

# HIV Pandemic, Medical Brain Drain, and Economic Development in Sub-Saharan Africa

*Alok Bhargava and Frédéric Docquier*

---

Country-level longitudinal data at three-year intervals over 1990–2004 are used to analyze the factors affecting emigration of physicians from Sub-Saharan countries and the effects of this medical brain drain on life expectancy and number of deaths due to AIDS. Data are compiled on emigrating African physicians from 16 receiving Organisation for Economic Co-operation and Development (OECD) countries. A comprehensive longitudinal database is developed by merging the medical brain drain variables with recent data on HIV prevalence rates, public health expenditures, physicians' wages, and economic and demographic variables. A triangular system of equations is estimated in a random effects framework using five time observations for medical brain drain rates, life expectancy, and number of deaths due to AIDS, taking into account the interdependence of these variables. Lower wages and higher HIV prevalence rates are strongly associated with the brain drain of physicians from Sub-Saharan African to OECD countries. In countries in which the HIV prevalence rate exceeds 3 percent, a doubling of the medical brain drain rate is associated with a 20 percent increase in adult deaths from AIDS; medical brain drain does not appear to affect life expectancy. These findings underscore the need to improve economic conditions for physicians in order to retain physicians in Sub-Saharan Africa, especially as antiretroviral treatment becomes more widely available. JEL codes: C33, C5, F22, I12, O11, O55.

---

The AIDS pandemic in Sub-Saharan Africa is affecting all dimensions of social and economic life. In many countries, gains in life expectancy achieved over the past several decades have been wiped out. Reductions in life expectancy are

Alok Bhargava (corresponding author) is Professor of Economics at the University of Houston; his email address is bhargava@uh.edu. Frédéric Docquier is a research associate at the National Fund for Economic Research and professor of economics at the Université Catholique de Louvain; his email address is frederic.docquier@uclouvain.be. The authors thank C. Ozden, M. Schiff, and A. Winters, of the World Bank, for encouragement and the International Migration and Development Research Program for research support. They also thank P. Ghys and K. Stanecki, of UNAIDS; L.J. Johnson and A. Wittrup, of the International Labour Organization; T. Tan-Torres and N. Van de Maele, of the WHO; and statistical and medical agencies in 16 OECD countries for help in obtaining the data used in the analysis. This article benefited from the helpful comments of three reviewers and the journal editor. The article is dedicated to the memory of Enid M. Fogel, who inspired many economists by her warmth and who devoted herself to improving the lives of young people.

THE WORLD BANK ECONOMIC REVIEW, VOL. 22, NO. 2, pp. 345–366  
Advance Access Publication May 15, 2008

doi:10.1093/wber/lhn005

© The Author 2008. Published by Oxford University Press on behalf of the International Bank for Reconstruction and Development / THE WORLD BANK. All rights reserved. For permissions, please e-mail: journals.permissions@oxfordjournals.org

detrimental at the macroeconomic level, because they reduce economic growth (Bhargava and others 2001). At the micro level, early parental deaths have created the enormous problem of AIDS orphans (USAID, UNICEF, and UNAIDS 2003; Subbarao and Coury 2004). Orphaned children have lower levels of psychological well-being and school attendance, which is critical for learning and for increasing awareness of HIV transmission routes (Bhargava 2005b). Informed policy formulation to deal with these problems requires analyses of data at the micro and macro levels.

The formulation of policies in the wake of the HIV/AIDS pandemic is complex and would benefit from research on broader biomedical and social science issues. For example, the World Health Organization (WHO) advocates antiretroviral treatment provided by public clinics for patients in HIV/AIDS Stage 4 or with a CD4 cell (type of white blood cell) count below 200 (Gutierrez and others 2004). Studies on the effects of antiretroviral treatment on productivity of undernourished populations can provide insights leading to enhanced treatment strategies. In a similar vein, a recent report by Physicians for Human Rights (2004) emphasizes the need for Sub-Saharan African countries to invest more in training physicians and nurses. The training of additional healthcare staff is hampered by low tertiary enrollment rates in Sub-Saharan African countries; the region could benefit from strategies such as training its physicians in Asia (Bhargava 2005a).

Individual-level surveys in six African countries indicate that more than half of all physicians would like to emigrate to developed countries, in search of better working conditions and more comfortable lifestyles (Awases and others 2003). Very large proportions of healthcare staff—38 percent in Ghana, 45 percent in Cameroon, 49 in Senegal, 58 percent in South Africa and Zimbabwe, 62 percent in Uganda—report being “stressed” by caring for HIV/AIDS patients. The risks associated with caring for HIV/AIDS patients and the possibility of children of healthcare staff contracting HIV as they enter adolescence may exacerbate medical brain drain (Awases and others 2003; Bhargava 2005a). Higher HIV prevalence rates can create a vicious circle, by increasing emigration of physicians and nurses, which can in turn increase deaths from AIDS and the numbers of orphaned children.

The trends underlying the international migration of skilled and unskilled labor are complex and reflect several aspects of labor supply and demand conditions in developing and developed countries (Ozden and Schiff 2006). Emigration of skilled workers in general increases remittances and creates business and information networks that can enhance economic performance in the countries of origin. The net effects of emigration of physicians and nurses from developing countries are likely to depend on the domestic demand for healthcare services over a long period. The AIDS pandemic makes it difficult for Sub-Saharan African countries to withstand attrition of already scarce healthcare workers.

