Reassessing the relationship between human resources for health, intervention coverage and health outcomes

Niko Speybroeck, Yohannes Kinfu, Mario R. Dal Poz and David B. Evans

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Introduction

Health interventions cannot be carried out without health workers. Personal health interventions involving patient contacts require the services of doctors, nurses or other types of health care providers, while the preservation and promotion of health require such additional health workers as public health specialists, health educationalists and media experts. The health system also needs the services of many other categories, including planners, health economists and accountants.

The statistical association between human resources for health (HRH), intervention coverage and health outcomes has recently attracted considerable attention. For example, the relationship between availability of doctors, nurses and midwives across countries and intervention coverage (the percentage of deliveries with skilled birth attendance and the proportion of children fully immunized against measles) was explored by Chen et al. (2004) and Anand & Bärninghausen (2006), who also examined the relationship with maternal, infant and under-five mortality. These analyses show that health status and levels of coverage are positively associated with health worker density, here defined as the number of health workers per 1000 population. Chen et al. go a step further and suggest that countries with fewer than 2.5 health workers per 1000 population were very unlikely to achieve minimum desirable levels of coverage (80%) for skilled birth attendants and measles immunization.

These studies build on an earlier literature that had produced contradictory results: some studies had found no association between health worker density and health outcomes and outputs, while others found the opposite (Anand & Bärninghausen, 2004). Part of the explanation lies in the fact that they used different sources of data, sets of explanatory variables, analytical methods and levels of analysis (facility versus geographical unit) (Anand & Bärninghausen, 2004).

The results of these studies also differed in the number of countries included in the respective analysis. For example, Anand & Bärninghausen (2004) ran regressions for 117 countries in some models and 83 in others, omitting many of the poorest from their analysis because of data limitations – particularly the lack of data on the numbers of health workers. In their subsequent study (Anand & Bärninghausen, 2006) they included even fewer—only 49—countries, this time limiting attention to those for which data on immunization coverage were available from demographic and health surveys (DHS).

Data availability and quality remain a serious limitation in cross-country studies. For this analysis we undertook intensive efforts to obtain access to available data on health workers, which allowed us to include many of the poorest nations and extend the analysis to 192 countries. The purpose of this paper, therefore, is to determine whether the relationships estimated previously are robust to the inclusion of many more countries in the data set. We also explore alternative functional forms and estimation procedures and investigate the impact of controlling for additional determinants of health outcomes and outputs.

Materials and methods

The starting point for this analysis was the global database on human resources maintained by the World Health Organization – the same used by Chen et al. (2004) and Anand & Bärninghausen (2004). However, it was revised and updated for this analysis by means of a number of sources (for a full discussion, see Dal Poz et al., 2006). First, questionnaires seeking information on health worker numbers were sent to WHO offices in countries in sub-Saharan Africa, North Africa, the Eastern Mediterranean and South-East Asia, areas where there was substantial missing information in previous data bases. The WHO offices interacted intensively with different

relevant agencies in the country to obtain the required information for the public and non-government sectors.

Second, other sources of data were actively sought and processed, including national censuses and labour force surveys. Census data were regarded as the gold standard as long as the census had been conducted no later than 2000 and had occupational classification to the four-digit level of the ISCO-88 system (or an equivalent scheme). The resulting database is, therefore, more complete than used hitherto.

In measuring the effects of human resources on health output and outcomes we focused on three measures: the density of doctors, the density of nurses and midwives and the combined density of these three types of health workers. This was partly because the data for doctors, nurses and midwives are more complete than for other health workers and also because these health workers are trained to administer vaccines and provide maternal and early childhood services.

