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Forecasting the global shortage of physicians: an economic- and needs-based approach

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Introduction

The world health report 2006: working together for health has brought renewed attention to the global human resources required to produce health.[1] It estimated that 57 countries have an absolute shortage of 2.3 million physicians, nurses and midwives. These shortages suggest that many countries have insufficient numbers of health professionals to deliver essential health interventions, such as skilled attendance at birth and immunization programmes. However, these estimates do not take into account the ability of countries to recruit and retain these workers, nor are they specific enough to inform policy-makers about how, and to what extent, health workforce investment should be channelled into training of different professions.

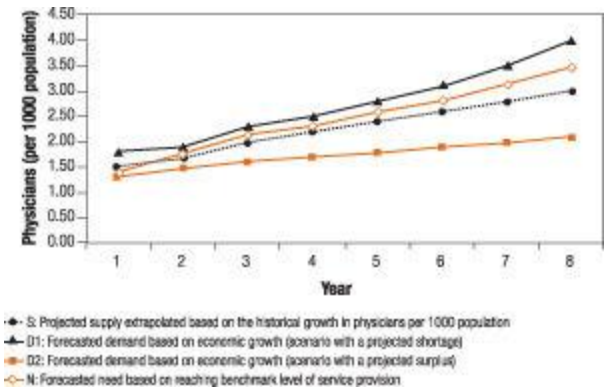
This paper focuses on physicians, who serve a key role in health-care provision. Using the most updated information on the supply of physicians over a 20-year period, we project the size of the future global need for, demand for and supply of physicians to year 2015, the target date for the Millennium Development Goals (MDGs).[2] Needs-based estimates use an exogenous health benchmark to judge the adequacy of the number of physicians required to meet MDG targets. Demand estimates are based on a country's economic growth and the increase in health-care spending that results from it, which primarily goes towards worker salaries. We then compare the needs-based and demand-based estimates to the projected supply of physicians, extrapolated based on historical trends. Our results point to dramatic shortages of physicians in the WHO African Region by 2015. We provide estimates of shortages by country in Africa and discuss their implications for different workforce policy choices.

Methods

For illustrative purposes, we provide a stylized version of the conceptual framework we employed for forecasting physician numbers in Fig. 1. First, we project the supply in the per capita number of physicians (S) based on historical data on physician numbers for each country; this serves as a baseline against which different forecasts can be evaluated. We employ two forecasting methods. The forecast for the needs-based estimate (N) is determined by calculating the number of physicians that would be required to reach *The world health report 2006* goal of having 80% of live births attended by a skilled health worker.[3] The second

forecasting method reflects the demand for physicians in each country as determined by economic growth (*D*1 and *D*2). With these different estimates, shortages or surpluses can be calculated. For example, by year 8, about 3.5 physicians per 1000 population will be needed compared to the projected supply of 3.0 per 1000, producing a 0.5 per 1000 shortage. In comparison, 4.0 per 1000 will be demanded according to the scenario represented by *D*1, resulting in a demand-based shortage of about 1.0 physicians per 1000. A different scenario can arise if supply exceeds demand, as represented by *D*2, resulting in a surplus. We can then multiply this estimated shortage by projected population numbers to calculate the absolute deficit of the numbers of physicians. In this illustrative case, the needs-based shortage exceeds the demand-based shortage. This framework can be applied at the country, regional and global levels of analyses, depending on the level of aggregation of physician numbers.

Fig. 1. Conceptual forecasting framework



We now describe our estimation procedures more formally. First, baseline supply projections to the year 2015 were estimated using the historical growth rate of physician densities in each country. The following regression equation was run for each country for time t = {1980, … , 2001}:

$$\ln(\text{physicians per 1000 population}_t) = \alpha_0 + \alpha_1 \times \text{year}_t + \varepsilon_t$$

where ε_t is the random disturbance term, and α_0 and α_1 are unknown parameters to be estimated from the model. This exponential growth model assumes that current trends in the growth of physician numbers will continue as they have historically for each country.