The results of numerous household-level studies of HIV/AIDS in Sub-Saharan Africa indicate that factors such as multiple sex partners and

sexually transmitted infections can exacerbate HIV transmission (Caral and Holmes 2001). HIV prevalence rates constructed from individual-level data that take account of survival time after contracting HIV are useful for estimating life expectancy.

The effects of medical brain drain on indicators of well-being—such as life expectancy and the number of adult deaths due to AIDS—cannot be investigated using data from household surveys; country-level data are needed. Longitudinal data are useful for modeling the relation between HIV prevalence rates and brain drain. Analyses at the country level can provide insights for designing surveys investigating economic and social factors underlying medical brain drain.

Variables reflecting medical brain drain are not available for Sub-Saharan African countries. Fortunately, most statistical and medical agencies in receiving countries of the Organisation for Economic Co-operation and Development (OECD) keep longitudinal information on immigration of physicians (information on nurses is not compiled in the same detailed fashion). Databases such as the *World Development Indicators* (World Bank 2005) contain limited information on HIV prevalence rates. UNAIDS (2006) recently expanded AIDS-related variables on a longitudinal basis for Sub-Saharan African countries. Data on wages from the International Labour Organization (ILO) (2005) and on public health expenditures from the WHO (2006) can be merged with economic and demographic variables from the *World Development Indicators* to create a comprehensive longitudinal database.

This article estimates medical brain drain rates, the number of adult deaths due to AIDS, and life expectancy for 1990–2004 from longitudinal data. Alternative specifications are tested using econometric techniques. The article is structured as follows. Section I briefly describes the data on medical brain drain and other variables. Section II develops the analytical framework for specification of the relations, outlining the likely forms of interdependence among medical brain drain rates, the number of deaths due to AIDS, and life expectancy. Section III describes the empirical models, and section IV the econometric methods used to estimate and test the models. Section V presents the results from estimating random effects models for medical brain drain rates, the number of adult deaths due to AIDS, and life expectancy for Sub-Saharan African countries at five points between 1990 and 2004. Certain exogeneity hypotheses for the variables are tested to assess the validity of the model assumptions. The last section summarizes the article's main conclusions and identifies some areas for further research.

## I. THE DATA

This article examines the 16 most important OECD countries (Australia, Austria, Belgium, Canada, Denmark, France, Germany, Ireland, Italy, New Zealand, Norway, Portugal, Sweden, Switzerland, the United Kingdom, and

the United States) for which longitudinal data on foreign-born physicians are available. These countries account for 93 percent of skilled immigrants in the OECD (Docquier and Marfouk 2006).

The medical brain drain can be evaluated in terms of stocks and rates, following Carrington and Detragiache (1999) and Docquier and Marfouk (2006). The rate of medical brain drain  $m$  for country  $i$  in time period  $t$  can be written as:

$$(1) \quad m_{it} = \frac{M_{it}}{P_{it} + M_{it}}$$

where  $M_{it}$  denotes the stock of physicians from country  $i$  working abroad and  $P$  denotes the number of physicians working in the home country.

Docquier and Bhargava (2007) developed an annual database covering 1991–2004 from data provided by national agencies. For the data extracted from national censuses, two or three data points are usually available; data for the remaining years were interpolated using a log-linear adjustment. Data on the country of qualification of immigrants are available from medical associations in Canada, France, New Zealand, Norway, United Kingdom, and the United States; these data cover 73 percent of the sample. When the country of qualification could not be determined, data on country of birth were obtained from national censuses and registers in Australia, Austria, Belgium, Denmark, Ireland, and Sweden; these data cover 18 percent of the sample. For countries for which these data were not available (Italy, Germany, Portugal, and Switzerland), emigrants were defined according to their citizenship; these data cover 9 percent of the sample.<sup>1</sup>

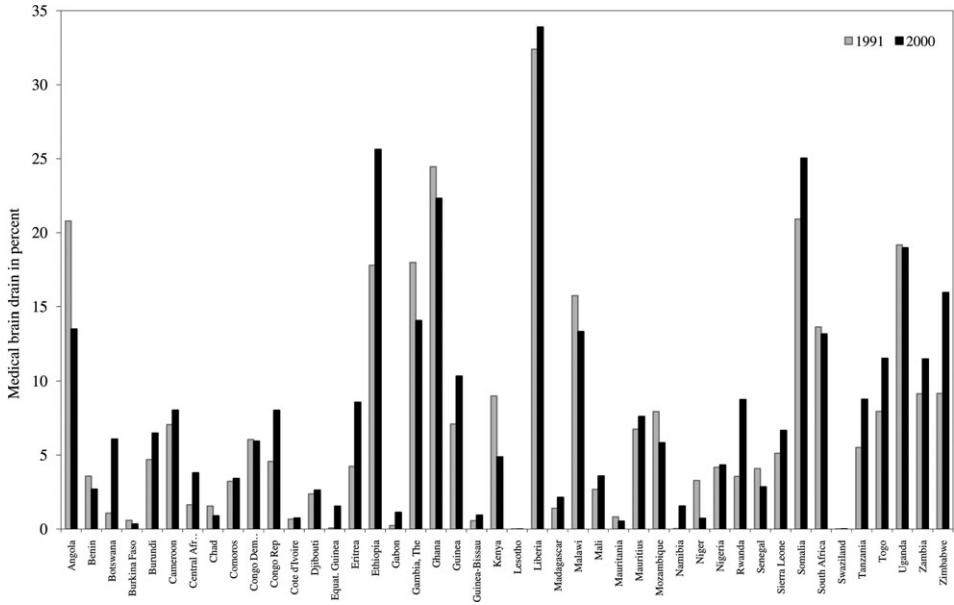
The data reveal that medical brain drain rates from 44 Sub-Saharan African countries to 16 OECD countries rose in most countries between 1991 and 2000 (figure 1). Only Angola, Benin, Burkina Faso, Chad, The Gambia, Ghana, Kenya, Malawi, Mauritania, Mozambique, Niger, Senegal, South Africa, and Uganda experienced declines in medical brain drain over this period.

