Health System Reform in China 5

China's human resources for health: quantity, quality, and distribution

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This is the fifth in a Series of seven papers about Health System Reform in China

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In this paper, we analyse China's current health workforce in terms of quantity, quality, and distribution. Unlike most countries, China has more doctors than nurses—in 2005, there were 1·9 million licensed doctors and 1·4 million nurses. Doctor density in urban areas was more than twice that in rural areas, with nurse density showing more than a three-fold difference. Most of China's doctors (67·2%) and nurses (97·5%) have been educated up to only junior college or secondary school level. Since 1998 there has been a massive expansion of medical education, with an excess in the production of health workers over absorption into the health workforce. Inter-county inequality in the distribution of both doctors and nurses is very high, with most of this inequality accounted for by within-province inequalities (82% or more) rather than by between-province inequalities. Urban–rural disparities in doctor and nurse density account for about a third of overall inter-county inequality. These inequalities matter greatly with respect to health outcomes across counties, provinces, and strata in China; for instance, a cross-county multiple regression analysis using data from the 2000 census shows that the density of health workers is highly significant in explaining infant mortality.

Introduction

China's economic reforms over the past three decades have generated unprecedented economic growth, increased household incomes, and reduced levels of absolute poverty. The benefits of growth, however, have not been fully translated into equitable social development. In the case of health, inequitable access to a poorly functioning system has generated much public dissatisfaction. The government has launched major reforms of the health-care system to address these problems. Given the success of its economic reforms, China clearly has the fiscal resources and capacity to fund improvements in its health sector.

Reform efforts will necessarily have to deal with the three major resource inputs of any national health system: financial, physical, and human. Of these three inputs, perhaps the least mapped and analysed in China is human resources for health. Yet there is clear evidence that human resources for health affect health outcomes, drive the performance of health systems, and command a large share of the health budget.[1,2] Without doubt, the success of China's national health reform will depend on developing and sustaining an adequate and appropriate health workforce.

See Online for webappendices 1–7

China has a history of successful innovations of the health workforce. In the 1950s, China organised its people for mass hygiene campaigns, integrated modern and traditional health practitioners and systems, and trained para-professional workers to extend basic health services. During the cultural revolution in 1966–76, China mobilised and dispatched so-called barefoot doctors to serve rural villages throughout the country. In 1998, China began to prioritise and expand its tertiary education system when it launched a major expansion of comprehensive universities, and this has led to a rapid growth of medical, nursing, and public-health education.

In this paper, we analyse the quantity, quality, and distribution of China's health workforce. These three dimensions of human resources for health provide a systematic framework for understanding the workforce, as indicated in reports such as that released by the Joint Learning Initiative[3] and the 2006 WHO World Health Report.[4] Benchmarking the human resources situation seems a prerequisite to any informed discussion of health care and health in China.

Data and methods

Data on China's human resources for health are available from multiple sources, all in the Chinese language. The panel provides an English translation of the definitions of different types of health workers in China—including licensed doctors, licensed assistant doctors, nurses, technicians, and management staff. We have attempted to achieve consistency across various data sources which are based on different collection instruments and methodologies. Our detailed investigation of China's multiple data sources is presented in the webappendices, and include detailed definitions of different types of health workers (webappendix 1); adjustments for definitional change of doctors in 2002 (webappendix 2); descriptions of medical education programmes (webappendix 3); a review of the qualification title system for health professionals (webappendix 4); reviews of population and health workforce data sources (webappendix 5); analyses based on cross-country regression which place China in an international perspective (webappendix 6); and the technical and computational basis for inequality and other estimates presented here (webappendix 7).

Administrative units

Province level refers to the first administrative division below national level. There are 33 "provinces", which comprise 22 provinces, four municipalities (Beijing, Shanghai, Tianjin, and Chongqing), five autonomous regions (Xinjiang Uyghur, Tibet, Inner Mongolia, Ningxia, and Guangxi), and two special administrative regions (Hong Kong and Macau). The special administrative regions are not included in the data presented here. County-level refers to counties, autonomous counties, county-level cities, qi, autonomous qi, and districts. Henceforth, county refers to these county-level units.

Health workers

We obtained year-end data on the numbers of doctors and nurses in China at the province level during 1990–2005 from the Chinese Ministry of Health's 2006 China Human Resources for Health report.[5] This report was produced using three administrative data collection systems: (1) annual organisation-based surveys; (2) 3-yearly individual-based surveys; and (3) annual village clinic surveys. County-level data for 2005 were obtained directly from the Center for Health Statistics and Information of the Ministry of Health, which did special computer runs for us.

