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"CONDITIONAL SCHOLARSHIPS" FOR HIV/AIDS HEALTH WORKERS: EDUCATING AND RETAINING THE WORKFORCE TO PROVIDE ANTIRETROVIRAL TREATMENT IN SUB-SAHARAN AFRICA

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ABSTRACT

Without large increases in the number of health workers to treat HIV/AIDS (HAHW), most developing countries will be unable to achieve universal coverage with antiretroviral treatment (ART), leading to large numbers of potentially avoidable deaths among people living with HIV/AIDS. We use Markov Monte Carlo microsimulation to estimate the expected net present value (eNPV) of a scholarship for health care education that is conditional on the recipient entering into a contract to work for a number of years after graduation delivering ART in sub-Saharan Africa. Such a scholarship could increase the number of health workers educated in the region and decrease the probability of HAHW emigration. "Conditional scholarships" for a team of health workers sufficient to provide ART for 500 patients have an eNPV of 1.23 million year-2000 US dollars, assuming that the scholarship recipients are in addition to the health workers who would have been educated without scholarships and that the scholarships reduce annual HAHW emigration probabilities from 15% to 5% for five years. When individual variable values are varied from this base case within plausible bounds suggested by the literature, eNPV of the "conditional scholarships" never falls below 0.5 million year-2000 US dollars.

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Introduction

Global epidemiology of HIV and HIV/AIDS health worker need

According to the Joint United Nations Programme on HIV/AIDS (UNAIDS) and the World Health Organization (WHO), in 2006 about 40 million people worldwide were HIV-positive, 37 million of whom lived in developing countries (UNAIDS/WHO, 2006). Sub-Saharan Africa bears the brunt of the HIV epidemic with 25 million HIV-positive people as of 2006, followed by South-East Asia with 7.8 million HIV-positive people. The number of people living with HIV continues to grow. From 2004 to 2006 the global total increased by 2.6 million (UNAIDS/WHO, 2006), despite substantial mortality from HIV/AIDS. In sub-Saharan Africa alone, 2.1 million people died of AIDS in 2006 (UNAIDS/WHO, 2006).

The number of people in developing countries who receive antiretroviral treatment (ART) has grown rapidly in the last three years – in sub-Saharan Africa, from less than 300,000 by the end of 2004 to more than 800,000 by the end of 2005 (WHO/UNAIDS, 2006b) and to more than 1 million by the end of 2006 (UNAIDS/WHO, 2006). Yet current ART coverage falls far short of need. In 2006, an estimated 4.6 million people in sub-Saharan Africa needed ART, more than four times the number of people on treatment (WHO/UNAIDS, 2006a). According to WHO/UNAIDS, in 2006 only 8 out of 92 developing countries for which data on ART coverage were available achieved coverage of 80% or higher (Figure 1) (UNAIDS/WHO, 2007).

< Figure 1 about here >

The unmet need for ART means the loss of many lives that could have been saved. It is well known that ART is effective in reducing HIV-related mortality (Hogg, Yip, Kully, Craib, O'Shaughnessy, Schechter et al., 1999). Recent evidence from Botswana (The Global Fund, 2007) and South Africa (Herbst, Cooke, Bärnighausen, KanyKany, & Newell, 2007) suggests that, even while a large proportion of people who currently need ART are not yet receiving treatment, the reduction in mortality among those who do receive ART has led to an overall decline in mortality among people living with HIV.

One of the main constraints in scaling up ART is human resources (Clark, 2006; Habte, Dussault, & Dovlo, 2004; Hosseinipour, Kazembe, Sanne, & van der Horst, 2002; Kober & Van Damme, 2004; Ooms, Van Damme, & Temmerman, 2007). A number of recent reports and international initiatives, such as the Commission for Africa (Commission for Africa, 2005; MSF, 2007a), the Institute of Medicine (IOM)'s 2007 evaluation of the President's Emergency Plan for AIDS Relief (PEPFAR) (IOM, 2007), the 2004 report on human resources by the Joint Learning Initiative (JLI) (JLI, 2004b), the 2006 *World Health Report* (WHO, 2006) and a 2007 report by Médecins sans frontièrs (MSF) (MSF, 2007a) have identified the shortage of health workers in developing countries as one of the main impediments to human development in general and access to ART specifically. The report of the Commission for Africa estimates that Africa's health workforce needs to be tripled over the coming decade in order to achieve human development goals (Commission for Africa, 2005). The 2007 IOM report states that "[s]evere human resource shortages are a continuing challenge to PEPFAR implementation" and proposes a shift in PEPFAR's involvement in national human resources strategies (IOM, 2007; The Lancet, 2007). IOM recommends that PEPFAR should not limit its activities to the provision of AIDS care-specific training to existing health workers and the promotion of task shifting between different types of health workers, but should actively work to increase national health workforces.

There are two main reasons for the shortage of health workers to treat HIV/AIDS (HAHW) in the developing world (JLI, 2004b; MSF, 2007a; USAID Bureau for Africa, 2003; WHO, 2006). First, education rates in many developing countries are too low to produce the number of health workers needed to deliver ART. In 2006, only 66 of the worldwide 1,691 medical schools and only 288 of the worldwide 5,492 nursing and midwifery schools were located in Africa (WHO, 2006). The United Republic of Tanzania is a case in point. In 2002, about 740 doctors were available to care for Tanzania's population of about 37 million people. We estimate that Tanzania would need between 229 and 458 additional doctors to be able to provide universal ART coverage (see Table 1a in the appendix). However, each year only about 90 doctors graduate from a medical school in Tanzania (JLI, 2004b).

Second, of the small numbers of health workers educated in developing countries, especially in Africa, large proportions tend to emigrate. It has been estimated that 20,000 health workers migrate each year from Africa to developed countries (WHO, 2004). According to the 2005 *Report of the Global Commission on International Migration (GCIM)*, 16,000 African nurses migrated to the UK alone between 2000 and 2005 (GCIM, 2005). A 2002 WHO survey of health workers in six sub-Saharan countries found that between 38% and 68% intended to emigrate (WHO, 2003).

Countries where the need to expand ART is high commonly have low numbers of health workers per capita. Figure 2 shows scatter plots of national HIV prevalence (UNAIDS/WHO, 2007; World Bank, 2007) against health worker densities (WHO, 2007c). Countries with higher HIV prevalence tend to have lower physician, nurse, and pharmacist densities than countries with lower prevalence (Figure 2, panels 1-3).

< Figure 2 about here >

The low health worker densities indicate that many developing countries must considerably increase their health workforce in order to be able provide ART to all people who currently need it. Table 1a in the appendix shows estimates of the numbers of additional doctors, nurses, and pharmacists that would have been needed in 88 developing countries to provide universal coverage with ART in December 2006 (UNAIDS/WHO, 2007).[1] These estimates assume that all added health workers would spend all of their work time providing ART – i.e. these estimates are the lower bounds of actual need. In our calculations, we use numbers of doctors, nurses, and pharmacists needed to provide ART per 1,000 patients from a recent review of ART programs in developing countries (Hirschhorn, Oguda, Fullem, Dreesch, & Wilson, 2006). We find that in order to treat the approximately 3.6 million people in sub-Saharan Africa who in December 2006 needed ART, but did not receive it, the stock of health workers in sub-Saharan Africa would have had to be increased by 3,600 to 7,200 doctors, 7,200 to 25,200 nurses, and 3,600 to 10,800 pharmacists.

The number of future health workers needed to achieve universal ART coverage depends on the development of the epidemic. Projections of the number of people living with HIV diverge considerably because both HIV incidence and mortality among HIV-positive people are determined by factors whose development over time is highly uncertain (Grassly, Morgan, Walker, Garnett, Stanecki, Stover et al., 2004; Mathers & Loncar, 2006). On the one hand, HIV incidence is a function of sexual behavior, which can change significantly over the course of a few years, e.g. as observed in Uganda (Hallett, Aberle-Grasse, Bello, Boulos, Cayemittes, Cheluget et al., 2006) and Thailand (Saengdidtha,

[1] The 88 developing countries are all developing countries for which data on ART need and ART coverage are available from UNAIDS/WHO (2007) (UNAIDS/WHO, 2007).

Lapparat, Torugsa, Suppadit, & Wakai, 2002) following successful national campaigns to reduce the spread of HIV. On the other hand, mortality among HIV-positive people depends *inter alia* on the speed of expansion of access to ART, people's ability to adhere to ART over their lifetimes, and technical advances that increase the effectiveness of ART. Moreover, general human and economic development is likely to influence both the spread of HIV and HIV-related mortality (Broughton, 1999).

In a UNAIDS scenario analysis for Africa, estimates of the total number of new HIV infections in adults and children that will occur between 2003 and 2025 range from 46 million in the best-case scenario to 89 million in the worst-case scenario, while estimates of total deaths from AIDS between 1980 and 2025 range from 67 to 83 million (UNAIDS, 2005). Another study suggests that HIV prevalence (and thus in the long run treatment need) may either significantly increase or decline in sub-Saharan Africa by the year 2020, depending on the success of future HIV prevention and treatment efforts (Salomon, Hogan, Stover, Stanecki, Walker, Ghys et al., 2005). However, the study finds that even in the best-case scenario, the number of people in need of ART in sub-Saharan Africa would decline only slightly by 2020 in comparison to 2006 (to 4.2 million), while it would double if the worst-case scenario came true (to 9.2 million) (Salomon et al., 2005). In the latter case, universal ART coverage could only be achieved if sub-Saharan countries were able to increase their human resources for health over 2006 numbers by 8,200 to 16,400 doctors, 16,400 to 57,400 nurses, and 8,200 to 24,600 pharmacists.