Comprehensive longitudinal data on HIV prevalence rates and the number of adult deaths due to AIDS were recently released by UNAIDS for 1990–2004 (UNAIDS 2006). They reveal skyrocketing levels of HIV prevalence rates in many countries between 1991 and 2000 (figure 2).

Longitudinal information on government expenditures on health by Sub-Saharan African countries are available for 1996–2004 (WHO 2006). Because of missing observations for 1990–95, average government health expenditures during 1996–2004 are treated as time-invariant variables in the

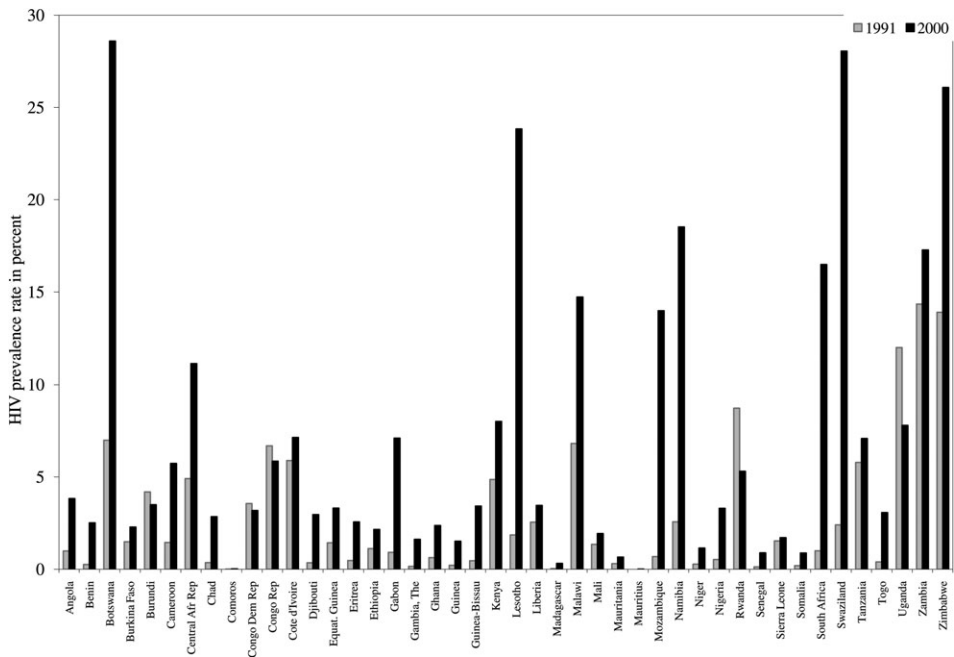
1. Because the medical brain drain rate is treated as an endogenous variable in the estimation, alternative definitions of emigrants are not critical. Moreover, highlighting differences in the definitions across OECD countries should promote a more unified approach in the future.

FIGURE 1. Medical Brain Drain Rates for Sub-Saharan Africa, 1991 and 2000



Source: Docquier and Bhargava 2007.

FIGURE 2. HIV Prevalence Rates in Sub-Saharan Africa, 1991 and 2000



Source: UNAIDS 2006.

econometric modeling. The ILO (2005) provides data on physicians' wages expressed in terms of average physicians' wages in the United States (see also Vujicic and others 2004).

Data on gross domestic product (GDP) (in 2000 dollars) are from the *World Development Indicators* (World Bank 2005). Additional information from UNESCO (2004) and the World Bank (2006) were used to reduce the numbers of missing observations.

Estimates of the proportion of the labor force with secondary or tertiary education are from Barro and Lee (2001), Docquier and Marfouk (2006), and Cohen and Soto (2007). The variables in the database were averaged to create five three-year interval time points over 1990–2004. Alternative data sets were created using two- and four-year averages; the three-year average figures are used here because of the structure of the data and the stochastic properties of the variables (Bhargava 2001); interpolations of variables such as life expectancy can create difficulties for econometric modeling.

A steady increase in HIV prevalence rates and the number of adult deaths due to AIDS is evident from the sample means (table 1). The number of physicians emigrating from Sub-Saharan African countries rose between 1990 and 2004, as did medical brain drain rates. Average life expectancy fell about two years between 1991 and 2003. There was an increase over time in net school enrollment rates in primary and secondary education. Physicians' wages in Sub-Saharan Africa declined slightly relative to physicians' wages in the United States.