The annual organisation-based administrative survey covers all health units at the township level and above, and includes counts of individual workers, in both the public and private sectors. These annual counts at the township level are then aggregated up to the county, provincial, and national levels. The 3-yearly individual-based administrative survey of health workers collects detailed information on attributes of workers such as age, sex, education, years of work experience, title, education, course of study, and specialty. While the organisation-based survey is supposed to cover private health facilities, we are unsure whether the individual-based survey canvasses private-sector practitioners (or does so only with a lag). It may explain why the number of health workers covered in the organisation-based survey exceeds the number in the individual-based survey by about 10%. Another reason for this may be that the response rate for the individual-based survey is lower than that for the organisation-based survey.

To examine the reliability of the Ministry of Health data, we compared these data for 1990 and 2000[5] with census data for 1990 and 2000.[6,7] In the 1990 census,[6] we found there were a total of 4·6 million or 5·0 million health workers, according to the two classifications provided by occupation and industry, respectively (ie, "medical and health care personnel" and "public health service employees"). These numbers match reasonably closely the Ministry's estimate of "all health workers" of 4·9 million in 1990.[5] In the 2000 census,[7] we found that there were 6·1 million workers employed as "health professionals and technical personnel" compared with the Ministry's estimate of all health workers in 2000 of 5·6 million.[5] Thus there is a difference of about 500 000 health workers between the two data sources (webappendix 5).

It is possible that the gap between the estimates from the 2000 census[7] and the Ministry of Health[5] could be explained by an expansion of private-sector health workers, which is not being picked up—or being picked up only with a lag—by the Ministry of Health's annual organisation-based surveys. Between 1990 and 2000, it is likely that new, private health-care organisations have arisen, whose workers have not been counted in the Ministry of Health data (possibly owing to an inadequate mechanism for transmitting information on licensed or registered medical practitioners to the Center for Health Statistics and Information).

Education

To assess the quality of health workers, we examined data on their education levels and professional titles, which are available at only national and not provincial level. We also examined data from the Ministry of Education[8–11] on the number of educational institutions in medical and allied health fields, as well as the number of graduating and admitted students in secondary schools and colleges in each province between 1990 and 2000. For 2005, data only on graduates of and admissions to college-level education institutions offering health programmes were available.

Panel: Health workers in China

China has developed its own system of nomenclature for health workers. Although it mostly follows international definitions, greater precision is accorded to education and qualifications, as follows.

Health professionals include doctors, nurses, pharmacists, laboratory technicians, clinical radiologists, and other technical staff with advanced education.

Doctors are those who pass a licensing examination and are registered at a county or higher-level health authority as either licensed doctors or licensed assistant doctors. **Licensed doctors** are medical graduates with a bachelor's or higher degree, and a year's internship supervised by licensed doctors at a clinic or preventive or health-care institution. **Licensed assistant doctors** are medical graduates of 3-year tertiary medical education programmes with an associate degree, or secondary education programmes with a diploma (2 years' medical education after high school), followed by 1 year of internship supervised by licensed doctors at a clinic or preventive or health-care institution.

Nurses are those who have obtained nursing certification with an associate degree (3 years' tertiary nursing education) or higher, or graduates from secondary education programmes with a diploma (2 years' nursing education after high school) and recommended by a health authority at provincial level or above. No examination is required.

Technicians are professionals who have undertaken specialised studies, and include pharmacists, laboratory technicians, radiology technicians, and other technical staff.

Other technicians, not classified as professionals, are graduates from secondary technical schools and higher education schools in non-medical specialties such as chemistry and mathematics, who are engaged in health research, communication, teaching, etc.

Management staff, also not classified as professionals, include principals at institutions engaged in personnel, financial, information, and party administration management.

	Total		Urban*		Rural*	
	Number (thousands)	Density†	Number (thousands)	Density†	Number (thousands)	Density†
All health workers	5427	4·2	3705	6·2	1722	2·6
Licensed doctors‡	1938	1·5	1291	2·1	647	1·0
Nurses	1350	1·1	1004	1·7	346	0·5
Other health professionals§	1172	0·9	..	..	..	..
Other health workers¶	967	0·8	..	..	..	..