"Conditional scholarships"

Table 2a in the appendix provides an overview of interventions that have been implemented or proposed to address health worker shortages in developing countries. We focus here on one particular intervention: scholarships for health care education given to qualified candidates conditional on their entering into a contract to work for a number of years after graduation delivering ART in a sub-Saharan African country. Such "conditional scholarships" could have two effects on national health workforces in the region. First, the "scholarship" could increase the number of health workers educated in the country by enabling the health care education of secondary school graduates who would otherwise not have the means to finance such an education. Second, the "condition" could increase the retention of recently graduated health workers in the country. As such, the "conditional scholarships" could address the two main factors contributing to a shortage of health workers in many developing countries: a low rate of health worker education and a high rate of health worker emigration (JLI, 2004b).

For "conditional scholarships" to work at least one of the following two assumptions must be true. First, there are qualified candidates in developing countries who desire a health care education but cannot obtain financing for such studies because of market imperfections in the supply of loans for education (Barr, 2004). There is evidence that secondary school graduates in developing countries do indeed forego a health care education because of financial constraints (Colborn, 1991, 1992; Frey & Frey, 1995; IRIN Humanitarian News and Analysis, 2006). Candidates may lack the financial means to pay for different components of a health care education: tuition and fees, living expenses while attending school, or the cost of required learning materials, such as books or medical equipment. Second, there are qualified candidates in developing countries who desire a health care education and do have access to sources of finance for such an education (e.g. loans from the extended family or access to bank loans) but find the "conditional scholarship" the most attractive amongst all available funding options. For instance, students may prefer a "conditional scholarship" to a bank loan. Unlike "conditional scholarships", which students receive in exchange for a commitment to work in a national ART program, bank loans carry the risk of bankruptcy because the borrower may not be able to meet future interest or redemption payments.

In the following we will first investigate whether the "conditional scholarships" would be socially worthwhile investments by estimating their expected social net present value (eNPV). In order to understand the specific contribution of each of the two possible effects of the "conditional scholarships" on scholarship eNPV, we will separately examine three types of scenarios: first, the only effect of the scholarships is to increase HAHW education rates; second, the scholarships increase HAHW education rates and decrease HAHW emigration rates; third, the only effect of the scholarships is to decrease HAHW emigration rates. We will then discuss choices countries would need to make if they decided to implement "conditional scholarships". These include the source of finance, selection of candidates, specification of the condition, enforcement mechanisms, and supporting interventions.

Methods

Model description

In order to calculate eNPV of the "conditional scholarships", we use a Markov Monte Carlo microsimulation.[2] Markov models are well suited for the question at hand because they allow different states of HAHW effectiveness with different costs and benefits at different times, and can easily incorporate discounting to calculate present values of future states. Markov models capture uncertainty as transition probabilities between different states (Hunink, Glasziou, Siegel, Weeks, Pliskin, Elstein et al., 2001). Microsimulation as one method to evaluate a Markov model has the advantage over the alternative cohort simulation that it yields an approximate distribution of NPV in addition to its expected value, eNPV,

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[2] Markov models divide a target population (here: of health worker teams) into a series of mutually exclusive states (here: of health worker effectiveness). Transitions between these health states are assigned probabilities and the model's predictions are evaluated over a series of cycles (Sonnenberg & Beck, 1993).

thus enabling assessment of uncertainty in the calculations due to individual heterogeneity (Weinstein, 2006).[3]

In providing ART, health workers reduce mortality among HIV-positive people and induce costs (salaries and costs of drugs). Both HAHW effectiveness and costs depend on the type of ART that they provide to their patients. First-line therapy in the first year of treatment is less effective than first- or second-line therapy in later years; second-line therapy is more expensive than first-line therapy. To capture these differences, we distinguish between the following mutually exclusive HAHW states in our Markov model: first-line ART in the first year of treatment (ART1); first-line ART in the second or a later year of treatment (ART2); second-line ART (ART3); and an absorbing state (Exit) which HAHW enter if they die or leave their assigned posts before completion of the service commitment. The unit of our analyses is a "minimum team" of health workers, consisting of nurses, treatment counselors, doctors, and pharmacists. We define a minimum team as the team with the smallest number of members in which none of the four categories of HAHW has less than one member. We fix the ratio of nurses to treatment counselors to doctors to pharmacists at 3:10:1:1 based on

[3] Markov models can be evaluated deterministically by cohort simulation or stochastically by Monte Carlo microsimulation. In cohort simulation, large cohorts of people are sent through the model simultaneously. The initial distribution of people in different Markov states and the transition probabilities between the states completely determine how many people are in each state after each cycle. In contrast, in microsimulation individuals are simulated moving between states from cycle to cycle one at a time. The transition probabilities in this case are realized as random events, so that different microsimulations with equal numbers of individuals are unlikely to yield exactly the same result. However, if a large number of individuals are simulated in microsimulation, the results from different microsimulations will be approximately the same and will closely approximate the result of the cohort simulation.

a 2006 review of staffing patterns at ART sites in Africa and Asia (Hirschhorn et al., 2006). In the base case, a minimum team is assumed to be able to provide treatment to 500 patients (Hirschhorn et al., 2006). We assume that in their first year of service commitment the minimum team treats only patients who are newly initiated on ART. This assumption closely resembles the situation in many developing countries with large unmet ART need (Braitstein, Brinkhof, Dabis, Schechter, Boulle, Miotti et al., 2006). After having completed the first year in ART1, the minimum team either leaves the required service prematurely (because of emigration or deaths of members) or continues its service. If the team continues its service, it will transition to ART2 if its patients survive, to ART1 if its patients die or are lost to follow-up, or to ART3 if its patients need to switch from first-line to second-line therapy because of toxicities or treatment failure. Similarly, in any future cycle a minimum team that does not end its service prematurely will transition either to ART1, ART2, or ART3, depending on whether it continues to see the same patients on first line treatment (ART2), the same patients on second-line treatment (ART3) or starts treating new patients (ART1).

The cycle length for the model is set to 1 year. In each cycle, the minimum team induces benefits (the monetary value of the life-years saved because of ART) and costs depending on its current Markov state. We adopt a modified societal perspective, in that the indirect costs of antiretroviral treatment that accrue to patients (time and travel costs) are not included in the analyses. Further, we do not take into account reductions in health spending that come about because patients on ART fall ill less often and less severely than people who need ART but do not receive it. In the base case, future costs and benefits were discounted at 3% per year, as recommended by the US Panel on Cost-Effectiveness in Health and Medicine (Siegel, Torrance, Russell, Luce, Weinstein, & Gold, 1997) and as is commonly done in priority setting for health in developing countries (Goldie, Yazdanpanah, Losina, Weinstein, Anglaret, Walensky et al., 2006; C. J. Murray & Lopez, 1996). In sensitivity analyses, we varied the discount rate between 2% and 8%. All costs and benefits were measured in year-2000 US dollars. Unless otherwise indicated, all dollar amounts in the text below are expressed in year-2000 US dollars. The model was implemented in TreeAge Pro Suite 2007 (TreeAge Software Inc., Williamstown, MA, USA).

Simulated scenarios

The two possible effects of the "conditional scholarship" – an increase in health care education rates and a decrease in health worker emigration rates – may play out differently in different countries. In some countries, health care education capacity is not fully utilized, i.e. additional health workers could be trained without additional investment in facilities or hiring of additional teachers. In these countries, "conditional scholarships" will lead to an increase in the output of trained health workers in the short term, if there is a pool of qualified candidates who desire a health care education but do not have access to a source of finance of a health care education other than the "conditional scholarships” because of market failures in formal or informal capital markets. In all countries – independent of their utilization of health care education capacity – the “conditional scholarships” could increase HAHW retention if scholarship recipients’ emigration rates are on average lower than the migration rates of people who do not receive the scholarships.

We thus estimate eNPV of the “conditional scholarships” in different scenarios: first, all scholarship recipients are in addition to the HAHW who would have been in place in the absence of the scholarship program, and emigration rates among scholarship recipients are the same as the rates among health workers who do not receive the scholarship; second, all scholarship recipients are in addition to the HAHW who would have been in place in the absence of the program, and emigration rates among scholarship recipients are lower than the rates among other health workers; third, the scholarship program does not increase the number of health workers but decreases emigration rates among health workers who receive the scholarships.

A new dataset published by the World Bank International Migration and Development Program contains doctor emigration rates from 46 sub-Saharan African countries for a total of 642 country-years (Docquier & Bhargava, 2006). When the number of doctors in each country in each year of observation is used as weighting factor and the annual rates are converted to annual probabilities, the weighted average annual probability of doctor emigration across the 642 country-years is 13.4%. In our model, we use values for the annual probability of HAHW emigration in the absence of “conditional scholarships” that are slightly higher (15%) or slightly lower (12%) than this weighted average. Further, in different scenarios we vary the effect of the “conditional scholarships” on annual emigration probabilities as a reduction to either 5% or 3% per year during the period of the service commitment. Finally, we vary the length of the service commitment (3, 5, or 7 years) (Table 2).

Estimates for model variables

Estimates for model variables, as derived from published studies, are shown in Table 1. The baseline costs of the “conditional scholarships” are based on estimates of the costs of medical school and nursing school in Malawi in 2006 (Muula, Panulo, & Maseko, 2006) and the cost of medical school in Kenya in 2005 (Kirigia, Gbary, Muthuri, Nyoni, & Seddoh, 2006). The estimates from Malawi and Kenya include tuition and the cost of living during the time of health care education (Kirigia et al., 2006; Muula et al., 2006). In univariate sensitivity analysis we vary the cost of the “conditional scholarships” up to a maximum (725,000 dollars) that would cover tuition and living expenses of a minimum team of HAHW, if such a team were educated in the United States (American Medical Student Association, 2007; Morrison, 2005).