## II. ANALYTICAL FRAMEWORK

The relations between HIV prevalence rates, medical brain drain, number of adult deaths due to AIDS, and life expectancy estimated using country-level data are of interest to policymakers. The nature of HIV transmission through sexual intercourse and the lags between contracting HIV and the onset of AIDS have important implications for the specification of macroeconomic models that go beyond the usual difficulties of deducing the effects of disease prevalence rates on aggregate economic indicators. It is even more complex to explain HIV prevalence rates at the country level, where information on the average number of sex partners, the prevalence of sexually transmitted infections, and patterns of migrant labor are unavailable. The effects of HIV prevalence rates on medical brain drain can nevertheless be analyzed, while allowing for the possibility that the HIV prevalence rate is potentially an endogenous variable in the system and may be influenced by medical brain drain.

Most rural residents in Sub-Saharan Africa have limited access to basic healthcare, and only a small proportion of people with HIV receive antiretroviral treatment. The lags between HIV infection and the onset of AIDS are thus likely to depend mainly on the natural rate of disease progression. That

TABLE 1. Sample Means and Standard Deviations of Selected Variables in Sub-Saharan Africa, 1990–2004 (3-year averages)

Variable	1991 <sup>a</sup>		1994		1997		2000		2003	
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
HIV prevalence (percent)	2.98	3.72	5.037	5.592	6.594	7.047	7.073	7.907	7.085	8.096
Number of AIDS deaths	3,960.82	7,777.64	10,253.64	16,672.51	19,713.29	28,002.43	30,245.11	40,974.4	36,963.61	54,538.9
Number of physicians per 1,000 population	0.15	0.24	0.15	0.22	0.16	0.24	0.16	0.24	0.16	0.24
Number of physicians emigrating	151.35	528.16	169.10	586.36	188.77	650.39	211.26	687.94	269.75	925.89
Medical brain drain <sup>b</sup>	0.09	0.11	0.10	0.12	0.10	0.11	0.10	0.11	0.11	0.12
Life expectancy (years)	50.79	8.21	50.13	8.28	49.36	7.75	48.59	7.88	48.21	8.56
GDP per capita (2000\$)	752.84	1,134.56	749.14	1,179.60	818.13	1,292.17	876.92	1,400.12	906.38	1,415.34
GDP per capita growth rate (percent)	1.67	1.55	1.95	2.13	4.18	8.23	2.81	2.86	3.63	3.74
Population (thousands)	11,536	16,747	12,511	18,310	13,515	19,799	14,539	21,223	15,581	22,692
Literacy rate (percent of adult population)	50.76	19.73	53.73	19.72	56.76	19.62	59.70	19.46	62.57	19.21

(Continued)

TABLE 1. Continued

Variable	1991 <sup>a</sup>		1994		1997		2000		2003	
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
Primary-school enrollment (percent)	58.11	25.01	60.20	25.41	61.00	23.31	62.57	20.98	67.00	19.71
Secondary-school enrollment (percent)	19.11	15.95	20.64	17.34	22.06	18.22	23.91	18.72	25.58	18.62
Percentage of population with secondary or tertiary education	13.2	10.2	14.8	11.7	16.0	12.6	17.0	12.9	18.0	13.7
Government health expenditure (percent of GDP)	4.32	1.31	4.68	1.42	4.84	1.75	4.87	1.79	4.98	1.75
Physicians' wages in home country/physicians' wages in United States	0.124	0.133	0.104	0.110	0.098	0.106	0.082	0.072	0.083	0.074
Investment (percent of GDP)	18.98	9.67	20.93	11.19	21.77	13.64	21.36	13.57	20.04	13.45

*Note:* There are at most 47 countries in the sample at each time point.

<sup>a</sup>Based on medical brain drain rates in 1991 and 1992.

<sup>b</sup>Ratio of number of physicians from Sub-Saharan Africa working in 16 OECD countries to the number of physicians working in Sub-Saharan and OECD countries.

*Source:* Docquier and Bhargava 2007.



progression is accelerated by poor nutritional status, including anemia (Belperio and Rhew 2004). Survival time for individuals contracting HIV in Sub-Saharan Africa is about 10 years (Jaffar and others 2004). These biological aspects are useful for interpreting empirical evidence from analyses of country-level data.

Medical brain drain should increase the number of adult deaths due to AIDS, especially among urban populations that receive some form of medical care. However, a 15-year period may not be long enough to observe the adverse effects of medical brain drain on HIV prevalence rates or on life expectancy, which is already low in Sub-Saharan Africa.

It is useful to outline the pathways through which HIV prevalence can depress economic activity. In developed countries, where antiretroviral treatment is widely available, high HIV prevalence rates may not significantly reduce productivity. By contrast, in developing countries AIDS-related work absenteeism is likely to be common. The effects of HIV prevalence rates on aggregate indicators of economic activity may be dampened somewhat by the fact that many people in Sub-Saharan Africa are engaged in household tasks and work on their own farms; when they fall ill, other household members can step in to perform their tasks (Bhargava 1997). Thus while the effects of HIV prevalence rates on GDP growth rates may not be evident, reductions in life expectancy due to HIV/AIDS can hamper economic growth (Bhargava and others 2001).