*Describes the Chinese classification of city/county. †Per 1000 population, computed by Ministry of Health[5] using household registration population data. ‡Refers to the Ministry of Health[5] count which reflects the change in the definition of doctors in 2002, unlike the numbers in the figure. §Health professionals (including pharmacists, lab technicians, etc) minus doctors and nurses. ¶All health workers minus health professionals.

Table 1: **Health workers in China, 2005[5]**

	Urban		Rural		Total	
	Doctors	Nurses	Doctors	Nurses	Doctors	Nurses
College or above	42·8%	3·0%	12·9%	0·7%	32·8%	2·5%
Secondary school	52·8%	90·4%	79·0%	89·2%	61·6%	90·0%
High school or less	4·4%	6·6%	8·1%	10·1%	5·6%	7·5%

In China, college level refers to bachelor's education or higher, while secondary school level includes secondary schools, secondary technical schools, and junior colleges.

Table 2: **Distribution of doctors and nurses by education level, 2005[5]**

Population

For province-level analysis, we used multiple sources of population statistics: the 1990 census,[12] the 1995 1% Population Survey,[13] the 2000 census,[14] and the 2005 1% Population Survey.[14] We calculated density of health workers using workforce data from the Ministry of Health[5] and population data from the above sources. We analysed time trends of health-worker density, nationally and provincially between 1990 and 2005 (webappendix 7). By contrast, the Ministry of Health[5] estimates of doctor and nurse density use household registration data, which record people by place of registration, not actual residence. These data will thus undercount urban migrants whose place of registration is rural.

Measures of inequality

We calculated three measures of inequality for density of health workers weighted by population: Gini coefficient, Theil *T*, and Theil *L*.[15] We also calculated inter-county inequality of doctors and nurses in 2005, and its decomposition into within-province and between-province inequality. Only two of these three indices are decomposable: Theil *T* and Theil *L*. For these two measures, overall inter-county inequality is the sum of within-province inequality and between-province inequality.

Quantity

In 2005, China had 5 427 000 health workers—4 460 000 professional workers (licensed doctors, nurses, and other health professionals) and 967 000 non-professional workers (in management, logistical, and other work; table 1). About 917 000 village health workers—mostly former barefoot doctors, village workers, and traditional practitioners—were not included in these official counts. Among professionals, there were 1 938 000 doctors, 1 350 000 nurses, and 1 172 000 other health professionals.[5] Note that the definition of doctors changed in 2002 to include only licensed physicians and licensed assistant physicians; hence the difference in health worker and doctor numbers in 2005 according to unadjusted Ministry of Health data[5] (table 1) and the figure.

Among doctors, 57% were men and 43% women; nurses were overwhelmingly female. About 72% of the doctors had studied western medicine, while 13% had studied traditional Chinese medicine. Other courses of study included public health (5%), dentistry (3%), and others (7%).[5] Unlike most other countries, China had more doctors than nurses: the national ratio of doctors to nurses was 1·4, with a ratio of 1·3 in urban areas and 1·9 in rural areas. There was strong urban bias in the distribution of medical professionals, with up to 70% of doctors and nurses resident in urban areas, which account for much less of the national population. Doctor density in urban areas was more than twice that in rural areas; nursing density showed more than a three-fold difference between urban and rural areas.

Both the absolute number and the density of doctors and nurses have steadily increased over the past 50 years, except during the decade of the cultural revolution in 1966–76.[5] In the 1960s, there was a flattening of numbers and a decline in density due to the closure of universities. When universities re-opened in the 1970s, medical admissions started to rise again. China returned to customary higher education degrees and courses in the 1980s. In 1998, China launched a major expansion of tertiary education with integration and growth of medical and nursing schools within comprehensive universities.

Quality

We use the education level of health workers as a proxy for their skill and technical competency. Table 2 shows that about a third of China's doctors have been educated to college level or above. The proportion of nurses educated to college level or greater is very small, only 2–3%. Most of China's doctors (67·2%) and nurses (97·5%) have been educated up to only junior college or secondary technical school level. About 6% of doctors and 8% of nurses have just high school or lower education. The proportion of urban doctors with college education or greater was 43%, which is more than three times as high as that for rural doctors. Less than 1% of rural nurses have college education or more.