Other costs included in the model are doctor, nurse, pharmacist, and treatment counselor salaries and treatment costs (first- and second-line ART, cotrimoxazole prophylaxis, CD4 counts). We use weighted averages of the prices of antiretroviral drugs across all sub-Saharan countries for which price information was available in the *WHO Global Price Reporting Mechanism (GPRM)* in June 2007 (WHO, 2007a). As weighting factors we use the number of people in each sub-Saharan country who according to WHO and UNAIDS needed ART in December 2006 but did not receive it (UNAIDS/WHO, 2007). Information on both drug price and people with unmet ART need was available for 35, 34, 32, 29, 23, 21, 19, and 16 sub-Saharan countries for nevirapine (NVP), efavirenz (EFV), lamivudine (3TC), stavudine (d4T), abacavir (ABC), lopinavir/ritonavir (LPV/r), didanosine (ddI), and tenofovir disoproxil fumarate (TDF), respectively. In the base case, we assume that first-line ART consists of d4T, 3TC, and NVP, which are offered as first-line ART in many sub-Saharan countries (South African Department of Health, 2004; WHO, 2007b). We calculate weighted average prices for three other first-line regimens (d4T, 3TC and EFV; zidovudine (AZT), 3TC and NVP; AZT, 3TC and EFV) and vary the price of first-line therapy in univariate sensitivity analysis, using the weighted average price of the most expensive of the four first-line ART (AZT, 3TC and EFV) as the maximum. Similarly, we assume in the base case that second-line ART in sub-Saharan Africa consists of ddI, 3TC and LPV/r (WHO, 2007b), but calculate weighted average prices for three alternative regimens (ddI, ABC and LPV/r; TDF, ABC and LPV/r; TDF, 3TC and LPV/r) to estimate the eNPV of the "conditional scholarships" if the least expensive and the most expensive of the four regimens are used as second-line ART (Table 3a).

Estimates of mortality among people with CD4 count below 200 who do not receive ART are taken from a study in South Africa (Badri, Lawn, & Wood, 2006), and estimates of mortality among people with CD4 count below 200 at initiation of ART in the first and subsequent years of treatment are based on a 2006 review of 18 ART programs in low-income countries (Braitstein et al., 2006). Mortality among patients who are switched from first- to second-line therapy because of toxicity or therapy failure are assumed to be the same as those on first-line therapy in the second or later years of treatment (MSF, 2007b).

The dominant benefit of an ART program is the reduction in mortality as a result of treatment (Cameron, Gibson, Helmers, Lim, Tressler, & Vaddanak, 2006). Only a few estimates of the monetary value of a statistical life year (VSLY) (Johansson, 2001, 2002) exist for developing countries and these estimates vary widely (Viscusi & Aldy, 2003). No estimate of the VSLY in Africa has been published. In our baseline estimation, we thus follow the convention suggested by the 2001 *WHO Commission on Macroeconomics and Health* to value a statistical life year at three times the per capita GDP (Commission on Macroeconomics and Health, 2001). This valuation is intended to capture "value of leisure time in addition to market consumption, the pure longevity effect, and the pain and suffering associated with disease" (World Bank, 2007). A number of recent studies both in developed and developing countries adopt this convention (Cutler & Richardson, 1997; C.J. Murray, Lauer, & Hutubessy, 2003;

Philipson & Soares, 2001). We use the weighted average of per capita GDP across sub-Saharan African countries (World Bank, 2007), with the numbers of patients who needed but did not receive ART in December 2006 as weighting factors (UNAIDS/WHO, 2007).

< Table 1 about here >

Results

Scenario analysis

Table 2 shows the eNPV of "conditional scholarships" for one minimum team of HAHW in 26 scenarios. The scenarios differ with regard to, first, whether the scholarships affect education output, migration, or both; second, the level of migration with and without scholarships; and third, the length of the service commitment. Using 10,000 microsimulation trials, all 26 scenarios yield large positive eNPV estimates for "conditional scholarships" for one minimum HAHW team. The eNPV of all scenarios in which the "conditional scholarships" increase education output of HAHW and decrease emigration (1.12 to 1.61 million dollars) is significantly higher than the eNPV of the scenarios in which the scholarships only increase education output (0.80 and 0.95 million dollars). In turn, the eNPV of the two scenarios in which the scholarships only affect education output is significantly higher than the eNPV of any of the scenarios in which the "conditional scholarships" only reduce HAHW emigration probabilities (0.15 and 0.56 million dollars). As must necessarily be the case in valid models, *ceteris* *paribus* all scenarios with shorter service commitments have lower eNPV than scenarios with longer commitments, and all scenarios with a larger reduction in emigration probabilities due to the scholarships have higher eNPV than scenarios with smaller reductions.

< Table 2 about here >

Sensitivity analysis

Figure 3 shows how eNPV varies with changes in selected variables from the base case (i.e. when it is assumed that the "conditional scholarships" increase education output and decrease the annual probability of emigration from 15% to 5% during a five-year service commitment, and all variables are set to their base-case values as shown in Table 1). The selected variables cause the largest changes in eNPV amongst all variables in the model, when each individual variable is varied between the minimum and maximum values shown in Table 1. The results were most strongly affected by variations in the number of patients treated by one minimum HAHW team, the value of a statistical life year and the costs of first-line ART. However, when individual variables are varied within plausible bounds suggested by the literature (see Table 1) (Bertozzi, Gutierrez, Opuni, Walker, & Schwartlander, 2004; Calmy, Pinoges, Szumilin, Zachariah, Ford, & Ferradini, 2006; Coetzee, Hildebrand, Boulle, Maartens, Louis, Labatala et al., 2004; Dovlo, 2007; Etard, Ndiaye, Thierry-Mieg, Gueye, Gueye, Laniece et al., 2006; Ferradini, Jeannin, Pinoges, Izopet, Odhiambo, Mankhambo et al., 2006; Gutierrez, Johns, Adam, Bertozzi, Edejer, Greener et al., 2004; Lawn, Myer, Bekker, & Wood, 2006; MSF, 2004, 2006, 2007b; C.J. Murray et al., 2003; Padarath, Chamberlain, McCoy, Ntuli, Rowson, & Loewenson, 2003; Philipson & Soares, 2001; Sambo, 2006; Yazdanpanah, Losina, Anglaret, Goldie, Walensky, Weinstein et al., 2005), eNPV never falls below 0.48 million dollars. The VSLY would need to be less than 1400 dollars in order for eNPV to be negative, when all other variables are set to their base-case values.

< Figure 3 about here >

Discussion

Value of "conditional scholarships"

"Conditional scholarships" pay for a health care education in return for a commitment to serve for a few years in an ART program in sub-Saharan Africa. They are socially highly desirable investments under a range of plausible assumptions about the cost of health care education, the efficiency of health workers providing ART, the cost and effectiveness of ART, and the value of a year of life, as well as the probabilities of emigration and death among health workers and of treatment failure, loss to follow-up, and death among patients. The values of some of the variables used in the model may change over time, for instance, as new models of ART delivery are developed or new antiretroviral medicines with different efficacies and costs become available. However, our main finding – that "conditional scholarships" would have large social benefits in countries in sub-Saharan Africa – is quite robust to changes in key model variables. It seems unlikely that this conclusion would be altered by reasonable changes in the values of some variables. One extreme – and given current knowledge unexpected (amfAR, 2007) – case of technological change would be a cure for HIV infection. A cure would dramatically alter the eNPV of the "conditional scholarships" as it would eliminate the need for ART. But it is unlikely that a "conditional scholarship" program would lead to large financial losses for a country because the program could stop accepting new entrants and existing scholarship recipients could be deployed to administer the HIV cure or work as part of the general health service.

Although either of the two possible effects of the "conditional scholarships" (an increase in health care education output and a decrease in emigration of HAHW) is sufficient on its own to make the scholarship a socially desirable investment, the social value of the education effect is much higher than the value of the migration effect. However, in countries where health care education capacity is currently fully utilized, the "conditional scholarships" will not affect national health education output in the short-term and can only increase the number of HAHW by increasing retention rates. Nevertheless, they may increase the demand for health care education. Where some "conditional scholarships" cannot be taken up because the current education capacity is too low, they will still give some people who were previously willing but not able to pay for health education the ability to pay for it. In countries with substantial private health care education markets, the increase in demand should lead to an increase in education supply via the price mechanism. In countries that currently do not have private education markets, governments could decide to increase public sector health care education capacity. Alternatively, governments in such countries could pass legislation legalizing private health care education institutions, while limiting their own role to accreditation and quality control (Cueto, Burch, Adnan, Afolabi, Ismail, Jafri et al., 2006; WHO and World Federation for Medical Education (WFME) Task Force on Accreditation, 2004). In many developing countries, for instance in India (Bansai, 2003), the Philippines, Nigeria (Cueto et al., 2006), Côte d'Ivoire, the Republic of Congo (Verspoor, Mattimir, & Watt, 2001), South Africa (South African Nursing Council, 2006), and Angola (De Carvalho, Kajibanga, & Heimer, 2007), private sector medical and nursing education institutions already produce a large proportion of the national health worker output, usually of quality *en par* with public sector institutions.