The relations among HIV prevalence, medical brain drain, the number of adult deaths caused by AIDS, and life expectancy can be embodied in a triangular system of equations. First, one can specify a model for medical brain drain that is likely to be affected by physicians' wages, GDP levels, and HIV prevalence rates, which increase the risks in the work environment. Second, HIV prevalence rates and medical brain drain are likely to increase the number of adult deaths due to AIDS and reduce life expectancy. Longitudinal data are available at five time points for estimating econometric models for the outcomes medical brain drain rates, number of adult deaths due to AIDS, and life expectancy; the simultaneous equation system is a "block triangular" system (the triangular system of equations contains longitudinal observations that are themselves triangular in form because of time orderings; see equation (8) below).

Appropriate techniques for efficiently estimating all the equations simultaneously are not available in the econometrics literature. Instead, each model can be estimated separately using longitudinal estimation methods that take into account the potential endogeneity of variables such as HIV prevalence rates. The models for medical brain drain rates, number of adult deaths due to AIDS, and life expectancy should be dynamic in nature, because past realization of these variables is critical for explaining their current levels.

## III. THE EMPIRICAL MODELS

The first equation in the simultaneous equations system is the model for the rate of medical brain drain. It is given by

$$\begin{aligned}
 (2) \quad & \text{Logistic } (\textit{medical brain drain rate})_{it} = a_0 \\
 & + a_1 \ln(\textit{physicians wage/USA ratio})_{it} \\
 & + a_2 \ln(\textit{school enrollment secondary})_{it} + a_3 \ln(\textit{GDP per capita})_{it} \\
 & + a_4 \ln(\textit{HIV prevalence rate})_{it} + a_5 \text{Logistic } (\textit{medical brain drain rate})_{it-1} \\
 & + u_{1it} \quad (i = 1, \dots, N; t = 2, 3, 4, 5)
 \end{aligned}$$

Transforming the variables into logs is generally useful; the initial observations on medical brain drain rate as well as the lagged dependent variables are treated as endogenous variable in the system (that is, correlated with the errors  $u_{1it}$ ) (Anderson and Hsiao 1981; Bhargava and Sargan 1983). The HIV prevalence rate is treated as an endogenous variable, and exogeneity assumptions are tested using likelihood ratio tests.

A dynamic model for HIV prevalence rate is estimated to investigate possible reverse causality (the possibility that higher medical brain drain rates predict higher HIV prevalence). Four-year averages at three time points are used in specification 4 to assess the robustness of the results from analyzing three-year averages. The errors,  $u_{1it}$ 's, can be decomposed in a random effects fashion as

$$(3) \quad u_{1it} = \delta_i + v_{it}$$

where the  $\delta_i$  terms are country-specific random effects that are distributed with zero mean and finite variance, and the  $v_{it}$  terms are independently distributed random variables with zero mean and finite variance. Equation (3) is a special case of the assumption invoked in the empirical modeling that the variance-covariance matrix of  $u_{1it}$  is an unrestricted positive definite matrix (Bhargava and Sargan 1983).

The empirical models for the number of adult deaths due to AIDS and for life expectancy are similar. The model for the number of deaths due to AIDS is written as

$$\begin{aligned}
 & \ln(\textit{number of adult deaths due to AIDS})_{it} = b_0 + b_1 \ln(\textit{population})_i \\
 & + b_2 \ln(\textit{proportion of labor force with secondary or tertiary education})_{it} \\
 (4) \quad & + b_3 \ln(\textit{GDP per capita})_{it} + b_4 \ln(\textit{HIV prevalence rate})_{it} \\
 & + b_5 \ln(\textit{medical brain drain rate})_{it} + b_6 \ln(\textit{deaths due to AIDS})_{it-1} \\
 & + u_{2it} \quad (i = 1, \dots, N; t = 2, 3, 4, 5).
 \end{aligned}$$

In equation (4), the country's entire population is accounted for, and medical brain drain and HIV prevalence rates are treated as endogenous variables. An interaction term between HIV prevalence and medical brain drain rates is included in an extended version of the model (specification 2, table 3). In view of the lags between contracting HIV and the onset of AIDS, lagged HIV prevalence rate is used instead of the current rate in specification 3 (table 3). In specification 4, the medical brain drain rate is replaced by the number of physicians in the home country (per 1,000 people) and the number working abroad. Although nonlinearities with respect to these variables are taken into account, it is difficult to simultaneously address all possible nonlinearities given the limited number of countries and time periods in the sample. In the model for life expectancy (table 4), specification 2 replaces the medical brain drain rate with the number of physicians in the home country and the number working abroad. Net percentages of school enrollment in primary education is a regressor in the model for life expectancy, because even a few years of primary education are associated with lower child mortality in Sub-Saharan Africa (Bhargava and Yu 1997).

#### IV. THE ECONOMETRIC FRAMEWORK

The methodology used to estimate dynamic random effects models in which some explanatory variables are endogenous was developed by Bhargava and Sargan (1983) and Bhargava (1991). Let the dynamic model be given by

$$(5) \quad y_{it} = \sum_{j=1}^m z_{ij}\gamma_j + \sum_{j=1}^{n_1} x_{1ijt}\beta_j + \sum_{j=n_1+1}^n x_{2ijt}\beta_j + \alpha y_{it-1} + u_{it}$$

where the  $z$  terms are time-invariant variables, the  $x_1$  terms are exogenous time-varying variables, and the  $x_2$  terms are endogenous time-varying variables. In the model for medical brain drain rates, for example, the HIV prevalence rate is likely to be an endogenous time-varying variable (that is, is included in the  $x_{2ijt}$ 's); unobserved factors affecting HIV prevalence rates may be influenced by country-specific random effects ( $\delta_i$ ) in equation (2).