Review of available data highlight three additional aspects of health-worker education. First, the recent

massive expansion of medical education will greatly increase health-worker stocks in the future. Second, there is a diversity of educational programmes offered for doctors and other personnel. Such diversity raises questions of standardisation and quality that are appropriate to the health conditions facing the country. Third, there is a mismatch between levels of production and changes in the stock of health workers.

Over recent decades there has been a massive expansion in the number of individuals admitted to medical and health-related education programmes. There was an interruption of university and college education during the cultural revolution, so that even by 2005 most doctors and nurses were not educated to college level (table 2). Since 1998, however, the government has made a substantial effort to expand education. Between 1998 and 2005, the number of admissions to college-level educational institutions in medical and health-related fields expanded by 350% while admissions to all post-high school educational institutions in the same fields expanded by 225%. In the same period, the number of graduating students in college-level educational institutions in the medical and health fields grew by 193% (and by 262% for all post-high school educational institutions in the same fields).[12]

The magnitude and rapidity of the expansion is reflected by the fact that admission cohorts have sometimes been about twice the size of graduating cohorts (figure). In 2005, the number admitted to colleges, universities, junior colleges, and vocational schools in health-related fields was 856 000 while the number of graduating students was 553 000.[12] For junior college and higher institutions, the number of nursing admissions (103 000) was more than twice the number of nursing graduates (43 000; webappendix 3).

China has enormous diversity in its educational programmes for medical professionals (table 3). In 2006, China's 330 health sciences colleges and universities offered programmes of four lengths—8 years, 7 years, 5 years, and 3 years. Entrance to college-level programmes require completion of high school. Graduates of the 5-year programme earn a bachelor's degree, the 7-year programme a master's degree, and the 8-year programme a doctoral degree. Graduates of the 3-year programme receive an associate degree. Only a small proportion of programmes (4%) provided an 8-year course. Most programmes follow a western medical school curriculum, while a few teach traditional Chinese medicine.

Training for nurses ranges from non-degree vocational schools to college-level universities. Most registered nurses, who are included in the estimates of the Ministry of Health,[5] have attended vocational schools that grant certificates. Nursing helpers, by contrast, have received only 10–15 days' training and are not counted in the Ministry's estimates.

Satisfying the basic health-care needs of people in different regions and strata may not require provision of doctors with 7 or 8 years of medical education: it may be sufficient to provide doctors with lower levels of training. The coexistence of 7 and 8-year long medical education programmes with programmes of shorter duration can help serve the specialist demands for health care without sacrificing the needs of the population for basic or primary health care.

To monitor the quality of doctors, the Ministry of Personnel introduced a licensing examination system in 1999. The number of doctors with the title chief or assistant chief doctor has increased sharply between 2000 and 2005—the former by 13 000 and the latter by 27 000 (webappendix 4). The number of those with the title doctors in charge and doctors with junior title fell between 2000 and 2005—the former by 7000 and the latter by 171 000.

Lastly, there are inconsistencies in the trend of worker production and changes in worker stock. Between 2000 and 2005, the stock of all health workers increased by 131 000 (figure). Over the same period, however, the total number of health workers graduating from all health educational institutions was 1 951 000 (webappendix 3). If