Table 1. Definition and measurement of dependent and independent variables

Variable names	Notations	Measurement
Dependent variables		
Skilled birth attendants	SBA	% of births attended by trained health personnel
Measles coverage	CVM	% of children immunized against measles in the correct age window
Infant mortality	IMR	Number of deaths of infants under one year of age per 1000 live births
Under five mortality	U5M	Probability of children dying between age one and five, expressed per 1000 children born alive
Maternal mortality	MMR	Annual number of maternal deaths per 100000 live births
Independent variables		
GDP	GDP	Gross domestic product per capita in international dollar
Income poverty	POV	proportion of the population living under one international dollar per day
Female literacy	LIT	Adult female literacy rate (%)
Land area	LAR	Total land area in square kilometers
Human resource density	HRH	Density of physicians, nurses and midwives per 1000 inhabitants
Doctors density	DOD	Density of physicians per 1000 inhabitants
Nurses density	NMD	Density of nurses and midwives per 1000 inhabitants

In addition to the type and density of health workers, a number of other variables affect levels of coverage and health outcomes within and across countries. For the present analysis we included female literacy rate, per capita income (in international dollars), land area and the proportion of people below the poverty line. Table 1 summarizes the independent and response variables used in the paper, while the actual sources for these data are listed in Annex 1.

We tested 19 separate models to examine the effects of health worker density on health outputs and outcomes. We first replicated Chen et al.'s (2004) analysis for coverage with skilled birth attendants, but using a much larger data set and alternative functional forms. Chen et al. (2004) probably used a log–log functional form, although it is not stated explicitly, without controlling for confounders. They then identified a level of health worker density below which virtually no country achieved 80% coverage, which was used as the threshold or cut point for defining health worker shortages. However, we found that the log–log functional form did not fit the data well, as it gave predicted coverage in excess of 100%. This required us to assess alternative functional

forms, particularly the logit–log and arcsine-log models. The functional forms of these alternative models along with that of Chen et al.'s original log–log model are shown below:

For the log–log model, we have:

$$\ln(SBA) = \alpha + \beta * [\ln[HRH]] \ldots\ldots (1)$$

For the logit–log model, we have

$$\ln \frac{SBA}{1 - SBA} = \alpha + \beta * [\ln[HRH]] \ldots\ldots (2)$$

For the arcsine-log model, we have

$$\arcsin(\sqrt{SBA}) = \alpha + \beta * [\ln[HRH]] \ldots\ldots (3)$$

where α and β are the parameters to be estimated from the data.

It is to be noted that of these three models, the arcsine-transformation is more consistent with statistical theory because the transformation of the dependent variable, which is a proportion, results in normally distributed responses (asymptotically) (Zar, 1996). On the other hand, it has not been proved if the other forms of transformation also provide a similar normal distribution of the dependent variable, even asymptotically.

We then extended the work to control for other possible determinants of coverage, specifically the proportion of the population living on less than one international dollar per day (poverty), adult female literacy and GDP per capita in international dollars.

For measles immunization coverage, we replicated Anand & Bärninghausen`s (2006) study, but using a much larger data set. Specifically, we used data from 186 countries for which measles immunization coverage is reported by WHO, compared to the 63 country-years (from 49 countries) used in their original study. However, to facilitate comparison, the model was fitted using the same logistic–log functional form as in the original work. We also used the same set of independent variables with the exception of GNI per capita, which was not available for the expanded data set. We therefore used gross national product (GDP) per capita (in international dollars). The general form of the full model is expressed as follows:

$$\ln\frac{CVM}{1-CVM} = \alpha + \beta_1 * [\ln[HRH]] + \beta_2 * [\ln[LIT]] + \beta_3 * [\ln[POV]] + \beta_4 * [\ln[GDP]] + \beta_5 * [\ln[LAR]]$$

Anand & Bärninghausen (2004) and Chen et al. (2004) also assessed the link between HRH density and health outcomes – adult, child and infant mortality rates – using a log–log formulation (described by equation 1 above), but only Anand & Bärninghausen (2004) had controlled for the effects of confounding factors. We re-ran the same equations as those of Anand & Bärninghausen (2004) using our enlarged data set on health workers. To ensure comparability, we also used the same log–log functional form and the same set of independent variables, with

the exception of GNI per capita, where, for the same reason, we again used gross domestic product (GDP) per person in international dollars.

Results

Descriptive results

A description of the dependent and independent variables used in this paper is summarized in Table 2. These show that female literacy is universal in the WHO European Region and nearly universal in the WHO Region of the Americas and the WHO Western Pacific Region, while only half of adult females in the WHO African Region and 60% in the WHO Eastern Mediterranean Region are literate.