A constraint to the expansion of health care education capacity may be the lack of health educators (WHO, 2006). This problem may be made worse by the HIV epidemic. At least in the early phases of the epidemic, teachers and professors were more likely to die of AIDS than the general population (Cohen, 2002). One solution to this problem may be to organize extended stays of volunteer health workers from developed countries, including retired doctors and nurses, to teach in developing country education institutions. Charities that organize such volunteer stays to teach and train health workers in developing countries already exist, for instance *US Physicians for Africa* ("US doctors for Africa: about us," 2007) and the *International Center for Equal Healthcare Access* ("International Center for Healthcare Access: about us," 2007). Other means of overcoming shortages of health care teachers include distance education and twinning arrangements between institutions in developing and developed countries (Hern, Vaughn, Mason, & Weitkamp, 2005; The Tropical Health and Education Trust, 2007).

An alternative to expanding education capacity in sub-Saharan African countries is to utilize education capacity in developed countries. “Conditional scholarships” could be offered to African nationals – or to any student independent of his or her nationality – who would be willing to commit to work in an ART program in sub-Saharan Africa after completion of a health care education in a developed country. We show that the social value of “conditional scholarships” is still highly positive if the value of the scholarships is increased to levels that could finance a health care education in the United States.

Value of a statistical life year

In order to measure the eNPV of a health care intervention that reduces mortality, a monetary value must be assigned to a year of life. We follow the suggestion of the 2001 *WHO Commission on Macroeconomics and Health* to value a life year at three times the per capita GDP (Commission on Macroeconomics and Health, 2001). However, this value was not derived from scientific studies, but arrived at through a consensus process amongst members of the Commission. VSLY can be investigated in two types of studies. In contingent valuation studies, respondents are asked how much they would be willing to pay for an additional year of life. Monetary values for a year of life can also be derived from preferences revealed in the market place via studies of prices of interventions that reduce mortality risk or differences in wage levels across jobs that are comparable except for the fact that they carry different mortality risks. No study of the VSLY in Africa has been published. However, a few estimates of VSLY exist for other developing countries (Viscusi & Aldy, 2003). Following Moore and Viscusi (1988) (Moore & Viscusi, 1988), we derive VSLY from the value of a statistical life (VSL) given in three studies of VSL in developing countries.[4] For India in 1990 we thus derive VSLY of 69,000 and 96,000 dollars from two VSL estimates published in a study of revealed preferences observed in the Indian labor market (Shanmugam, 2000). For Thailand in 2003 and Cambodia in 2004 we derive, respectively, VSLY of 10,000 and 20,000 dollars from studies of stated preferences (Cameron et al., 2006; Gibson, Barns, Cameron, Lim, Scrimgeour, & Tressler, 2007). These values represent multiples of per capita GDP which are higher than our base case assumption of 3 times per capita GDP – 220 and 306 times per capita GDP for India in 1990; 4.5 times per capita GDP for Thailand in 2003; and 55 times per capita GDP for Cambodia in 2004 (World Bank, 2007).

[4] We use a discount rate of 3% and the life expectancy in the year of the study in the country of the study (India in 1990, Thailand in 2003, and Cambodia in 2004) and assume that the average respondent in the study was 30 years of age.

As Viscusi and Aldy note in a review of VSL estimates throughout the world, “[e]stimates for the Indian labor market yield a value of a statistical life greater than the VSLs in other developing countries despite the fact that per capita income in India is an order of magnitude smaller than in these countries” (Viscusi & Aldy, 2003). While the high VSLY-to-GDP ratios estimated for India may thus not be generalizable to other developing countries, even the substantially lower ratios observed in Cambodia and Thailand suggest that we underestimate – perhaps severely – the monetary benefit from the “conditional scholarships” by valuing a statistical life year at three times GDP.

Implementation decisions

Obtaining repayment of education finance through labor in sectors with excess social demand for labor is not a new idea. For instance, Ethiopia, South Africa, and Thailand (Wibulpolprasert & Pengpaibon, 2003) require medical students to perform community service in rural areas after graduating from publicly funded medical schools. However, in all three countries there continue to be health worker shortages in rural areas. In Ghana, doctors are “bonded” to serve for five years in the public sector or to repay their training costs. However, because the monetary value of the bond is defined in nominal terms and inflation is high in Ghana, many doctors choose to repay their training costs (at a large financial loss to the government) rather than serve in the public sector. Moreover, because enforcement of the bonding policy is poor, some doctors emigrate without either completing the required public service or paying their bond (Mensah, 2005).

As the example of Ghana suggests, the attributes chosen for the scholarships will determine their effectiveness in increasing the national health workforce for ART. Attributes of the "conditional scholarships" include the source of finance, selection of candidates, specification of the conditional term, enforcement mechanisms, and supporting interventions.

1. Sources of finance

Finance for the "conditional scholarships" could come from tax revenues, international aid agencies, or the International Finance Facility (IFF). Because the scholarships have a positive social eNPV, in the absence of other sources of finance governments should always choose to finance them from the public sector budget, if funds are available even after projects with higher eNPV have been chosen. However, governments of developing countries may face borrowing constraints or may not be able to allocate monies to the "conditional scholarships" for political reasons. An alternative is to finance the scholarships through aid from international agencies. However, aid agencies tend to finance projects for periods that may not be sufficiently long to create a sustainable "conditional scholarships" program and they may be reluctant to provide "running cost" support for training health workers. The latter problem is highlighted by recent discussions about whether large disease-specific aid agencies, e.g., PEPFAR, the Global Fund to fight AIDS, Tuberculosis and Malaria, and the GAVI Alliance, should invest in human resources for health in developing countries (GAVI, 2003; JLI, 2004b; Ooms et al., 2007; The Global Fund, 2007).

Another funding option would be through the IFF as proposed by the UK's Department for International Development (DFID) (DFID and HM Treasury, 2003). An IFF would leverage development aid by issuing bonds on international capital markets against long-term commitments of annual payments from developed countries to developing countries. A project financed by the IFF would need to pass two economic tests (DFID and HM Treasury, 2004). First, its rate of return must be higher than the cost of borrowing needed to raise funds for the project. Second, the rate of return must be greater than the recipient country's target rate of return for public investment. It is likely that the project would pass both tests. On the one hand, the cost of borrowing would be very low because the financial pledges would come from countries with the highest creditworthiness ratings. On the other hand, we find that the eNPV of the "conditional scholarships" remains positive if the discount rate in our model is increased to 8%, i.e., the internal rate of return of the "conditional scholarship" is higher than the commonly used target rate of return of 8% for public investment in developing countries (DFID and HM Treasury, 2004).

2. Selection of candidates

The optimal selection of candidates for the scholarships will depend on whether policy makers want to achieve additional objectives with the intervention. Financial equity in access to tertiary education could be improved if eligibility for the scholarships were based on a means test. Merit could be rewarded if eligibility were based on secondary school performance. The proportion of health care students from traditionally underrepresented population groups (e.g., women or people from rural areas) could be increased if these groups received a proportion of the scholarships higher than their proportion in the population.

The selection of candidates may also influence the effectiveness of the scholarships. For instance, there is evidence from both developing and developed countries that medical students from rural areas are more likely than their peers from urban areas to take up practice in rural areas after graduation (Daniels, Vanleit, Skipper, Sanders, & Rhyne, 2007; World Organization of Family Doctors (WONCA) Working Party on Rural Practice, 2002). For instance, a 2003 study from South Africa found that ten years after graduating from medical school doctors of rural origin were 3.5 times more likely than doctors of urban origin to practice in rural areas (de Vries & Reid, 2003). People who grew up in rural areas may be more likely than urban candidates to honor their “conditional scholarship” contracts and to remain at the station of their service commitments after completion of their contracts in rural ART programs, possibly because they feel a greater sense duty to help rural patients or because they prefer rural life-styles.

One possible problem with the “conditional scholarships” is that it takes time to train health workers, while human resources to deliver ART are needed now. The “conditional scholarship” policy may address this problem if scholarships are made available to people at any stage of their training and health care careers. The scholarships could be attractive to people who are already fully qualified health workers as an option for repaying education loans. A case in point is the U.S. National Institute of Health loan repayment program which requires medical graduates to work for some years in research rather than in (better paying) practice (Ley & Rosenberg, 2005). It is likely that such a model could be successful in those developing countries where health education graduates have usually incurred substantial amounts of debt. For instance, it has been estimated that in Colombia it takes a non-specialist doctor on average 4 years and a physiotherapist on average 10 years to pay back health care education loans (JLI, 2004a).

3. Specification of the condition

Our eNPV model rests on the assumption that scholarship recipients work in ART programs after graduation. This exclusive condition might be perceived as institutionalizing a priority for AIDS treatment over other health care. However, the finding that the “conditional scholarships” are eNPV-positive is robust to changes in the assumption that scholarship recipients spend all of their work time in ART programs. Microsimulation suggests that even if scholarship recipients spend only a proportion of their work time delivering ART, eNPV will remain highly positive. For instance, we find an eNPV of 0.45 million dollars for scholarships for a minimum team of HAHW assuming that scholarship recipients work only half-time in an ART program, that the probability of emigration is 5% during a 5 year service commitment and 15% otherwise, and that the scholarships increase education output. Rather than not implement a "conditional scholarship" program, countries should ask recipients of "conditional scholarships" to commit to part-time work in an ART program.