The needs-based approach is based on an $\sin^{-1}$-log model that relates physician density with coverage of skilled birth attendants, weighted by population size. This model is used to identify a level of physician density below which virtually no country has achieved 80% coverage. While physicians may not necessarily be the same workers who attend live births, we can determine the overall required number of health-care workers to achieve the goal and thus gauge the subset number of physicians needed to maintain the desired level of service coverage. This approach assumes that skills mix in health service delivery remains constant. The needs-based model estimates the following equation for all countries *i* at time *t*:

$\sin^{-1}(\%\ \text{coverage}_{it}) = \beta_0 + \beta_1 \times \ln(\text{physicians per 1000 population}_{it}) + \mu_i + \eta_t + \delta_{it}$

where μ_i and η_t reflect country and time fixed effects, respectively, δ_{it} is a random error term, and β_0 and β_1 are unknown parameters to be estimated from the model. This threshold density figure, along with population estimates for future years, was subsequently used to calculate the number of physicians that would be needed in each country to attain the MDG of 80% coverage of live births. We opted for the $\sin^{-1}$ transformation because it is more consistent with statistical theory; the transformation of the dependent variable, which is a proportion, results in normally distributed responses (asymptotically). The $\sin^{-1}$-log model also achieved the highest R^2 and best goodness-of-fit to the data as measured by the deviance.[4] This approach is similar to that followed in *The world health report 2006*.

The demand-based approach utilizes gross national income (GNI) per capita as the predictor of demand for physicians per 1000 population, along with country fixed effects to account for unobservable heterogeneity across countries, weighted by population size. Previous research has shown that indicators of gross domestic product or national income are the best predictors of health expenditures, of which, labour is the principle component.[5–9] This method has also been employed in other forecasts of physician demand.[10] This approach estimates the following relationship for country i at time t:

$\ln(\text{physicians per 1000 population}_{it}) = \gamma_0 + \gamma_1 \times \ln(\text{GNI per capita}_{it-5}) + \gamma_2 \times \text{income level}_i + \mu_i + \zeta_{it}$

where μ_i reflects a vector of country fixed effects, ζ_{it} is the disturbance term, and γ_0 and γ_1 are unknown parameters to be estimated from the model. GNI per capita is lagged 5 years to account for time required for economic growth to affect health-care spending and, in turn, influence changes in the health-care system and the workforce. Because GNI data were only available until 2002 at the time of data assembly, values for 2003–2010 were predicted using the historical growth rate. For each country at time t, the growth rate in GNI per capita was calculated as:

$\exp(\lambda_1) - 1$

from the equation:

$\ln(\text{GNI per capita}_t) = \lambda_0 + \lambda_1 \times \text{year}_t + \nu_t$

where ν_t is the disturbance term, and λ_0 and λ_1 are unknown parameters to be estimated from the model. Classification of countries by income level (low, medium and high) from the World Bank was included in the demand equation as countries at different levels of development may exhibit stronger or weaker relationships between economic growth and health-care spending, depending on the complexities of the health-care system and structure of local markets.

Data

Data were compiled from several sources. The World Bank *Health, nutrition and population database* contains physician numbers from 1980 to 2001.[11] GNI per capita (adjusted for purchasing power parity using the atlas method) for 1975–2002 was obtained from the *World development indicators database*.[12] Physician numbers were updated with the most recent figures from the *World health statistics 2006* database and from the *OECD health data 2005* database for OECD countries.[13,14] Historic and projected population numbers were obtained from the United Nations Population Division.[15] We employ physician density (per 1000 population) in our analyses to account for differences in health-system size and weight all regressions by population size. Our benchmark indicator for need is the number of live births attended by a skilled health worker, also available from *World health statistics 2006*. We constructed a panel of 158 countries from 1980 to 2001, grouped according to WHO regional classifications (available at: http://www.who.int/about/regions).

Data were missing for some countries, either due to unavailability or differences in reporting practices. Missing data points occurring between two data points were linearly interpolated; those that were not bounded by two real data points were not interpolated. For figures on physicians per capita, missing data for up to 6 consecutive years were interpolated as some countries only reported periodically in the 22-year span of our data compilation; interpolated values comprise 35.6% of the 2819 data points for physician supply numbers used in this analysis. Because GNI per capita data are more readily available, only 4.7% of the 4238 GNI per capita data points used were interpolated. This method of treating missing data points raises concern over the robustness of our estimation results. To address this, we systematically drop countries from our sample for which the number of data points for physicians per capita are fewer than six (24 countries), fewer than seven (41 countries), and fewer than eight (63 countries). Estimated coefficients from these subsamples may differ from the main sample due to the fact that data reporting issues are more frequently encountered for lower-income countries. We carry out formal *F* tests of our economic demand model on these different subsamples in our robustness checks.