Table 2. Means and proportions of dependent and independent variables by WHO regions

Independent & dependent variables	AFRO	AMRO	EMRO	EURO	SEARO	WPRO	Total
Doctors density	2.2	14.9	10.8	40.3	5.8	9.7	17.0
Nurses and midwives density	14.0	26.7	22.3	97.3	15.0	33.6	43.5
Human resource density	16.2	41.5	33.1	137.7	20.8	43.2	60.5
Under five mortality	147.3	28.4	65.1	19.3	69.4	35.7	61.8
Infant mortality	90.8	22.5	47.1	15.9	51.4	28.1	42.2
Maternal mortality	825.3	150.7	324.0	31.4	331.2	139.8	324.7
Measles coverage	70.3	89.8	84.0	91.9	81.6	83.9	83.7
Skilled birth attendants	53.1	85.5	73.1	97.4	54.8	87.7	76.8
GDP	2645.9	9206.4	8215.1	19082.1	3121.9	9266.9	9860.8
Income poverty	0.4	0.1	0.1	0.0	0.2	0.1	0.2
Female literacy	0.5	0.9	0.6	1.0	0.7	0.9	0.8
Land area	506419	1129613	632672	533144	677251	819529	695318

Source: Authors` calculation based on WHO database.

Less than 55% of the deliveries in the African and South-East Asian regions are assisted by trained health professionals, compared to over 80% in the remaining four regions. The infant mortality rate in the six regions varies from as low as 16 per thousand in the European Region to as high as 91 per 1000 in the African Region. The African Region also has the highest level of maternal and child mortality and the lowest coverage of measles vaccination. These patterns are consistent with low densities of health workers in the region. Human resource density varies from 16 per 1000 in the WHO African Region to as high as 138 per 1000 in the WHO European Region. The density of doctors in the African Region is a third of the level in the South-East Asian Region, seven times lower than the that of the Region of the Americas and almost 20 times lower than the level in the European Region.

Effects of health workforce on coverage of skilled birth attendants

Model I in Table 3 presents the univariate relationship between density of health workers and coverage of skilled birth attendants. The result shows a strong and positive association between aggregate health workforce density and coverage of skilled birth attendants. The analysis is based on the arcsine–log model which, in addition to being theoretically the most appropriate, was found to be the most stable with respect to the number of countries included in the analysis. The

arcsine–log model also showed the highest R-squared and best goodness-of-fit to the data as measured by the deviance.

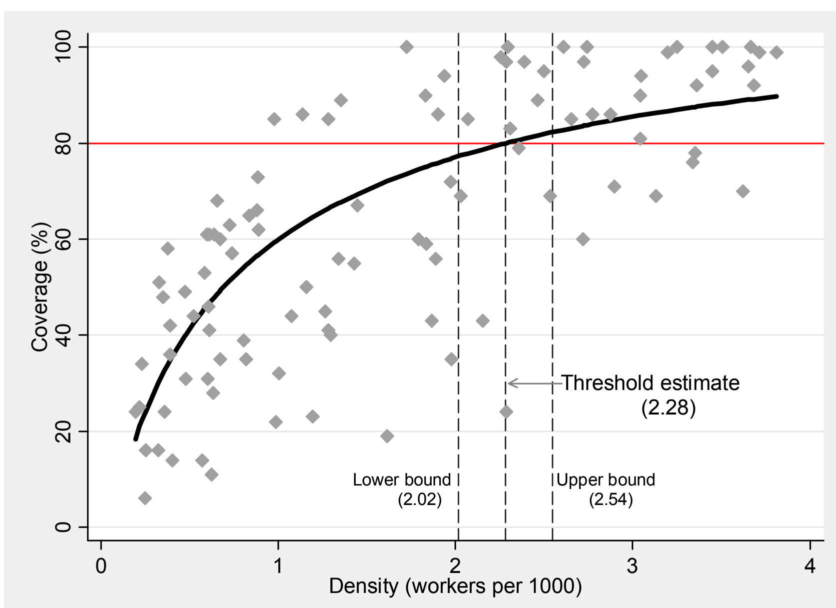
Table 3. Relationship between HRH and coverage of skilled birth attendants

	Model I : Univariate regression with aggregate HRH density			Model II: Regression with additional covariates		
	Coef.	t	P>|t|	Coef.	t	P>|t|
Income poverty				-0.0061	-0.8300	0.4080
GDP				0.0725	2.9600	0.0400
Female literacy				0.2301	5.8100	< 0.0001
Aggregate HRH density	0.2610	20.7400	< 0.0001	0.1206	5.8300	< 0.0001
Constant term	0.8938	43.3200	< 0.0001	0.4913	2.6200	0.0090
N			192			191
R-squared			0.6936			0.7794
F			430			164.27
Prob > F			< 0.0001			< 0.0001

Source: Authors` calculation based on WHO database.