In addition, our estimates of the numbers of different types of health workers needed to provide ART to one patient come from real-life ART programs. In these programs, HIV-positive patients commonly receive not only ART but also treatment for other HIV-related diseases, especially tuberculosis, and care for conditions that are not related to HIV. Although we estimate the "conditional scholarship" project's economic value with benefits stemming from ART delivery alone, its costs include care for HIV-positive patients over and above ART. The work of scholarship recipients in an ART program thus frees up time of health workers in other health services, where HIV-positive patients without access to an ART program would present with their illnesses. Moreover, people who need ART but do not receive it fall ill more frequently and more severely than patients on ART. In countries with generalized epidemics, large proportions of in- and outpatient admissions in the general health services are related to HIV (Bardgett, Dixon, & Beeching, 2006; Dedicoat, Grimwade, Newton, & Gilks, 2003; Floyd, Reid, Wilkinson, & Gilks, 1999). Thus, a scholarship condition requiring work in ART services will likely strengthen the overall health care system, especially in countries with high HIV prevalence.

In addition to requiring service in ART delivery, the condition may specify the setting of the service. The effectiveness of the scholarships in addressing health care worker shortages may be increased if this setting is defined by a characteristic that increases the probability that the area is underserved (as in rural areas). They may be most effective if the setting is not defined *ex ante*, but rather if scholarship recipients are asked to commit to serve in an ART program in any setting that policy makers identify as being most in need of additional HAHW at the time of the worker's service.

Finally, the condition may specify alternatives to the service commitment, for instance, a certain payment. Payment as an alternative to service has the advantage that it renders the condition less restrictive, and may thus increase the attractiveness of the "conditional scholarships" to candidates. However, without prior experience it may be difficult for governments to set the appropriate price, such that it is neither too high to be paid back by any candidate (which would make the payment option meaningless), nor so low as to be easily paid back by most recipients immediately after graduation (which would make the "conditional scholarship" meaningless). Price setting will be especially difficult in countries with high inflation, because policy makers in such countries will either need to accurately predict the real future values of a current nominal price or link the value of the payment to inflation.

4. Enforcement mechanisms

Enforcement mechanisms will depend on legal, institutional, and technological factors specific to a country. Regulation, such as withholding diplomas or licenses from scholarship recipients until they have completed their community service, may decrease the risk that scholarship recipients breach their contracts (Table 2a). Other enforcement mechanisms, such as visa restrictions on health workers before completion of their required service times or employment of private monitoring agencies to check that graduates fulfill their conditions as stipulated (for instance, that they do not work in private practice), may be effective in enforcing the condition, but may come with the disadvantage of limiting basic freedoms or impinging on the privacy of health workers. Information management systems may help to plan and monitor the flow of scholarship recipients through the education system and into their assigned posts.

5. Supporting interventions

Other interventions to increase the number of health workers in a country (or to improve their distribution) could be implemented simultaneously with the "conditional scholarships" in order to increase the effectiveness of the scholarships. For instance incentives that increase the attractiveness of service in the country (or underserved parts of the country) may, in addition to promoting an increase in health workers more generally, increase retention rates after health workers have completed their service commitment. Such incentives might include improved working conditions, more attractive career paths, or free ART for health workers and their families (Table 4). Focusing health education curricula on the health care needs that scholarship recipients are most likely to encounter when delivering ART (such as opportunistic infections, HIV-related cancers, or ART toxicities) may increase the effectiveness of scholarship recipients' clinical services.

Conclusions

In spite of recent large-scale efforts to roll out ART in developing countries, millions of people who need ART currently do not receive it. Among the resources needed to deliver ART in developing countries, health workers are one of the scarcest. Without large increases in health workers in the coming years, most developing countries will be unable to achieve universal coverage with ART, leading to large numbers of potentially avoidable deaths. A scholarship for health care education that is conditional on the recipient entering into a contract to work for a number of years after graduation delivering ART in sub-Saharan Africa could address two of the main reasons for the low numbers of health workers in developing countries. First, the "scholarship" could increase the number of health workers educated in the country. Second, the "condition" could decrease the probability of emigration of HAHW. We use microsimulation to estimate the eNPV of “conditional scholarships” in sub-Saharan Africa. We find that under a wide range of plausible assumptions the scholarships are highly eNPV positive. “Conditional scholarships” for a team of health workers sufficient to provide ART for 500 patients have an eNPV of 1.23 million dollars, assuming that HAHW who receive the scholarships are in addition to the health workers who would have been educated without scholarships and that the scholarships reduce HAHW annual emigration probabilities from 15% to 5% for five years. When individual variable values are varied from this base case within plausible bounds suggested by the literature, eNPV of the “conditional scholarships” never falls below 0.5 million dollars. Although the “conditional scholarships” are a socially desirable investment, implementation success will likely depend on the sources of finance, selection of candidates, specification of the condition, enforcement mechanisms and supporting interventions.

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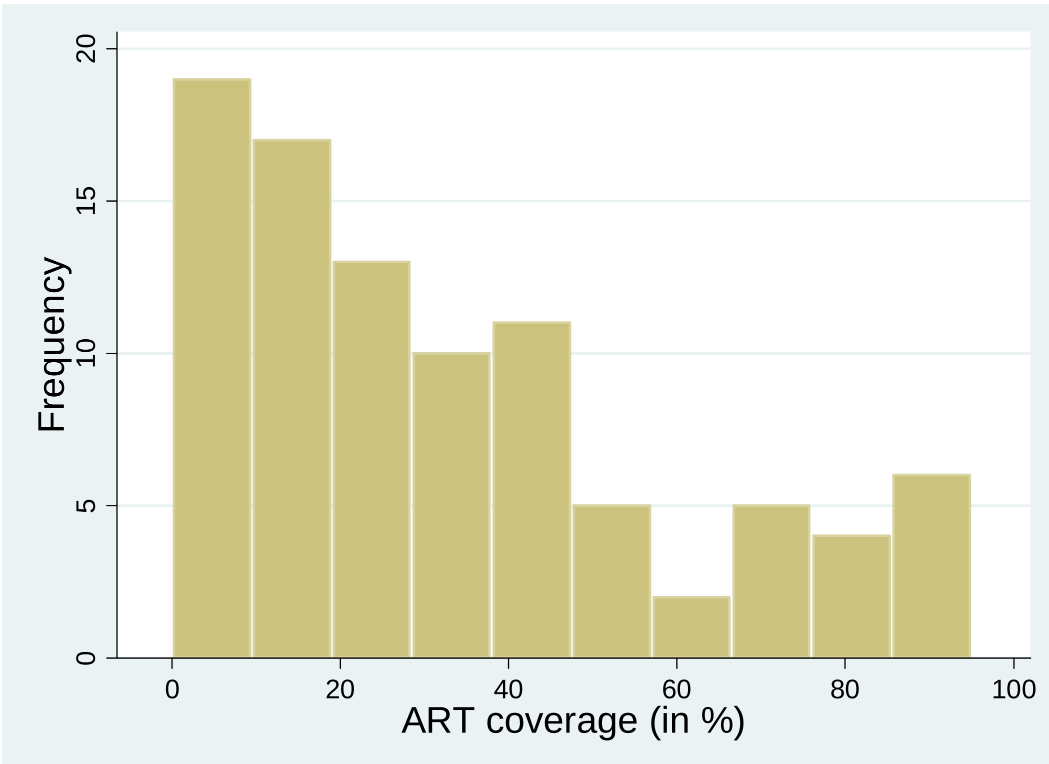
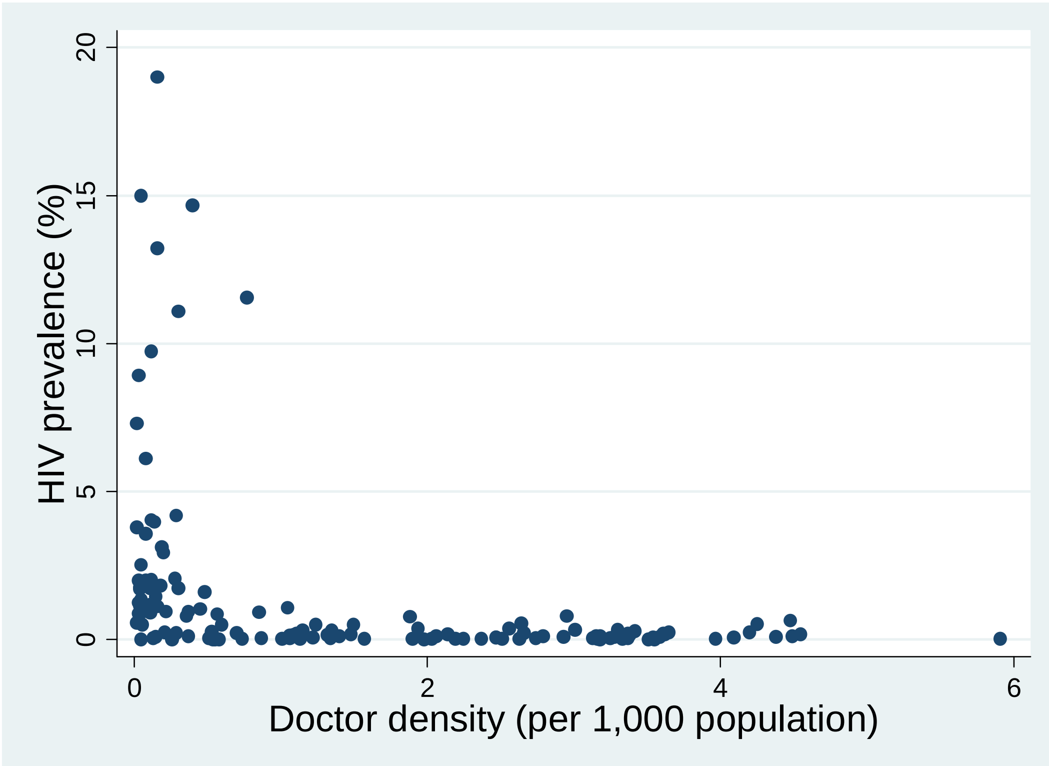
Figures