It is useful to rewrite the dynamic model in a simultaneous equations framework by defining a reduced form for the initial observations and a system of  $(T - 1)$  structural equations for the remaining time periods (Bhargava and Sargan 1983):

$$(6) \quad y_{i1} = \sum_{j=0}^m z_{ij}\zeta_j + \sum_{j=1}^T \sum_{k=1}^T v_{jk}x_{ijk} + u_{i1} \quad (i = 1, \dots, N)$$

and

$$(7) \quad \begin{matrix} B & \cdot & Y' & & C_z & \cdot & Z' & & C_x & \cdot & X' & = & U' \\ (T-1) \times T & & T \times N & + & (T-1) \times (m+1) & & (m+1) \times N & + & (T-1) \times nT & & nT \times N & & (T-1) \times N \end{matrix}$$

In equations (6) and (7),  $Y$ ,  $Z$ , and  $X$  are matrices containing observations on the dependent, time-invariant, and time-varying explanatory variables; dimensions of the matrices are written below the respective symbols.  $B$  is a  $(T - 1) \times T$  lower triangular matrix of coefficients:

$$(8) \quad B_{ii} = \alpha, B_{i,i+1} = -1, B_{ij} = 0 \quad \text{otherwise} \quad (i = 1, \dots, T - 1; j = 1, \dots, T).$$

Matrix  $C_z$  contains coefficients of time-invariant regressors. Matrix  $C_x$  contains coefficients of time-varying regressors. Matrix  $U$  contains the error terms.

The profile log-likelihood functions of the model in equation (2) can be optimized using a numerical scheme such as E04 JBF from Numerical Algorithm Group (1991). Assuming that the number of countries is large but the number of time observations is fixed, asymptotic standard errors of the parameters are obtained by approximating second derivatives of the function at the maximum. The random effects decomposition in equation (3) can be tested in this framework using likelihood ratio tests. Given five time observations, under the null hypothesis of the random effects decomposition, the likelihood ratio statistic is distributed for a large  $N$  as a chi-squared variable with 12 degrees of freedom.

In short panels, it is reasonable to assume that a variable such as the HIV prevalence rates in equation (2) is correlated with the country-specific random effects,  $\delta_i$ :

$$(9) \quad x_{2ijt} = \lambda_j \delta_i + x_{2ijt}^*$$

where  $x_{2ijt}^*$  is uncorrelated with  $\delta_i$ , and the  $\delta_i$  terms are randomly distributed variables with zero mean and finite variance, as in equation (3). This correlation pattern was invoked by Bhargava and Sargan (1983); the advantage in employing equation (9) is that deviations of the  $x_{2ijt}$ 's from their time means that

$$(10) \quad x_{2ijt}^+ = x_{2ijt} - \bar{x}_{2ij} \quad (t = 2, \dots, T; j = n_1 + 1, \dots, n; i = 1, \dots, N)$$

where

$$(11) \quad \bar{x}_{2ij} = \sum_{t=1}^T x_{2ijt} / T \quad (j = n_1 + 1, \dots, n; i = 1, \dots, N)$$

can be used as  $[(T - 1)n_2]$  additional instrumental variables to facilitate identification and estimation of the parameters. While more general correlation patterns between the explanatory variables and errors are possible (Bhargava 1991), the identification conditions may not be met in dynamic models estimated from short panels. Exogeneity hypotheses can be tested using likelihood ratio tests. Given five time observations, the likelihood ratio statistic for testing correlation between the random effects and time means of HIV prevalence rates in equation (2) is distributed as a chi-squared variable with five degrees of freedom. Fixed-effects estimators (with dummy variables for countries) can be used to circumvent certain endogeneity problems, but the rise in the number of parameters that accompanies the increase in sample size leads to the problem of incidental parameters (Neyman and Scott 1948).

## V. EMPIRICAL RESULTS

This section presents the results from estimating random effects models for medical brain drain rates, the number of adult deaths due to AIDS, and life expectancy for Sub-Saharan African countries at five time points over the period 1990–2004.

### *Effect on Medical Brain Drain Rates*

Specification 1 of the model in equation (2) treats the HIV prevalence rate as an exogenous variable; it does not restrict the variance-covariance matrix of the errors in the simple random effects fashion (equation 3) (table 2). The variance-covariance matrix is restricted to be that of the random effects model in specification 2, and the between/within variance ratio and the within variance are estimated. Specification 3 treats HIV prevalence rates as an endogenous variable that is correlated with the country-specific random effects. Specification 4 analyzes four-year averages.

These specifications yield several important findings. First, the likelihood ratio statistic for testing specification 2 against specification 1 is 50.96; it is distributed as a chi-squared variable with 12 degrees of freedom. The test rejects the null hypothesis of simple random effects decomposition (the 5 percent critical level is 21.0). The likelihood ratio statistic for testing the exogeneity of the HIV prevalence rate assumes the value 12.04, which is close to the 5 percent critical limit of 11.10. Thus the null hypothesis is rejected. In view of the closeness of the statistic to its critical limit, it is perhaps not surprising that the results from specifications 1 and 3 are close. The discussion focuses on the results from specification 3.