Following the approach of Chen et al. (2004), we then used the model to determine the threshold level of health worker density associated with 80% coverage for the expanded data set (see Figure 1). Compared to the earlier threshold, the inclusion of more countries resulted in a reduction of the threshold from 2.5 to 2.28 health workers (doctors, nurses and midwives) per 1000 population. Allowing for uncertainty, the range is from 2.02 to 2.54 (confidence intervals based on non-linear combination of estimators following Oehlert (1992)).

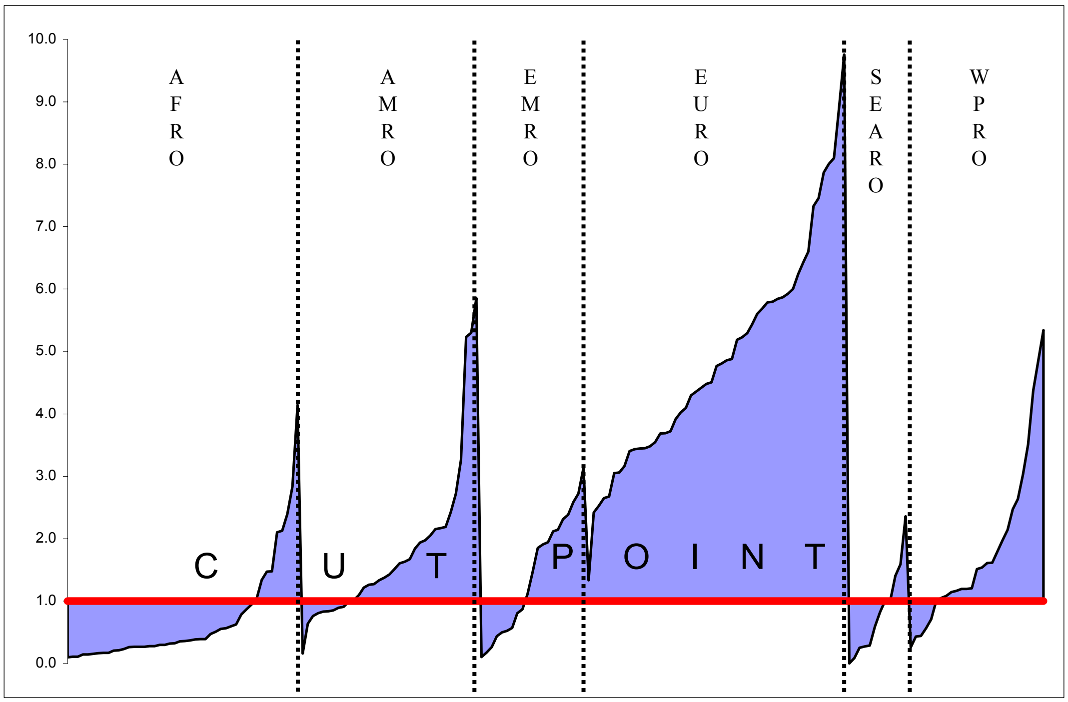
Figure 1. Association between worker density and coverage of deliveries with skilled birth attendants



Source: Authors` calculation based on WHO database.

Countries with fewer than 2.28 doctors, nurses and midwives combined per 1000 population were defined as deficit countries, and global shortages estimated as the difference between target and actual densities in those settings. This is depicted in Figure 2, where the vertical axis shows the ratio of the country's health worker density (per 1000 population) to the threshold of 2.28 described above. Countries below the horizontal line at 1, therefore, have shortages. It is clear that there are no shortages according to this definition in the European region of WHO, with the African Region being the area most in need (for a full discussion on inequality of distribution of human resources see Speybroeck et al., 2006).