Figure 1: Distribution of ART coverage across 92 developing countries in 2006



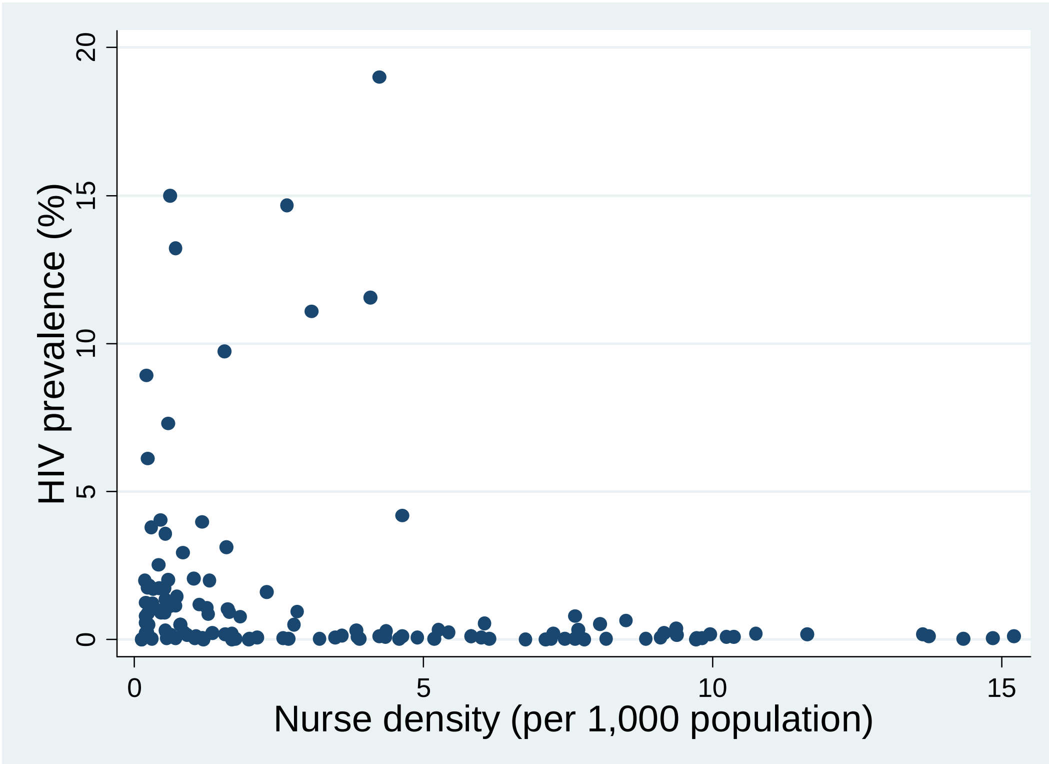
Source: (UNAIDS/WHO, 2007)

Figure 2 (panel 1): Doctor density and HIV prevalence



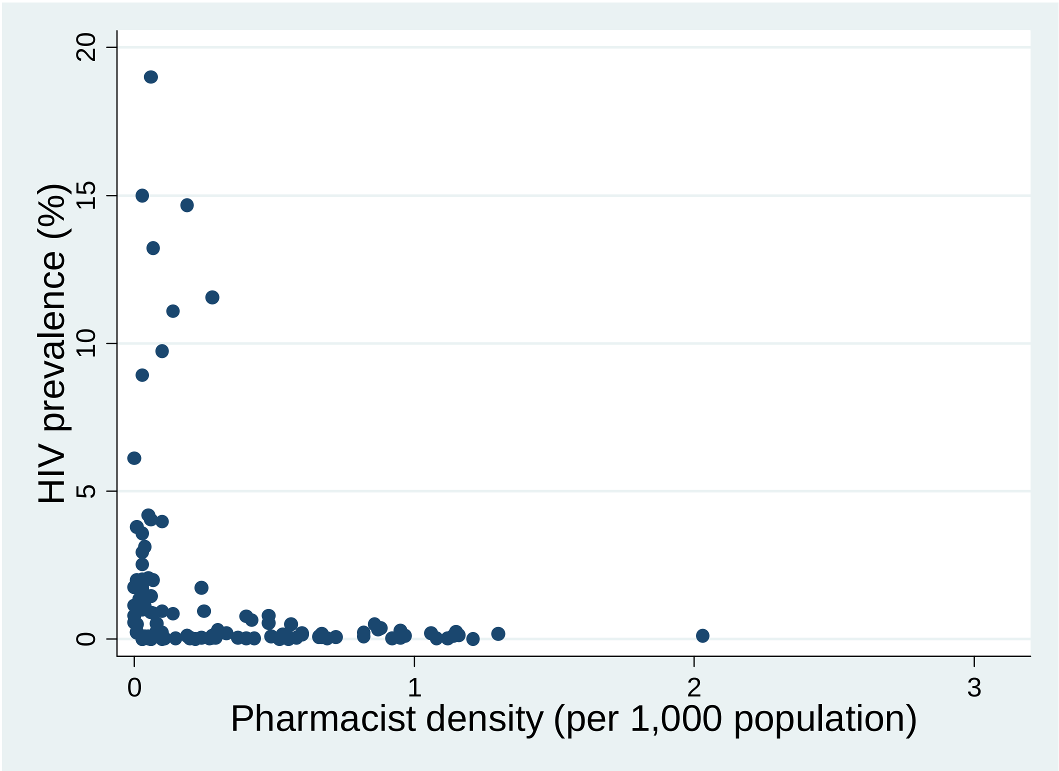
Sources: (UNAIDS/WHO, 2007; WHO, 2007c; World Bank, 2007)

Figure 2 (panel 2): Nurse density and HIV prevalence



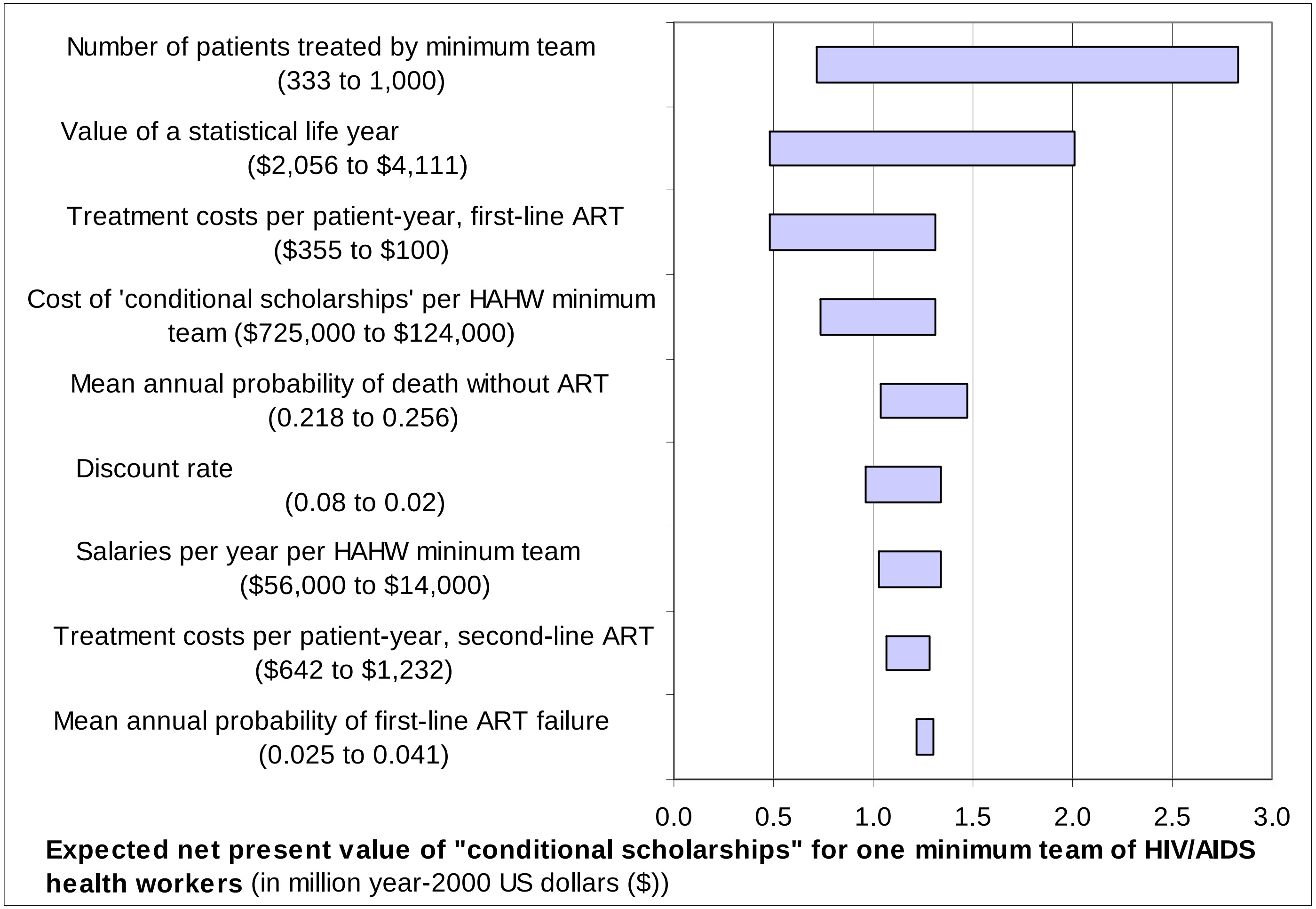
Sources: (UNAIDS/WHO, 2007; WHO, 2007c; World Bank, 2007)