Second, the coefficient of the variable measuring physicians' wages in Sub-Saharan African countries as a percentage of physicians' wages in the United States is significant at the 5 percent level: countries with higher physician wages have lower emigration rates. These findings are consistent with the responses of health-care personnel who want to emigrate, among whom large

TABLE 2. Maximum Likelihood Estimates for Medical Brain Drain from Sub-Saharan African Countries Explained by Socioeconomic Variables and HIV Prevalence Rates, 1990–2004

Explanatory variable	Specification 1		Specification 2		Specification 3 <sup>a</sup>		Specification 4 <sup>b</sup>	
	Coefficient	Standard error	Coefficient	Standard error	Coefficient	Standard error	Coefficient	Standard error
Constant	-0.465**	0.146	-0.815**	0.224	-0.485**	0.151	-1.055**	0.201
ln( <i>physicians' wages in home country/physicians' wages in United States</i> )	-0.036**	0.019	-0.057**	0.030	-0.035**	0.019	-0.066**	0.032
ln( <i>percent school enrollment secondary</i> )	0.115**	0.045	0.236**	0.069	0.124**	0.048	0.248**	0.081
ln( <i>GDP per capita</i> )	-0.035	0.033	-0.102**	0.057	-0.037	0.034	-0.085	0.066
ln( <i>HIV prevalence</i> )	0.079**	0.017	0.082**	0.022	0.071**	0.021	0.107**	0.036
Lagged dependent variable	0.921**	0.028	0.811**	0.053	0.914**	0.031	0.769**	0.035
Between/within variance ratio			0.445	0.354				
Within variance			0.051					
2 (maximized log-likelihood function)	512.75		461.79		570.55		300.45	
Chi-squared test for random effects decomposition (12 degrees of freedom)			50.96**					
Chi-squared test for exogeneity of HIV prevalence rate (5 degrees of freedom)					12.04**			

Dependent variable: Logistic (*medical brain drain rate*).

\*\*Significant at the 5 percent level.

Note: Data on 39 countries, with five time observations at 3-year intervals.

<sup>a</sup>HIV prevalence rate is treated as an endogenous variable.

<sup>b</sup>Specification uses 4-year averages at three time points.

Source: Authors' estimation results.

majorities—68 percent in Cameroon, 77 percent in Zimbabwe, 78 percent in South Africa, 84 percent in Uganda, 85 percent in Ghana—report a desire to earn more as a motivation (Awases and others 2003).

Third, net enrollment in secondary education is a positive and significant predictor of medical brain drain, with an estimated short-run elasticity of 0.12. This result is not surprising, as higher enrollments in secondary education entail greater expenditures on education; physicians educated in such environments are likely to have better emigration prospects.

Fourth, the HIV prevalence rate is a significant predictor of medical brain drain, with the short-run elasticity (0.07) robust across the first three specifications. Moreover, the coefficient of the lagged dependent variable is estimated at 0.91 in specification 3, indicating that the long-run impacts of the explanatory variables are about 11 times greater than the short-run coefficients. Thus the long-run elasticity of the medical brain drain rate with respect to HIV prevalence is about 0.8. This means that a doubling of the HIV prevalence rate implies an 80 percent increase in the medical brain drain rate in the long run. This is a large effect, with important policy implications, especially given that the average number of physicians per 1,000 people is only 0.15 in Sub-Saharan Africa (see table 1). Furthermore, higher ratios of physicians to the population will be needed as more people with HIV develop AIDS.

Fifth, the large estimated coefficients of the lagged dependent variable suggest that emigration patterns in Sub-Saharan African countries are becoming well established, presumably as a result of stable demand from OECD countries for physicians trained in specific countries. While specification 2 is rejected in favor of specification 1 by the likelihood ratio test, the estimated between/within variance ratio is not significant in specification 2, possibly because of the relatively small number of countries in the sample.

Sixth, the results from specification 4 employing four-year averages are similar to those from specification 1, indicating robustness of the results from three-year averages at five time points. In fact, use of four-year averages entails a loss of information, because the data from 2002, 2003, and 2004 cannot be used in specification 4.

Finally, a model similar to equation 2 was estimated for HIV prevalence rates with medical brain drain rate as an explanatory variable to investigate possible reverse causality. Coefficients of medical brain drain rate were not significant in any of the specifications, thereby supporting the model formulation and exogeneity assumptions.

#### *Effect on Numbers of Adult Deaths Due to AIDS and on Life Expectancy*

The results for the numbers of adult deaths due to AIDS are shown for four specifications (table 3). Specification 2 includes an interaction term between medical brain drain and HIV prevalence rates; this term is included because higher HIV prevalence rates can exacerbate the effects of medical brain drain on adult deaths caused by AIDS. In specification 3, the current HIV prevalence

TABLE 3. Maximum Likelihood Estimates for Number of Adult Deaths due to AIDS, 1990–2004