Figure 2. Actual health worker density (per 1000 population) as a ratio of the HRH density associated with 80% coverage of skilled attendants (2.28 workers per 1000 population)



Source: Authors` calculation based on WHO database.

While this is useful in determining global shortages for advocacy purposes, for detailed country planning a more precise model can be developed. This involved extending Model I to include other possible determinants of coverage – in this case poverty, adult female literacy and GDP per capita, all transformed logarithmically. Model II in Table 3 presents the results of this analysis.

Income poverty is strongly associated with coverage, while GDP per capita is significant at the 5% level. This suggests that in very poor countries, with high poverty rates, it will be very difficult to increase coverage by increasing health worker numbers alone. Complementary steps to reduce poverty and increase overall income will also be required.

Effects of health workforce on vaccine coverage

Table 4 presents the relationship between coverage of measles vaccination and the number of health workers per 1000 population. Model I is for the density of doctors, nurses and midwives combined, while Model II separates the effects of doctors from nurses and midwives.

Table 4. Relationship between HRH and measles coverage

	Model I : Regression with aggregate HRH density			Model II: Regression with separate entries for doctors & nurses densities		
	Coef.	t	P>|t|	Coef.	t	P>|t|
GDP	0.0998	0.8400	0.4030	0.0796	0.6600	0.5110
Female Literacy	0.5590	2.1000	0.0370	0.5260	1.9500	0.0530
Land area	-0.0620	-1.9600	0.0510	0.0694	-2.1500	0.0330
Aggregate HRH density	0.4306	3.0400	0.0030			
Doctors density				0.2759	2.4500	0.0150
Nurses density				0.1298	0.9600	0.3360
Constant term	1.8227	1.82	0.071	2.5542	2.31	0.022
N			187			186
R-squared			0.3699			0.3755
F			26.71			21.65
Prob > F			< 0.0001			< 0.0001

Source: Authors` calculation based on WHO database.

Like Anand & Bärninghausen (2006), we find that the combined density of the three types of health workers has a strong and statistically significant relationship with measles coverage with coefficients (elasticities in the log–log model) close to those they reported. However, when the health workers density is disaggregated into doctors and nurses densities and entered separately into the equation, our results show the opposite effect to their findings: the density of doctors is significantly correlated (p=0.015) with measles coverage, while the density of nurses is not (p=0.336). Female literacy and land area are either significant (at the 0.05 level) or borderline significant in both models and are of the expected signs. Surprisingly, however, GDP per capita does not seem to have an independent effect on coverage, probably because immunization interventions in many poor countries receive substantial global support.

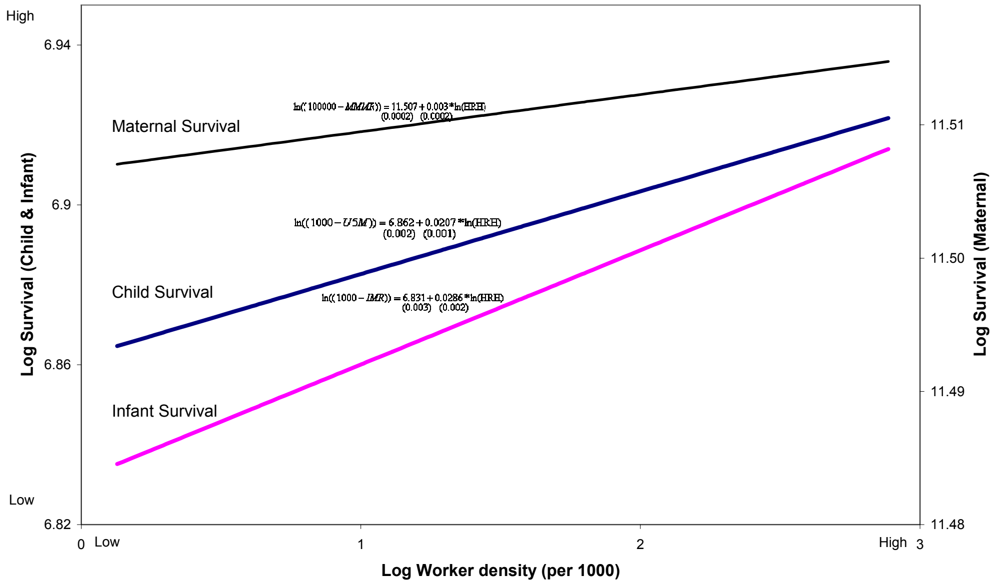
Effects of health workforce on health outcome

Figure 3 shows the univariate association between HRH and survival rates, the inverse of mortality rates, on a log scale. This graph updates the work of Chen et al. (2004). Not surprisingly, we also find that countries with higher aggregate densities of health workers (again, combined doctors, nurses and midwives) have better health outcomes.

