.

**Table 9**  $H_0$  and  $M_0$  in urban and rural areas ( $k = 2$ )

	2000	2004	2006	2009
$H_0$				
Urban	23.30 %	18.75 %	17.03 %	4.01 %
Rural	36.28 %	32.58 %	25.72 %	6.00 %
Rural/urban	1.56	1.74	1.51	1.50
$M_0$				
Urban	0.1076	0.0850	0.0779	0.0188
Rural	0.1845	0.1629	0.1285	0.0276
Rural/urban	1.71	1.92	1.65	1.47

**Table 10** Poverty and population contributions of rural and urban areas

	2000	2004	2006	2009
Urban				
Poverty contribution	24.44	25.80	31.15	36.79
Population contribution	35.67	39.98	42.73	46.06
Rural				
Poverty contribution	75.56	74.20	68.85	63.21
Population contribution	64.33	60.02	57.27	53.94

deprived not only according to the prevalence of poverty (a higher proportion of deprived households) but also with respect to the breadth or intensity of poverty (the average number of deprivations). This situation didn't reverse until 2009. Finally, on a positive note, when we compare our results with results elsewhere, we see that while the urban/rural mean income ratio increased quite significantly from 2.79 in 2000 to 3.33 in 2009 (see Fig. 6), the gap in terms of multidimensional poverty did not expand after 2004. There even was a slight decrease of the urban–rural gap as measured by  $H_0$  as well as  $M_0$ , suggesting that the increased income distance between the two areas was compensated by a reduction in the gap in deprivation in the other considered dimensions. This may be related to the rapid growth in public investment and transfer schemes in rural areas by the Chinese government after 2003 under the slogan of “Constructing Socialist New Countryside.”

Finally, Table 10 presents the evolution of the contribution of rural and urban areas to aggregate  $M_0$  alongside the evolution of the population shares. Over the study period, rural areas contribute to poverty much more than urban ones (75.56 vs. 24.44 % in 2000 and 63.21 vs. 36.79 % in 2009). Also, rural areas' contribution to  $M_0$  was about 9–15 percentage points higher than their population share, reflecting the higher prevalence of multidimensional poverty there. However, the figure also indicates that the contribution of rural areas to overall poverty declined alongside a reduction in their population contribution and (as a complement) the opposite happened for urban areas after 2000.

#### 4 Conclusions

As is well known, China has undergone a process of economic reforms, moving from a planned economy to a market-oriented economy. The real per capita GDP grew at a trend rate of 8.3 % per year (World Bank 2009, p. iv). Accompanying this growth process there

has been an astonishing reduction in poverty as measured by income. Although there are discrepancies regarding the most accurate income poverty line, all estimates agree upon the remarkable income poverty reduction since 1981.

In this paper we have estimated multidimensional poverty in China using data from the China Health and Nutrition Survey 2000–2009 and applying the new methodology developed by Alkire and Foster (2007, 2011). This broader approach to poverty measurement enables us to evaluate whether the growth process has resulted not only in a reduction in income poverty but also in other dimensions, and more importantly, in the reduction of *simultaneous* deprivations. To do so, we selected five dimensions: income, living standard, education, health and social security. Each of these has a rationale for being included, but clearly do not exhaust the list of relevant dimensions to be considered. Unfortunately, our study period is relatively short (from 2000 to 2009), but this is due to the comparability of the data over this period.

In line with China's outstanding growth performance, the levels of multidimensional poverty found are relatively low. In fact, about 95 % of households were deprived in less than the equivalent of two of the five selected dimensions, and only about 5 % of the households were deprived in two or more equivalent dimensions. Setting the multidimensional poverty cutoff at two or more equivalent dimensions, we found that the proportion of poor households decreased from 31.65 to 5.08 % between 2000 and 2009. Thus, there seems to be a consistent pattern of poverty reduction not merely in terms of income but also including other dimensions simultaneously.

Breaking down multidimensional poverty by dimension reveals that, among the five considered dimensions, social security was the largest contributor to aggregate multidimensional poverty between 2000 and 2006. However, following the efforts to re-build the health insurance system in both rural and urban areas after 2003, social security was no longer the largest contributor in 2009 and income became the most important contributor to aggregate  $M_0$ . However, we only use access to health insurance as a proxy of social security, yet universal access to health insurance in recent years does not necessarily mean that China has done well enough in developing other components of the social security system, such as a pension system for rural residents and migrant workers, an unemployment insurance system, and minimum living allowance, among others.

Deprivation in education, which is defined as no household member having completed primary school, exhibited an increase, reflecting the outflow of better-educated family members. It is worth noting that this kind of education outflow occurred mainly in rural areas and in less-developed provinces. Thus the most important reason for education outflow probably is migration from rural to urban areas and from less developed regions to more developed regions.

In the first 20 years of the reforming period, China adopted urban-biased and coastal-biased development policies, which resulted in large urban–rural and regional disparities. For this reason, China has experienced a phenomenal internal migration from rural to urban areas, described as the largest peacetime movement of people in history. Large numbers of rural workers have migrated to the cities to work, pulled by jobs in China's fast-growing manufacturing and service industries and pushed by the growing pool of surplus labour resulting from reforms in the agricultural sector (World Bank 2009, p. x).

The education outflow doesn't lower the average education level of the country, but it may further exacerbate urban–rural and regional disparities in human wellbeing and human capital and make these remote areas further marginalized. Hence increasing deprivation in education should also be a concern of the policymakers. Providing more training opportunities for rural

labourers and investing more in education in less-developed areas would help to mitigate the effects of education (and human capital) outflow in these areas.

Comparing the relative performance of the nine considered provinces, we find that although all provinces made remarkable progress in alleviating multidimensional poverty, progress was uneven across them. Guizhou and Guangxi were the two provinces with the highest incidence of multidimensional poverty in 2009, and Henan was the largest contributor to the overall  $M_0$ . These three provinces should be given priority in making poverty alleviation policies in the future.

In summary, China has made remarkable progress in improving the living conditions of its population. However, many challenges remain, especially in terms of guaranteeing more even development across the different provinces and between urban and rural areas.

In future research we intend to consider other relevant dimensions, such as employment and shelter, and will try alternative indicators within the selected dimensions, testing alternative weighting sets and performing other robustness analysis.

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