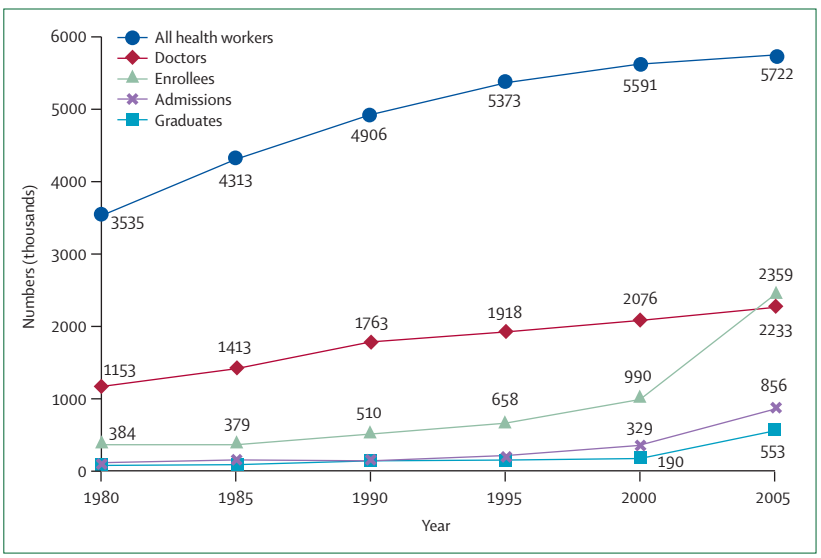

Figure: **Stock and production of health workers, 1980–2005**[5,12]
The number of doctors for 2005 has been adjusted to make it comparable with earlier estimates that include unlicensed physicians and assistant physicians (webappendix 2). In 2002, there was a definitional change in the category of doctors to include only licensed physicians and licensed assistant physicians and a subset of the institutions with which doctors are affiliated. See webappendix 3 for a breakdown by college and secondary level of the number of enrollees, admissions, and graduates.

	8 year	7 year	5 year	3 year	Total
Western medicine	12	30	73	53	168
Traditional Chinese medicine	0	13	9	5	27
Nursing	0	0	84	95	179
Pharmacy	0	0	4	2	6
Total	12	43	170	155	330

Table 3: **College-level medical education programmes in China, 2006**[16]

Measure	Doctors	Nurses
Overall inter-county inequality		
Theil *T*	0·235	0·408
Theil *L*	0·210	0·370
Gini	0·362	0·471
Between-province inequality		
Theil *T*	0·043	0·067
Theil *L*	0·038	0·057
Within-province inequality		
Theil *T*	0·192	0·340
Theil *L*	0·172	0·312
Within-province inequality as a percentage of overall inter-county inequality		
Theil *T*	81·7%	83·3%
Theil *L*	81·9%	84·3%

County-level population data for 2005 are based on household registration data,[17] as the 2005 1% population survey data were not available for counties.

Table 4: **Decomposition of inter-county inequality by province, 2005 (N=2854)**

	Doctors			Nurses		
	Theil *T*	Theil *L*	Gini	Theil *T*	Theil *L*	Gini
Overall inter-county inequality	0·235	0·210	0·362	0·408	0·370	0·471
Urban inequality	0·213	0·210	0·358	0·321	0·326	0·437
Rural inequality	0·094	0·086	0·217	0·156	0·141	0·288
Between-strata inequality (% of overall)	0·064 (27·2%)	0·066 (31·4%)	..	0·133 (32·6%)	0·142 (38·5%)	..
Within-strata inequality (% of overall)	0·171 (72·8%)	0·144 (68·6%)	..	0·275 (67·4%)	0·227 (61·5%)	..

Table 5: **Decomposition of inter-county inequality by urban-rural stratum, 2005 (N=2854)**

one accounts for attrition in the health workforce at 3% a year (ie, 15% over the 5-year period, or 839 000), this represents an excess of some 981 000 health workers produced during 2000–05 who were not absorbed into the workforce. It is possible that the Ministry of Health database has underestimated the total number of health workers for 2005, but this is unlikely to account for the massive difference between production and absorption of health workers during 2000–05. By contrast, the assumed rate of attrition of 3% a year could be an underestimate (depending on the age structure of the workforce), and we have ignored out-migration—two factors which both tend to overstate the calculated difference.

If one examines the category of doctors, there was an increase of 157 000 in the stock of doctors between 2000 and 2005 (figure), while over the same period the number of all college and university graduates from medical and health programmes amounted to 674 000 (which includes some who obtained university degrees in pharmacy, nursing, etc; webappendix 3). Again, after accounting for attrition in the stock of doctors at an assumed rate of 3% a year, there seems to be a surplus of some 206 000 college and university graduates in medical-related fields during 2000–05 who are not practising as doctors.

What has happened to these graduates who are not counted as part of the health workforce? The mismatch between increases in the stock of doctors and the number of graduates of medical-related fields may in part be due to under-estimation in the Ministry of Health database, as noted earlier. It is more likely that many medical graduates do not join the health workforce but seek employment elsewhere—eg, in the pharmaceutical or biotech industries.

Distribution

With our county-level dataset for 2005, we can examine inter-county, inter-provincial, and urban-rural inequalities in availability of doctors and nurses. These inequalities may be associated with corresponding economic disparities—eg, between counties, between provinces, and between strata (ie, urban–rural). Apart from these geographical categories, however, we do not have data to examine differences in people's access to health workers by, for example, income level, education, occupation, etc.