The results estimated separately for maternal, infant and under-five mortality rates, after controlling for other determinants, are reported in Table 5. Here, for the sake of consistency, we follow the work of Anand & Bärninghausen (2004) who used mortality between the ages of 1 and 5 years, but described it as under-five mortality, although in strict sense the latter was supposed to be measured from birth to age 5.

Consistent with Anand & Bärninghausen (2004), total health worker density is negatively associated with maternal mortality rates, and estimated elasticities are very similar to the earlier estimates. However, in contrast to them, our coefficients of health worker density in the equations for infant and under-five mortality rates are not statistically significant.

Figure 3: Relationship between health worker density and health outcome



Source: Authors` calculation based on WHO database.

We also re-estimated the effects on health outcomes of doctor and nurse densities separately, as presented in Table 6. The results are similar: doctor density had a significant effect on all indicators of mortality, while the density of nurses had a significant independent effect only on maternal mortality. This latter effect remained even after controlling for income poverty, which was not the case in Anand & Bärninghausen (2004).

To explore these relationships further, we then included an interaction term between the density of nurses and doctors (see model VII–VIX). The hypothesis is that the marginal impact of doctors on health outcome will depend on the contribution of nurses, and vice versa. This interaction term proved to be statistically significant for maternal and infant mortality but not for under-five mortality.

Table 5. Multiple regression equations for infant, child and maternal mortality with human resources (aggregated) for health as independent variables

	Model I: Maternal mortality			Model II: Infant mortality			Model III: Under-five mortality		
Explanatory variables	Coef.	t	P>|t|	Coef.	t	P>|t|	Coef.	t	P>|t|
Panel A: Without poverty									
GDP	-0.6878	-8.4300	< 0.0001	-0.7178	12.9700	< 0.0001	-0.8917	12.1200	< 0.0001
Female literacy	-0.1852	-1.0900	0.2770	-0.1930	-1.5900	0.1140	-0.5672	-3.5100	0.0010
Aggregate HRH density	-0.5825	-6.2000	< 0.0001	-0.1175	-1.7800	0.0770	-0.1540	-1.7500	0.0810
Constant term	11.0794	16.9300	< 0.0001	9.3785	21.2400	< 0.0001	9.5529	16.2700	< 0.0001
N			168			191			191
R-squared			0.8195			0.7929			0.8011
F			248.21			238.65			251.01
Prob > F			< 0.0001			< 0.0001			< 0.0001
	Model IV: Maternal mortality with poverty			Model V: Infant mortality with poverty			Model VI: Under-five mortality with poverty		
	Coef.	t	P>|t|	Coef.	t	P>|t|	Coef.	t	P>|t|
Panel B: With poverty									
Income poverty	0.1106	3.2800	0.0010	0.0973	4.5300	< 0.0001	0.0660	2.2200	0.0270
GDP	-0.4314	-3.9400	< 0.0001	-0.4942	-6.8500	< 0.0001	-0.7375	-7.4000	< 0.0001
Female literacy	-0.2906	-1.7300	0.0860	-0.2908	-2.4700	0.0150	-0.6332	-3.8900	< 0.0001
Aggregate HRH density	-0.5719	-6.2300	< 0.0001	-0.1010	-1.6000	0.1120	-0.1447	-1.6500	0.1000
Constant term	9.2331	11.0400	< 0.0001	7.7704	14.1300	< 0.0001	8.4420	11.1000	< 0.0001
N			167			190			190
R-squared			0.8306			0.8125			0.8052
F			198.59			200.43			191.22
Prob > F			< 0.0001			< 0.0001			< 0.0001

Source: Authors` calculation based on WHO database.