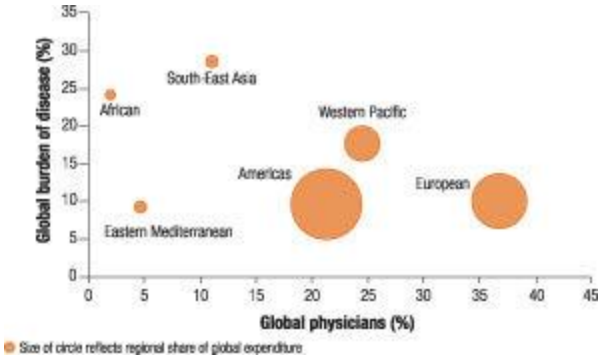
Results

Current distribution

We first describe the current distribution of physicians by level of health expenditures and burden of disease, displayed in Fig. 2. The size of the circle represents the proportion of world health expenditures comprised of the countries in a given region. In 2004, the WHO Americas Region registered the highest proportion of the world's health expenditures (over 50%), but had just over 20% of the world's supply of physicians, and only 10% of the global burden of disease. With a similar level of burden of disease, the WHO European Region has over 35% of the world's supply of physicians along with about 32% of the world's health expenditures. In contrast, countries in the WHO South-East Asia Region suffer the highest proportion of the global burden of disease (29%) with only 11% of the world's supply of physicians and just about 1% of world health expenditures. Similarly, the WHO African Region experiences 24% of the global burden of disease, while having only 2% of the global physician supply and spending that is less than 1% of global expenditures. Clearly,

there is a dramatic imbalance in the global distribution of physicians, with countries in the WHO African and South-East Asia Regions currently facing the largest disparities.

Fig. 2. Physician distribution by burden of disease and health expenditure, by WHO region, 2004

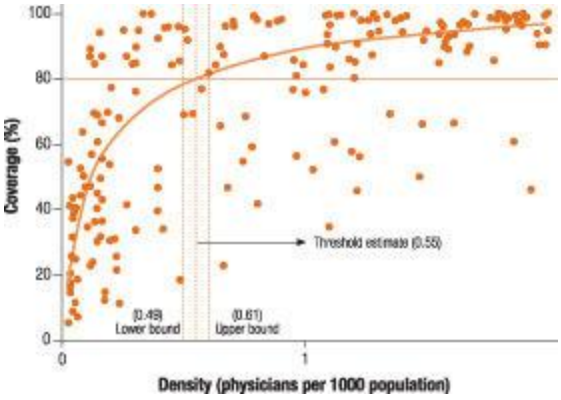


Source: World health statistics 2006. [13]

Forecasting results

The results of our analysis of the future global distribution of physicians are shown in Table 1. If current trends continue, we will have 12.7 million physicians supplied by 2015 globally. Given the standard error of our estimated growth rates of physicians for each country, this supply number can range from 11.4 million to 14.3 million (95% confidence interval). Our needs-based model projects the ratio of physicians required to achieve 80% coverage of live births by a skilled attendant to be 0.55 per 1000 population, ranging from 0.41 to 0.61 based on a 95% confidence interval (regression results in Table 2 and Fig. 3, available at: http://www.who.int/bulletin/volumes/86/7/07-046474/en/index.html). Note that this criterion of need reflects a relatively low level of health-service provision that is already met in many middle- and high-income countries. Consequently, this needs-based approach estimates that the global required number of physicians to achieve 80% coverage is about 3.8 million, ranging from 3.4 million to 4.2 million. This implies that there will be many more physicians in 2015 than are needed to reach the benchmark outcome. However, the issue of equitable workforce distribution remains. Even though the global supply of physicians exceeds that of the “need”, the WHO African Region is likely to experience a shortage of physicians (about 167 000 in 2015) according to the needs-based approach.

Fig. 3. Needs-based estimate of the number of physicians per capita required to achieve 80% coverage of live births by a skilled attendant



In contrast, based on projected GNI growth, there will be a global demand for about 10.8 million physicians by 2015 (regression results in Table 2). However, when we account for the 95% confidence interval, our demand-based global estimates of the number of physicians suggest a balance with the projected supply of physicians in 2015. Furthermore, countries in the WHO African, Americas and the Eastern Mediterranean Regions will likely experience surpluses of physicians of 111 000, 888 000 and 557 000 respectively in 2015. Such a projected surplus in excess of projected demand indicates that future economic growth based on the historical growth rate since 1975 may not sufficiently increase health expenditures in these areas to retain newly trained physicians. This has important implications for out-migration from shortage areas, as physicians may be attracted to areas with higher demand and higher salaries.