Table 4 shows overall inter-county, between-province, and within-province inequality in the per-head availability of doctors and nurses. Several observations about these estimates are in order. First, overall inter-county inequality in the distribution of both doctors and nurses is very high, with Gini coefficients of 0·362 for doctors and 0·471 for nurses (note that these Gini coefficients are calculated across population groups—counties with an average population of 446 000 individuals—rather than across individuals themselves). Second, there is consistently higher inequality in the distribution of nurses than in that of doctors at each level and according to all indices. Third, within-province inequality accounts for as much as 82% of overall inter-county inequality in the distribution of doctors (for both Theil *T* and *L*), and 83–84% of overall inter-county inequality in the distribution of nurses (for both Theil *T* and *L*). Hence, most of the inter-county inequality in distribution of doctors and of nurses is explained by within-province inequalities rather than by between-province inequalities.

Doctor and nurse distribution is also worse in provinces with low income per head. Correlations of inter-county inequality of doctors and of nurses within provinces and provincial income per head are negative and significant (webappendix 7). Low-income provinces are thus disadvantaged in terms of both their low income and their high workforce inequality. As poorer provinces are also likely to be disadvantaged in terms of less educated workforces, the inequality in per-head availability of well-trained health workers is likely to be larger.

Table 5 shows inter-county inequality in urban areas and in rural areas, and its decomposition between and

within these strata. In urban areas, the level of inter-county inequality for both doctors and nurses is much higher than that in rural areas (more than twice as high, according to Theil *T* and *L*). The rural areas, although more homogeneous in this respect than urban areas, have a lower average density of doctors and nurses (table 1). Urban-rural disparity in the per-head availability of doctors accounts for about a third of overall inter-county inequality (27% according to Theil *T* and 31% according to Theil *L*). Urban-rural disparity in the availability of nurses accounts for a larger percentage of overall inter-county inequality (33% according to Theil *T* and 39% according to Theil *L*). Comparing tables 4 and 5, we see that between-strata inequality is at least 1·5 times as large as between-province inequality for doctors, and at least twice as large for nurses.

Such workforce inequalities matter greatly with respect to health outcomes across counties in China. From the 2000 census,[7] we extracted data at county level on health professionals and technical personnel (using the occupation classification) and health-care workers (using the industry classification), as well as a number of other socioeconomic variables (table 6). With these data at county level, we regressed infant mortality against the density of health professionals and technical personnel and other covariates including land area of county, the proportion of households earning less than 10 000 yuan per year, the female adult illiteracy rate, the proportion of households with access to improved (ie, piped) water, and the proportion of households using improved cooking fuel (gas or electricity). A parallel set of regressions was done with density of health-care workers as an independent variable. All variables were transformed into natural logarithms.

Table 7 presents the regression results. We find that the density of health professionals and technical personnel (and separately the density of health-care workers) matter significantly in explaining infant mortality across counties. All variables have the expected signs and show very high levels of significance (all p values <0·0001). Controlling for all other variables (column five of table 7), a 1% increase in density of health professionals and technical personnel leads to a 0·133% decrease in the infant mortality rate. The land area of a county, which is intended as a proxy for the average distance between health workers and health-care seekers, has a positive coefficient, suggesting that a given density of health workers is less effective if they have to serve a larger geographical area. Other things equal, absolute income poverty (as measured by the proportion of households earning less than 10 000 yuan a year) is positively associated with infant mortality; female adult illiteracy is positively associated with infant mortality; and both the proportion of households with access to improved water sources and the proportion using improved cooking fuel are negatively associated with infant mortality.

	Mean (SD)
Population (thousands)	433 (341)
Infant mortality rate (per 1000 livebirths)	24·1 (21·4)
Density* of health professionals and technical personnel (occupation classification)	4·90 (2·85)
Density* of health-care workers (industry classification)	5·78 (5·12)
Land area of county (in km²)	3272 (8984)
Proportion of households earning less than 10 000 yuan per year	0·478 (0·182)
Female adult illiteracy rate (age 15 years and above)	13·5 (8·6)
Proportion of households with access to improved (ie, piped) water	0·457 (0·320)
Proportion of households using improved cooking fuel (gas or electricity)	0·277 (0·296)

Data are mean (SD). 2851 counties, from 2000 census. *Per 1000 population.

Table 6: **Variables at county level, 2000**

The regression results for health-care workers are comparable, except that the coefficient of health-care workers is smaller in absolute value than that of health professionals and technical personnel in the corresponding regressions. This is not surprising because the former variable is likely to be a less accurate measure of the workers actually delivering health care, being based on the industry rather than the occupation of workers. Note that the coefficients and *t*-ratios of the non-health worker variables are very similar in the two sets of regressions. Hence our results in explaining infant mortality with these covariates seem to be robust.