Table 6. Multiple regression equations for infant, child and maternal mortality with densities of doctors and nurses separately as independent variables

	Model I: Maternal mortality			Model II: Infant mortality			Model III: Under-five mortality		
Explanatory variables	Coef.	t	P>|t|	Coef.	t	P>|t|	Coef.	t	P>|t|
Panel A: Without poverty									
GDP	-0.6405	-7.8900	< 0.0001	-0.6996	12.4100	< 0.0001	-0.8211	11.4600	< 0.0001
Female literacy	-0.0930	-0.5500	0.5850	-0.1633	-1.3300	0.1840	-0.4362	-2.8100	0.0060
Doctors density	-0.3333	-4.4600	< 0.0001	-0.0860	-1.6700	0.0970	-0.3100	-4.7300	< 0.0001
Nurses density	-0.2743	-3.1500	0.0020	-0.0464	-0.7500	0.4530	0.1042	1.3300	0.1850
Constant term	10.1549	14.5400	< 0.0001	9.1062	18.7800	< 0.0001	8.6297	14.0100	< 0.0001
N			167			190			190
R-squared			0.8288			0.7949			0.8200
F			196.13			179.23			210.67
Prob > F			< 0.0001			< 0.0001			< 0.0001
Panel B: With poverty									
Income poverty	0.1259	3.7900	< 0.0001	0.1019	4.7200	< 0.0001	0.0838	2.9500	0.0040
GDP	-0.3503	-3.2100	0.0020	-0.4616	-6.2800	< 0.0001	-0.6269	-6.4900	< 0.0001
Female literacy	-0.1918	-1.1600	0.2490	-0.2534	-2.1500	0.0330	-0.5088	-3.2900	0.0010
Doctors density	-0.3654	-4.9900	< 0.0001	-0.1075	-2.1700	0.0310	-0.3300	-5.0700	< 0.0001
Nurses density	-0.2287	-2.6600	0.0090	-0.0101	-0.1700	0.8650	0.1371	1.7500	0.0820
Constant term	8.0468	9.2400	< 0.0001	7.3783	12.5500	< 0.0001	7.2203	9.3400	< 0.0001
N			166			189			189
R-squared			0.8420			0.8160			0.8271
F			170.58			162.28			175.05
Prob > F			< 0.0001			< 0.0001			< 0.0001
Panel C: With poverty & Interaction									
Income poverty	0.0831	2.5300	0.0120	0.0846	3.8600	< 0.0001	0.0787	2.6700	0.0080
GDP	-0.4470	-4.2400	< 0.0001	-0.4957	-6.8100		-0.6370	-6.5000	< 0.0001
Female literacy	-0.3437	-2.1400	0.0340	-0.3604	-2.9900	0.0030	-0.5404	-3.3300	0.0010
Doctors density	-0.3395	-4.8900	< 0.0001	-0.0817	-1.6600	0.0990	-0.3224	-4.8700	< 0.0001
Nurses density	-0.2120	-2.6100	0.0100	-0.0100	-0.1700	0.8640	0.1372	1.7500	0.0820
Interaction between doctors &nurses	-0.1584	-4.4600	< 0.0001	-0.0758	-3.0200	0.0030	-0.0224	-0.6600	0.5090
Constant term	8.8513	10.5000	< 0.0001	7.6609	13.1400	< 0.0001	7.3036	9.3100	< 0.0001
N			166			189			189
R-squared			0.8596			0.8247			0.8275
F			162.29			142.73			145.5
Prob > F			< 0.0001			< 0.0001			< 0.0001

Source: Authors` calculation based on WHO database.

Conclusions and suggestions for future work

There is a statistically significant relationship between the aggregate density of health workers and coverage for both measles immunization and skilled birth attendants, even including a larger set of poor countries in the analysis. This remains true even when controlling for other possible determinants.

When health workers are divided into two groups – doctors and nurses/midwives – our results, however, differ from those of the earlier studies on measles immunization. We find that the coefficient of doctor density is significant, while that for nurses is not. This might be because Anand & Bärninghausen (2006) used DHS estimates of measles coverage, or because they did not take into account the possible clustering effect on their estimates, which were based on multiple observations from some countries. In addition, their data are largely dominated by low-income countries where the density of doctors is generally low, which might also have contributed to the non-significant effect of doctors in their analysis.