Figure 2 (panel 3): Pharmacist density and HIV prevalence



Sources: (UNAIDS/WHO, 2007; WHO, 2007c; World Bank, 2007)

Figure 3: Sensitivity analysis of selected model variables



Tables

Table 1: Values of model variables

	Base-case	Minimum	Maximum	Reference
Value of a statistical life year (year-2000 US dollars)	3,084	2,056	4,111	(Commission on Macroeconomics and Health, 2001)
HAHW minimum team				
Ratio nurses:treatment counselors:doctors:pharmacists	3:10:1:1			(Hirschhorn et al., 2006)
Number of patients treated by minimum team	500	333	1,000	(Hirschhorn et al., 2006)
Education costs = value of “conditional scholarship” (year 2000 $)				
Doctors	42,000	32,000	200,000	(Muula et al., 2006)
Nurses	24,000	19,000	95,000	(Kirigia et al., 2006; Muula et al., 2006)
Pharmacists	35,000	25,000	140,000	
Treatment counselors	3,000	1,000	10,000	
HAHW minimum team	179,000	124,000	725,000	
Salaries per year (year-2000 US dollars)				
Doctors	7,000	3,000	15,000	(Vujicic, Zurn, Diallo, Adams, & Dal Poz, 2004)
Nurses	2,000	1,000	7,000	(Vujicic et al., 2004)
Pharmacists	5,000	3,000	10,000	
Treatment counselors	700	500	1,000	(Foundation for hospices in sub-Saharan Africa, 2007)
HAHW minimum team	25,000	14,000	56,000	
Patient probabilities				
Mean annual probability of death without ART	0.237	0.218	0.256	(Badri et al., 2006)
Mean annual probability of death in first year of treatment, first-line ART	0.064	0.057	0.071	(Braitstein et al., 2006)
Mean annual probability of death in second or later year of treatment, first-line ART	0.027	0.022	0.032	(Braitstein et al., 2006)

Mean annual probability of death in second or later year of treatment, second-line ART	0.027	0.022	0.032	
Mean annual probability of loss to follow-up	0.100	0.024	0.156	(Marazzi, Guidotti, Liotta, & Palombi, 2005; Nacher, El Guedj, Vaz, Nasser, Randrianjohany, Alvarez et al., 2006)
Mean annual probability of first-line treatment failure	0.033	0.025	0.041	(Orrell, Harling, Lawn, Kaplan, McNally, Bekker et al., 2007)
HAHW minimum team probabilities				
Mean annual probability of emigration	See table 2			(Docquier & Bhargava, 2006)
Minimum team, age-specific probability of death	Age and sex-specific			(INDEPTH Network, 2004)
Treatment costs per patient-year (year-2000 US dollars)				
First-line ART	120	100	355	(South African Department of Health, 2004; WHO, 2007a, b)
Second-line ART	698	641	1,232	(South African Department of Health, 2004; WHO, 2007a, b)
CD counts	8	5	20	(Carter, 2004; ReaMetrix, 2007)
Cotrimoxazole prophylaxis	3	2	4	(WHO, 2007a)
Discount rate	0.03	0.02	0.08	

Table 2: Expected net present value of "conditional scholarships" for one minimum team of HIV/AIDS health workers

		Mean	95% CI	Mean	95% CI	Mean	95% CI
Scenario	**Increased education output only**						
	15% mean annual probability of emigration	799,067	(781,688 - 816,446)				
	12% mean annual probability of emigration	954,097	(934,586 - 973,607)				
	Length of service commitment	*3 years*		*5 years*		*7 years*	
	Increased education output and decreased emigration						
	5% mean annual probability of emigration during the service requirement; 15% otherwise	1,119,711	(1,102,096 - 1,137,325)	1,238,763	(1,220,025 - 1,257,501)	1,354,293	(1,334,562 - 1,374,024)
	5% mean annual probability of emigration during the service requirement; 12% otherwise	1,284,889	(1,264,631 - 1,305,147)	1,349,004	(1,328,526 - 1,369,482)	1,417,743	(1,396,472 - 1,439,015)
	3% mean annual probability of emigration during the service requirement; 15% otherwise	1,223,939	(1,206,584 - 1,241,295)	1,385,393	(1,366,789 - 1,403,997)	1,507,784	(1,488,342 - 1,527,226)
	3% mean annual probability of emigration during the service requirement; 12% otherwise	1,343,552	(1,324,126 - 1,362,978)	1,476,995	(1,456,459 - 1,497,532)	1,607,055	(1,585,487 - 1,628,623)
	Decreased emigration only						
	5% mean annual probability of emigration during the service requirement; 15% otherwise	168,209	(143,923 - 192,496)	287,261	(262,350 - 312,172)	402,792	(377,232 - 428,351)
	5% mean annual probability of emigration during the service requirement; 12% otherwise	148,670	(120,755 - 176,585)	212,785	(184,481 - 241,088)	281,524	(252,956 - 310,093)
	3% mean annual probability of emigration during the service requirement; 15% otherwise	272,438	(248,674 - 296,202)	433,891	(408,920 - 458,863)	556,283	(530,696 - 581,869)
	3% mean annual probability of emigration during the service requirement; 12% otherwise	207,333	(179,934 - 234,731)	340,776	(312,364 - 369,188)	470,836	(441,869 - 499,803)

Appendix

Table 1a: Number of additional doctors, nurses, and pharmacists needed to provide universal ART coverage

Country	Estimated number of people needing ART[a]	Estimated ART coverage[b]	Estimated number of people who needed ART but did not receive it	Number of doctors needed to achieve universal ART coverage[c]		Number of nurses needed to achieve universal ART coverage[d]		Number of pharmacists needed to achieve universal ART coverage[e]	
				Low estimate	High estimate	Low estimate	High estimate	Low estimate	High estimate
Algeria	2,300	25%	1,725	2	3	3	12	2	5
Angola	66,000	10%	59,604	60	119	119	417	60	179
Argentina	42,000	79%	8,780	9	18	18	61	9	26
Azerbaijan	590	<1%	590	1	1	1	4	1	2
Bangladesh	1,700	<3%	1,700	2	3	3	12	2	5
Barbados	710	87%	94	0	0	0	1	0	0
Belarus	2,400	20%	1,926	2	4	4	13	2	6
Belize	680	59%	280	0	1	1	2	0	1
Benin	20,000	38%	12,379	12	25	25	87	12	37
Bolivia	1,100	24%	837	1	2	2	6	1	3
Botswana	84,000	>95%	4,200	4	8	8	29	4	13
Brazil	210,000	85%	30,880	31	62	62	216	31	93
Burkina Faso	33,000	39%	19,985	20	40	40	140	20	60
Burundi	31,000	26%	22,805	23	46	46	160	23	68
Cameroon	110,000	25%	82,057	82	164	164	574	82	246
Central African Republic	49,000	6%	46,016	46	92	92	322	46	138
Chad	36,000	14%	31,035	31	62	62	217	31	93
Chile	8,900	83%	1,524	2	3	3	11	2	5
China	110,000	27%	79,849	80	160	160	559	80	240
Colombia	37,000	50%	18,500	19	37	37	130	19	56

Country	Estimated number of people needing ART[a]	Estimated ART coverage[b]	Estimated number of people who needed ART but did not receive it	Number of doctors needed to achieve universal ART coverage[c]		Number of nurses needed to achieve universal ART coverage[d]		Number of pharmacists needed to achieve universal ART coverage[e]	
				Low estimate	High estimate	Low estimate	High estimate	Low estimate	High estimate
Congo	23,000	17%	19,059	19	38	38	133	19	57
Costa Rica	1,900	>95%	95	0	0	0	1	0	0
Côte d'Ivoire	110,000	28%	79,078	79	158	158	554	79	237
Cuba	1,500	>95%	75	0	0	0	1	0	0
Democratic Republic of the Congo	200,000	10%	179,041	179	358	358	1,253	179	537
Djibouti	3,100	19%	2,496	2	5	5	17	2	7
Dominican Republic	14,000	37%	8,822	9	18	18	62	9	26
Ecuador	5,200	34%	3,438	3	7	7	24	3	10
Egypt	910	22%	709	1	1	1	5	1	2
El Salvador	8,500	39%	5,156	5	10	10	36	5	15
Equatorial Guinea	1,800	24%	1,377	1	3	3	10	1	4
Eritrea	12,000	8%	11,002	11	22	22	77	11	33
Gabon	12,000	35%	7,751	8	16	16	54	8	23
Gambia	3,500	12%	3,072	3	6	6	22	3	9
Georgia	700	32%	476	0	1	1	3	0	1
Ghana	63,000	16%	53,123	53	106	106	372	53	159
Guatemala	12,000	52%	5,725	6	11	11	40	6	17
Guinea	17,000	10%	15,225	15	30	30	107	15	46
Guinea-Bissau	6,300	6%	5,932	6	12	12	42	6	18
Guyana	2,500	72%	712	1	1	1	5	1	2
Haiti	22,000	39%	13,490	13	27	27	94	13	40