Discussion

As China undertakes health-care reforms, effective policies will be needed to develop and manage its health workforce. In this paper, we have attempted to analyse its workforce in terms of quantity, quality, and distribution. We have not had the opportunity to examine the adequacy of health workers in these terms. To do so would require a detailed analysis of both demand and need—effective, latent, and potential—disaggregated for example by geographical, socioeconomic, epidemiological, and demographic categories. Our focus has been limited to the supply or availability of, but not the demand for, health workers.

We have three key findings from our analyses. First, there is an apparent surplus of people trained as health workers but who are not employed as such. This mismatch suggests a less than optimal allocation of educational investment in China; it also suggests the need for improved coordination between the Ministry of Health and the Ministry of Education. Second, China faces the challenge of educational programme diversity and skill mix so as to best meet the needs of its population. However, there is no clear-cut answer in the debate on setting uniform national standards for physician training and qualification. Third, like many countries, there is a severe maldistribution of health professionals, who tend to serve in provincial urban centres rather than in rural

areas. This maldistribution can only be corrected through national or provincial policies that create effective incentives for health professionals, especially physicians, to work and remain in rural health stations.

The recent dramatic expansion of tertiary education in comprehensive universities will generate large future cohorts of health workers. There has been a sharp increase in the number of admissions to and graduates from both college-level and medium-level educational institutions in medical and health-related fields (webappendix 3). New admissions are about twice the size of graduating cohorts, stretching both faculty and facilities. The production of doctors in the country appears to follow government imperatives to expand medical education rather than responding to labour market demand. The apparent large surplus seems to be absorbed in occupations other than health-care work (eg, the pharmaceutical industry). This hypothesis is consistent with a recent survey by the Peking University Health Science Centre (Department of Education, unpublished data) which found that only 28% of its 418 5-year clinical medicine graduates between 2004 and 2006 are currently working as doctors, with the remainder pursuing other options.

In a cross-country regression of the density of doctors and the density of nurses (plus midwives) against gross national income per head at purchasing power parity (PPP) dollars, we found that for its income level China

	Regressions with health professionals and technical personnel as an independent variable					Regressions with health-care workers as an independent variable				
Constant										
	2·837	1·848	1·810	1·504	1·494	2·566	1·662	1·686	1·421	1·446
	(25·902)	(14·432)	(13·918)	(10·209)	(10·116)	(25·468)	(14·226)	(14·246)	(11·222)	(11·398)
	<0·0001	<0·0001	<0·0001	<0·0001	<0·0001	<0·0001	<0·0001	<0·0001	<0·0001	<0·0001
Density of health professionals and technical personnel										
	–0·364	–0·243	–0·201	–0·157	–0·133	..	..	..	..	..
	(–12·174)	(–8·043)	(–6·337)	(–4·431)	(–3·694)	..	..	..	..	..
	<0·0001	<0·0001	<0·0001	<0·0001	<0·0001	..	..	..	..	..
Density of health-care workers										
	..	..	..	..	..	–0·207	–0·139	–0·119	–0·106	–0·096
	..	..	..	..	..	(–11·332)	(–7·606)	(–6·419)	(–5·504)	(–4·964)
	..	..	..	..	..	<0·0001	<0·0001	<0·0001	<0·0001	<0·0001
Land area of county										
	0·125	0·102	0·093	0·084	0·079	0·136	0·109	0·096	0·086	0·080
	(11·320)	(9·424)	(8·458)	(7·421)	(6·947)	(12·488)	(10·109)	(8·775)	(7·645)	(7·085)
	<0·0001	<0·0001	<0·0001	<0·0001	<0·0001	<0·0001	<0·0001	<0·0001	<0·0001	<0·0001
Proportion of households earning less than 10 000 yuan per year										
	0·483	0·377	0·353	0·295	0·284	0·521	0·402	0·370	0·296	0·285
	(15·231)	(11·901)	(11·067)	(8·633)	(8·312)	(16·664)	(12·773)	(11·630)	(8·679)	(8·346)
	<0·0001	<0·0001	<0·0001	<0·0001	<0·0001	<0·0001	<0·0001	<0·0001	<0·0001	<0·0001
Female adult illiteracy rate										
	..	0·344	0·313	0·369	0·348	..	0·349	0·308	0·362	0·339
	..	(13·796)	(12·058)	(13·877)	(12·826)	..	(13·990)	(11·796)	(13·666)	(12·520)
	..	<0·0001	<0·0001	<0·0001	<0·0001	..	<0·0001	<0·0001	<0·0001	<0·0001
Proportion of households with access to improved water										
	..	..	–0·092	..	–0·079	..	..	–0·104	..	–0·080
	..	..	(–5·149)	..	(–3·913)	..	..	(–5·966)	..	(–3·959)
	..	..	<0·0001	..	<0·0001	..	..	<0·0001	..	<0·0001
Proportion of households using improved cooking fuel										
	..	..	..	–0·103	–0·088	..	..	..	–0·112	–0·095
	..	..	..	(–7·754)	(–6·396)	..	..	..	(–9·077)	(–7·242)
	..	..	..	<0·0001	<0·0001	..	..	..	<0·0001	<0·0001
n	2851	2851	2839	2735	2734	2836	2836	2824	2723	2722
R^2	0·366	0·406	0·407	0·414	0·417	0·362	0·403	0·406	0·413	0·417
F	548·453	486·279	389·374	384·801	324·449	534·786	477·599	385·065	382·872	322·943
p	<0·0001	<0·0001	<0·0001	<0·0001	<0·0001	<0·0001	<0·0001	<0·0001	<0·0001	<0·0001