Using the same equations (logit–log form) as used in Anand & Bärninghausen (2006) for measles, we investigated the relationship between skilled birth attendants and health workers, controlling for GDP per capita, female literacy and land area (results not shown). We could show that health workers density, defined as the number of doctors, nurses and midwives per 1000 population has a strong and statistically significant effect on skilled birth attendance. We also estimated the effects on skilled birth attendance of doctor and nurse densities separately. Doctor density had only a borderline (p-value about 0.05) significant effect on all indicators, while the density of nurses had a strong ($p<0.001$) significant effect. These results are much clearer than the results for measles.

We also replicated Chen et al.'s (2004) work on health worker shortages. The simple regression of coverage with skilled birth attendants on health worker density suggested that countries with fewer than 2.28 health providers per 1000 population are unlikely to achieve the minimum target level of 80% coverage. But, as shown in the multivariate analyses, it is also important to note that some countries will find it extremely difficult to attain the desired coverage without complementary policies to reduce poverty and increase literacy.

Combined health worker density is also strongly associated with health outcomes. When health workers are disaggregated, the relationship between doctor density and the three outcomes is statistically significant, while we can find a statistically significant independent impact of nurses and midwives only on maternal mortality. In the other cases, nurses and midwives have a statistically significant impact, but only through their interaction with doctors.

One important qualification, however, should be made to this finding. As noted by Anand & Bärninghausen (2004), the insignificant effect of nurse and midwife density does not mean they do not matter. The variation in the duration of training, accreditation and classification rules across countries means that there is more heterogeneity in the measurement of nurses and midwives than for doctors. This measurement error could mask the true effect on health outcomes.

The models used to explore these relationships have not, to date, been particularly sophisticated. In particular, we feel that separating the direct inputs to the production of health from the factors likely to mediate their ability to do their jobs efficiently is a possible area for further development. A frontier production function of this nature is used to explain variations in coverage and health outcomes across sub-national units in Brazil and Viet Nam, and feel that this is likely to be a fruitful avenue for further work (Prasad A. et al., 2006; Sousa A. et al., 2006).

We also feel that the interaction between the different types of health workers is something that should be explored more in the future; doctors do not work in isolation from other types of health

workers and how the presence of one type of worker complements other types is something for future analysis. Future research should also endeavour to include additional explanatory variables such as the spatial distribution of populations, levels of health expenditure for particular activities and access to external resources for such activities from multilateral and bilateral sources.

On the other hand, from a technical point of view, it is also possible that alternative approaches such as regression trees and path analysis could prove fruitful (Breiman, 1974; Wermuth, 1980). They could provide new insights into the mechanisms behind the different responses to increasing health worker density. These will be the focus of subsequent analysis.

References

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Annex A: Sources of the variables used in this paper

Under five mortality rate	2003 Estimates, World Health Report 2005
Infant mortality rate	2003 Estimates, World Health Report 2005
Maternal mortality ratio	World Health Report 2005 http://www.who.int/whr/2005/annex/annex8.xls
Measles coverage (%)	UNICEF Statistics http://www.childinfo.org/areas/immunization/database.php
Skilled birth attendance	UNICEF Global Database on Skilled Attendant at Delivery - Mar/2005 http://www.childinfo.org/areas/deliverycare/countrydata.php
	WHO - Reproductive-Health - Publications - MSM_96_28 http://www.who.int/reproductive-health/publications/MSM_96_28/msm_96_28_table4.html
GDP, cap, Int$	http://www.who.int/nha/country/en/
Poverty	Internal WHO calculations
Female Literacy	UNESCO Institute for Statistics (UIS) - May 2005 www.uis.unesco.org/ev.php?URL_ID=5204&URL_DO=DO_TOPIC&URL_SECTION=201
	CIA - The World Factbook 2005 http://www.cia.gov/cia/publications/factbook/fields/2103.html
	UNDP - Human Development Report 2004 http://hdr.undp.org/statistics/data/indic/indic_221_1_1.html
	WHO Database http://www.wpro.who.int/NR/rdonlyres/E7D36199-99E9-4969-A471-98FDBC025E4A/0/20_stat_annex.pdf
Total health expenditure	http://www.who.int/nha/country/en/