Country	Estimated number of people needing ART[a]	Estimated ART coverage[b]	Estimated number of people who needed ART but did not receive it	Number of doctors needed to achieve universal ART coverage[c]		Number of nurses needed to achieve universal ART coverage[d]		Number of pharmacists needed to achieve universal ART coverage[e]	
				Low estimate	High estimate	Low estimate	High estimate	Low estimate	High estimate
Honduras	11,000	40%	6,646	7	13	13	47	7	20
Indonesia	25,000	20%	19,912	20	40	40	139	20	60
Iran, Islamic Republic of	8,400	5%	7,973	8	16	16	56	8	24
Jamaica	4,500	56%	1,996	2	4	4	14	2	6
Kazakhstan	3,700	10%	3,320	3	7	7	23	3	10
Kenya	290,000	44%	162,400	162	325	325	1,137	162	487
Lesotho	57,000	31%	39,373	39	79	79	276	39	118
Madagascar	8,100	1%	8,008	8	16	16	56	8	24
Malawi	190,000	43%	108,126	108	216	216	757	108	324
Malaysia	12,000	22%	9,375	9	19	19	66	9	28
Mali	27,000	37%	17,135	17	34	34	120	17	51
Mauritania	2,400	17%	1,997	2	4	4	14	2	6
Mexico	46,000	76%	11,065	11	22	22	77	11	33
Morocco	3,400	41%	2,004	2	4	4	14	2	6
Mozambique	280,000	14%	240,604	241	481	481	1,684	241	722
Myanmar	76,000	7%	70,736	71	141	141	495	71	212
Namibia	45,000	71%	12,875	13	26	26	90	13	39
Nepal	13,000	4%	12,464	12	25	25	87	12	37
Nicaragua	940	35%	607	1	1	1	4	1	2
Niger	16,000	6%	15,118	15	30	30	106	15	45
Nigeria	550,000	15%	469,994	470	940	940	3,290	470	1,410
Pakistan	12,000	<1%	12,000	12	24	24	84	12	36
Panama	4,200	70%	1,250	1	3	3	9	1	4
Papua New Guinea	9,800	8%	9,018	9	18	18	63	9	27

Country	Estimated number of people needing ART[a]	Estimated ART coverage[b]	Estimated number of people who needed ART but did not receive it	Number of doctors needed to achieve universal ART coverage[c]		Number of nurses needed to achieve universal ART coverage[d]		Number of pharmacists needed to achieve universal ART coverage[e]	
				Low estimate	High estimate	Low estimate	High estimate	Low estimate	High estimate
Paraguay	1,800	64%	642	1	1	1	4	1	2
Peru	18,000	50%	9,000	9	18	18	63	9	27
Philippines	1,900	10%	1,719	2	3	3	12	2	5
Russian Federation	140,000	11%	124,600	125	249	249	872	125	374
Rwanda	48,000	72%	13,525	14	27	27	95	14	41
Senegal	12,000	34%	7,924	8	16	16	55	8	24
Sierra Leone	9,400	14%	8,129	8	16	16	57	8	24
Somalia	8,800	<1%	8,712	9	17	17	61	9	26
South Africa	1,000,000	32%	675,196	675	1,350	1,350	4,726	675	2,026
Sri Lanka	710	<8%	675	1	1	1	5	1	2
Sudan	66,000	1%	65,255	65	131	131	457	65	196
Suriname	740	93%	55	0	0	0	0	0	0
Swaziland	44,000	42%	25,565	26	51	51	179	26	77
Tajikistan	500	<5%	500	1	1	1	4	1	2
Thailand	130,000	88%	15,600	16	31	31	109	16	47
Togo	23,000	24%	17,434	17	35	35	122	17	52
Trinidad and Tobago	5,700	45%	3,126	3	6	6	22	3	9
Uganda	230,000	41%	135,551	136	271	271	949	136	407
United Republic of Tanzania	280,000	18%	228,981	229	458	458	1,603	229	687
Uruguay	2,800	51%	1,386	1	3	3	10	1	4

Country	Estimated number of people needing ART[a]	Estimated ART coverage[b]	Estimated number of people who needed ART but did not receive it	Number of doctors needed to achieve universal ART coverage[c]		Number of nurses needed to achieve universal ART coverage[d]		Number of pharmacists needed to achieve universal ART coverage[e]	
				Low estimate	High estimate	Low estimate	High estimate	Low estimate	High estimate
Venezuela, Bolivarian Republic of	23,000	71%	6,616	7	13	13	46	7	20
Viet Nam	42,000	17%	34,693	35	69	69	243	35	104
Zambia	230,000	35%	148,950	149	298	298	1,043	149	447
Zimbabwe	350,000	15%	298,463	298	597	597	2,089	298	895
Total	5,731,080		3,916,916	3,917	7,834	7,834	27,418	3,917	11,751

[a]estimate as of December 2006 (based on UNAIDS/WHO 2007)

[b]estimates as of December 2006, ART coverage assumed 0% if coverage given as <1% or <5%, ART coverage assumed 5% if given as <8%, ART coverage assumed 95% if given as >95% (based on UNAIDS/WHO 2007)

[c]assuming 1 (low estimate) or 2 (high estimate) doctors needed to provide ART to 1,000 patients

[d]assuming 2 (low estimate) or 7 (high estimate) nurses needed to provide ART to 1,000 patients

[e]assuming 1 (low estimate) or 3 (high estimate) pharmacists needed to provide ART to 1,000 patients

Table 2a: Interventions to increase health worker densities

	INTERVENTIONS TO INCREASE THE NUMBER OF HEALTH WORKER NEED IN A COUNTRY	POTENTIAL TO INCREASE "CONDITIONAL SCHOLARSHIP" EFFECTIVENESS
Incentives		
Financial		
1	Increase salaries	+
2	Permit health workers in the public sector to do some private practice	+
3	Provide more benefits (pay for education for children, housing, meals, health insurance, pension insurance)	+
4	Provide financial incentives for health care workers who return to their country of origin	
5	Demand compensation from departing workers	+
6	Tax income of health workers who leave the country	+
	Non-financial	
7	Increase opportunities for further education and training in the country	+
8	Institute attractive career paths	+
9	Decrease workload	+
10	Improve working conditions (workplace safety, supply of medicines and equipment, management information systems)	+
11	Increase health care capital inputs (facilities, laboratory equipment, imaging technologies, surgical technologies)	+
12	Improve human resources management (recruitment, promotion, transfer, discipline, grievances, termination)	+
13	Offer psychological support for health workers	+
14	Provide free ART for health workers	+
Regulation		
15	Delay departure through compulsory service	
16	Introduce "ethical" recruitment policies in recipient countries	+
17	Implement inter-country non-migration policies	+
18	Withhold diplomas from health care workers until have served a period of time in the country	+
19	Make it easier for foreign health workers to obtain visas and work permits	

20	Make it easier for foreign health workers to obtain health care licenses	
Education		
21	Provide scholarships for health care studies	
22	Provide loans for health care studies	
23	Implement marketing campaign for health care careers in schools	+
24	Increase number of secondary education graduates per year	+
25	Hire health care teachers from other countries	+
26	Increase training of health care teachers	+
27	Build health education facilities	+
Inventions		
Technological		
28	Train health workers who are not internationally mobile	
29	Focus training curricula on local health needs	
Programmatic		
30	Rotate individual health care workers from developed to developing countries	
31	Introduce hospital partnerships with rotations of teams of health care workers	
32	Re-employ retired health care workers from the country	
33	Hire retired health care workers from other countries	
34	Transfer programmatic responsibilities to health care relief organizations	
35	Institute recruitment intermediaries between developed and developing countries	

INTERVENTIONS TO DECREASE HEALTH WORKER NEED IN A COUNTRY

Inventions		
Technological		
36	Use telemedicine to provide specialist medicine where there are no specialists	
37	Standardize treatment for common disease, so that it can be provided by less educated health workers	
38	Provide technological aid to enable less educated health workers to provide diagnosis and treatment	
39	Provide patient training to improve performance of self-diagnosis to decrease the number of unnecessary provider-patient contacts	
40	Invest in prevention interventions	

INTERVENTIONS TO IMPROVE DISTRIBUTION OF HEALTH WORKERS IN A COUNTRY		
Incentives		
Financial		
41	1-3 in underserved areas, but not in well-served areas	+
42	Introduce education loan payback programs in underserved areas	
Non-financial		
43	7-14 in underserved areas, but not in well-served areas	+
Regulation		
44	Make service in underserved areas a requirement for admittance to specialist training	
Education		
45	Increase recruitment of students from underserved areas into health care education programs	+
46	Build education facilities in underserved areas	+
47	Rotate students through underserved areas during their education and training	+
Interventions		
Technological		
48	Train health workers who can only find jobs in underserved areas (e.g. community health workers)	
49	Focus training curricula on health needs in underserved areas	+
Programmatic		
50	30-35 in underserved areas	+

Table 3a: Weighted average costs of first- and second-line ART across sub-Saharan African countries

	Year-2007 dollars	Year-2000 US dollars
First-line ART		
d4T, 3TC and NVP	145	120
AZT, 3TC and NVP	223	185
d4T, 3TC and EFV	326	270
AZT, 3TC and EFV	404	335
Second-line ART		
ddI, 3TC and LPV/r	843	698
ddI, ABC and LPV/r	1,488	1,232
TDF, ABC and LPV/r	1,419	1,175
TDF, 3TC and LPV/r	774	641
CD4 counts	50	41
Cotrimoxazole	4	3

ART = antiretroviral treatment. d4T = stavudine; 3TC = lamivudine; NVP = nevirapine; AZT = zidovudine; EFV = efavirenz; ddI = didanosine; LPV/r = lopinavir/ritonavir; ABC = abacavir; TDF = Tenofovir disoproxil fumarate. We used the number of people with unmet ART need as the weighting factor in the calculation of the weighted average.