All dependent and independent variables were transformed into natural logarithms for the regressions. The numbers in the cells are *b* (regression coefficient), *t*, (*t* value of *b*), and p value.

Table 7: **Multiple regression equations for infant mortality rate, 2000**

has a higher than expected density of doctors but a lower than expected density of nurses (plus midwives; webappendix 6). Indeed we estimated the ratio of doctors to nurses in China to be 1·4, which is higher than in most countries. Clearly, China needs to step up its training of nurses to perform the many health-service tasks that doctors do not or cannot undertake.

The deficit in the availability of nurses has begun to be addressed through a policy of increasing admissions of nursing students rapidly in recent years (webappendix 3). The low ratio of nurses to doctors obviously limits delegation of key functions from highly trained and well-paid professionals to others (ie, nurses). It also reflects historical developments when nurse training was even more neglected than doctor training (during the cultural revolution) and recent policies of personnel quotas in hospitals which lack financial incentives to employ nurses.

Doctors and nurses in China are trained at various levels (webappendix 3). In health-worker training in China, a major question is whether a uniform national standard of education and qualification should be applied throughout the country. China's epidemiological, demographic, sociocultural, and economic diversity may necessitate a differentiated health workforce with training matched to specific circumstances. Satisfying the primary health-care needs of a rural population does not require a graduate with 8 years of medical training. However, wealthy urban elites are unlikely to be satisfied with a doctor with 3 years of training. In the foreseeable future, China will have to rely on a mix of workers with different education and skill levels.

We found that doctors and nurses are highly maldistributed according to various gradients that we examined—urban–rural, regional, provincial, etc. We also found that within-province inequality accounts for more than 80% of overall inter-county inequality, suggesting that inequality needs to be addressed at the provincial rather than the national level. Nurses are even more maldistributed than doctors, including within-provinces and within-strata (urban and rural areas). Urban–rural disparities in health worker density are much larger than inter-province disparities, with the former accounting for about a third of overall inter-county inequality. These inequalities in per-head availability of health workers will obviously contribute to inequalities in health outcomes across counties, provinces, and strata, as our regression results demonstrate.

The maldistribution of the health workforce in terms of quantity or numbers is accentuated if one takes account of the quality or education level of health workers. Disadvantaged areas have both lower densities of workers and less-educated workforces. Increases in the production and overall supply of college-level medical graduates will not necessarily address this maldistribution problem. Effective incentives will be needed to ensure that better-educated workers are willing to serve in poor counties and in rural areas.

Although the production of doctors and nurses has greatly expanded in recent years, serious problems of distribution remain. As the government seeks to achieve its aim of a Healthy China by 2020, the goal of its health reform should be to promote equitable and universal access to basic health services. This will require that every Chinese family—living in poor or rich counties and rural or urban areas—has access to an appropriately trained and supported health worker.

Conflict of interest statement

We declare that we have no conflict of interest.

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