We further investigate whether the inclusion of countries with more missing data, and thus relatively more interpolated observations, affects the regression coefficients. We systematically drop countries with fewer than six, seven and eight actual data points from our full sample and re-ran our demand regression equation. In all cases, the coefficient for the elasticity of physicians per capita with respect to lagged GNI for the omitted category (high-income countries) is significant, does not appreciably vary across different subsamples and is precisely estimated. However, coefficients on dummy variables for middle- and low-income countries do differ across subsamples, reflecting the fact that missing data are more likely to occur for these countries. Nevertheless, all coefficients on these dummy variables are negative and significant, consistently indicating that the elasticity of physicians per capita is less sensitive to GNI per capita in middle- and low-income countries than it is in higher-income countries. Results of *F* tests comparing the full-sample specification to each of the restricted subsamples fail to reject the null hypothesis of no difference.

Table 3 compares the number of countries that are projected to experience shortages in 2015 from the needs- and demand-based models. We define a country as having a shortage if the projected supply of physicians meets less than 80% of the projected demand or need. Overall, we find that 45 countries will have a shortage in 2015 according to the needs-based approach, the overwhelming majority of which are located in the WHO African Region. According to the demand-based model, 37 countries are likely to experience a shortage in 2015; 15 of these countries are located in the WHO African Region, 10 in the WHO

Eastern Mediterranean Region, and 7 in the WHO Western Pacific Region. These results for the world are graphically displayed in Fig. 4. Countries that are projected to experience demand-based shortages are also countries that will likely experience strong economic growth in the near future. For example, the demand for physicians will increase dramatically in China if the rapid economic growth experienced in recent history continues into the near future. Other countries, such as Indonesia, are projected to experience a needs-based shortage only, suggesting that even though their economies may grow strongly enough to support the supply of physicians, the overall workforce number will not be adequate to meet the needs-based benchmark of 80% of live births covered by a skilled attendant.

Fig. 4. Physician shortages in 2015 based on demand and need models

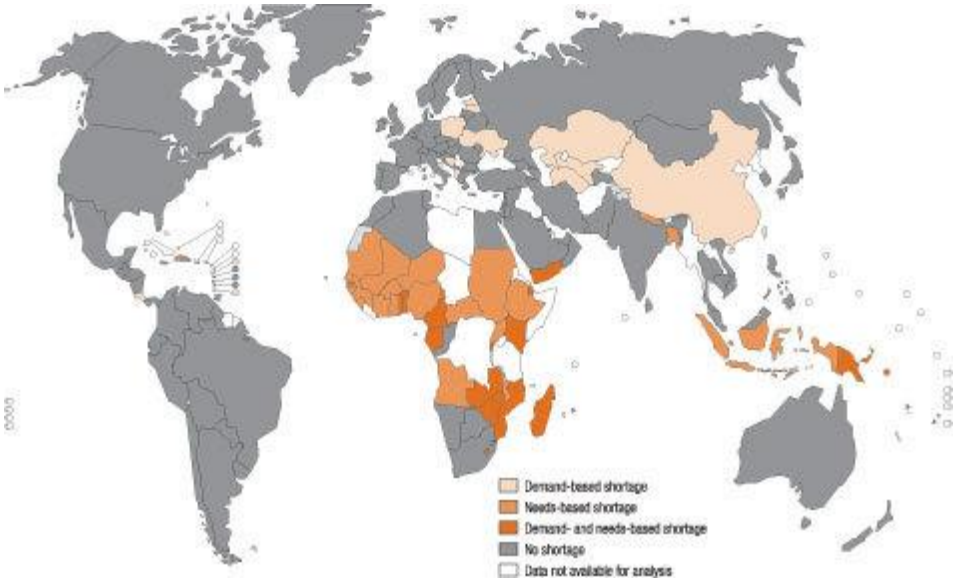


Table 1. Projected supply of, need for and demand for physicians, by WHO region, 2015
html, 7kb

Table 2. Ordinary least squares regression results of needs-based and demand-based models[a]
html, 4kb

Table 3. Number of countries with physician shortages[a] in 2015
html, 2kb

Results for Africa

In the WHO African Region, some countries will have both a needs-based and demand-based shortage. This indicates that, even though there is a critical need for more physicians, and projected economic growth will demand a larger physician workforce, the projected supply of physicians will not increase sufficiently by 2015 to achieve balance. These countries do not have the required capacity to train the numbers that will be demanded by 2015, and will likely need to depend on newly recruited workers from abroad, possibly from neighbouring countries with poor economic performance. Table 4 (available at: http://www.who.int/bulletin/volumes/86/6/07-046474/en/index.html) displays the projected need for, demand for and supply of physicians in the year 2015 for all African countries included in our analysis. For

example, Kenya will need 24 000 physicians on average in 2015 (a shortage of about 18 000 physicians) and the economy will be strong enough to demand 7600 physicians on average, but the supply in Kenya is only projected to reach an average of 6100 physicians. Algeria, on the other hand, will have an ample supply of 97 000 physicians, a surplus of almost 77 000 physicians beyond what is needed and a surplus of 67 000 physicians beyond what will be demanded. In Ethiopia, we see another scenario where 53 000 physicians will be needed by 2015, but the economy will only demand about 3000 physicians, even though the supply of physicians is projected to reach about 5000. These scenarios suggest that future migration of physicians could take an increasingly regional dimension.

Table 4. Projected supply of, need for and demand for physicians in 2015 for countries in the WHO African Region
html, 14kb

Discussion

Our projections suggest that, by the year 2015, the global supply of physicians will be roughly in balance with demand, while a significant surplus will arise according to the needs-based model. However, regional trends show that distributional problems will likely persist. More than any other region of the world, Africa will likely experience most of the physician shortages in 2015. Given the disproportionate burden of disease in this region, policies for increasing the supply of physicians are urgently needed to stem projected shortages. According to our needs-based target of 80% coverage of live births by a skilled attendant, a 65% increase in the physician supply in the WHO African Region will be required compared to an increase of 44% of physicians to equilibrate demand with supply. These enormous increases will require significant increases in health-care spending and active policy intervention.

Policy implications

The type of policy intervention pursued will depend on the type of shortage likely to be experienced. Given the difficulty of redistributing physicians across country borders, countries that may face only a needs-based shortage may want to consider expanding medical training programmes. For countries that face a demand-based shortage only, out-migration may be a particular concern, suggesting policies geared towards retention. Countries that face both demand-based and needs-based shortages may prefer a mixture of training and recruitment policies. Government and donor organizations should consider increasing financial support of health-care workers as a means of improving recruitment and retention.

The exact nature and extent of any policy intervention adopted will depend crucially on the characteristics of each country's health-care system and institutions. While this analysis provides a direction for where policies should be targeted, such cross-country comparisons cannot fully account for these complexities as well as other aspects of distribution (e.g. physician specialty, race/ethnicity), practice styles (e.g. work hours) and trends in the demographic characteristics of the workforce supply (e.g. ageing, gender mix), which have also been found to have important effects on health-care service delivery and access.[16–18] Moreover,

health-worker mix is another critical factor in health-services production; further work is required in the area of predicting the future numbers of nurses, midwives and other ancillary health-care workers who will be needed and demanded. As the WHO report shows, nurses and other health workers can help to make the clinical work more productive, particularly in certain patient-care services where there are skill overlaps.[19] The use of telemedicine may also have merit as a cost-effective workforce model.[20,21] Limited resources clearly point to merits of these approaches.

Limitations and future directions

While we have sought to provide some indication of the numbers of physicians that will likely be required in the future, some caution is warranted in interpreting these figures. First, our criterion of need only reflects one aspect of health-care delivery; thus different numbers of physicians will be required to meet alternative normative criteria for health services. Second, our projections of demand and supply both rely on trends in either economic growth or physicians per capita, each of which are continually being affected by policy intervention. Comparable cross-country data along these dimensions are currently unavailable and consequently cannot be fully accounted for in this type of forecasting. Moreover, projections of demand will also likely be affected by other factors other than economic growth, suggesting directions for further work in refining such demand models. Given these limitations, we nevertheless believe that this exercise has been useful and informative for providing an overall sense of where physician workforce policies should be undertaken. ■

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