Explanatory variable	Specification 1 <sup>a</sup>		Specification 2 <sup>a</sup>		Specification 3 <sup>b</sup>		Specification 4 <sup>c</sup>	
	Coefficient	Standard error	Coefficient	Standard error	Coefficient	Standard error	Coefficient	Standard error
Constant	-2.833**	0.422	-3.412**	0.165	-5.011**	0.203	3.553**	0.481
$\ln(\text{population})$	0.450**	0.017	0.480**	0.006	0.635**	0.008		
$\ln(\text{proportion of population with secondary or tertiary education})$	-0.045	0.027	-0.005	0.026	0.024	0.016	-0.114	0.085
$\ln(\text{GDP per capita})$	-0.014	0.025	-0.072**	0.025	-0.008	0.006	-0.093**	0.047
$\ln(\text{HIV prevalence})$	0.542**	0.039	0.778**	0.038			0.660**	0.052
$\ln(\text{HIV prevalence})_{-1}$					0.836**	0.016		
$\ln(\text{medical brain drain rate})$	0.095**	0.019	-0.059**	0.023	-0.080**	0.020		
$\ln(\text{number of physicians in home country}/1,000 \text{ people})$							-0.007	0.173
$\ln(\text{number of physicians abroad})$							0.113**	0.035
$[\ln(\text{number of physicians in home country}/1,000 \text{ people})]^2$							0.001	0.028
$[\ln(\text{number of physicians abroad})]^2$								
$\ln(\text{medical brain drain}) \times \ln(\text{HIV prevalence})$			0.049**	0.008			0.014**	0.006
$\ln(\text{medical brain drain}) \times \ln(\text{HIV prevalence})_{-1}$					0.061**	0.005		





TABLE 4. Maximum Likelihood Estimates from Dynamic Random Effects Models for Life Expectancy in Sub-Saharan African Countries Explained by Socioeconomic Variables and HIV Prevalence and Medical Brain Drain Rates, 1990–2004

Explanatory variable	Specification 1		Specification 2	
	Coefficient	Standard error	Coefficient	Standard error
Constant	1.117**	0.005	1.012**	0.004
$\ln(\text{government health expenditure as percent of GDP})$	0.040**	0.003	0.029**	0.003
$\ln(\text{percent primary school enrollment})$	0.022**	0.009	0.022**	0.002
$\ln(\text{GDP per capita})$	0.001	0.007	0.009**	0.004
$\ln(\text{HIV prevalence})$	-0.027**	0.003	-0.026**	0.004
$\ln(\text{medical brain drain rate})$	-0.005	0.003		
$\ln(\text{physicians in home country, per 1,000 people})$			-0.0001	0.003
$\ln(\text{physicians abroad})$			0.0001	0.002
Lagged dependent variable	0.662**	0.002	0.700**	0.001
$2 \times (\text{maximized log-likelihood function})$	1558.80		1588.15	
Chi-squared test for exogeneity of medical brain drain rate or physicians abroad (5 degrees of freedom)	16.64**		24.46**	

Dependent variable:  $\ln(\text{life expectancy})$ .

\*\*Significant at the 5 percent level.

Note: Data on 39 countries with five time observations at 3-year intervals in are used in the estimation. The medical brain drain rate (ratio of number of physicians from Sub-Saharan Africa working in 16 OECD countries to the number of physicians working in Sub-Saharan and OECD countries) is treated as an endogenous variable.

Source: Authors' estimation results.

rate is replaced by the value lagged one period (that is, three years). Specification 4 replaces the medical brain drain rate with the number of physicians in the home country and those working abroad, taking into account some nonlinearities. Constraints on the variance-covariance matrix implied by the random effects decomposition are rejected in all specifications.

The results in table 3 show the importance of HIV prevalence rates for the number of adult deaths due to AIDS. Although the short-run elasticity from specification 1 is just 0.54, the long-run elasticity is close to 1.0. In view of the lack of antiretroviral treatment for the vast majority of people with HIV during the sample period, it is not surprising to find large long-run effects of HIV prevalence rates on adult deaths.

In specification 1, the medical brain drain rate is a significant predictor of the number of deaths due to AIDS, with a short-run elasticity of 0.1 and a long-run elasticity of 0.2. Even where antiretroviral treatment is not provided, reduced access to physicians who provide basic care, such as treatment of

tuberculosis and other illnesses that accompany HIV, is likely to exacerbate the progression of the illness. Thus at the aggregate country level, medical brain drain appears to reduce the survival time of people with HIV.

In specifications 2 and 3, the interaction term medical brain drain and HIV prevalence rates is significant, indicating that the effects of medical brain drain are likely to depend on national HIV prevalence rates. The results from specifications 2 and 3 are close, indicating small differences between using current and lagged HIV prevalence rates. While the effects of medical brain drain rate on the number of deaths due to AIDS become positive after HIV prevalence rates cross the 3 percent threshold, it is difficult to precisely estimate the standard errors in nonlinear models with modest sample sizes. Nevertheless, the results in table 3 suggest the importance of devising economic and other incentives for reducing medical brain drain as HIV prevalence rates cross the 3 percent threshold (average HIV prevalence rates after 1991 in table 1 are above this threshold).

The results from specification 4 show that the number of physicians abroad is a significant predictor of the number of adult deaths due to AIDS, while the number of physicians in the home country is not statistically significant. It is difficult to precisely estimate the coefficients in the presence of nonlinearities among explanatory variables using only five time observations on 39 countries.

The results on life expectancy are presented for two specifications (table 4). Specification 2 replaces the medical brain drain rate with the numbers of physicians in the home country and those working abroad. The exogeneity hypotheses for the medical brain drain rate in specification 1 and for the number of physicians abroad in specification 2 are rejected. Because specification 1 is a special case of specification 2, another likelihood ratio test can be applied to choose between these two specifications. Specification 2 is the preferred model in table 4, because the likelihood ratio statistic assumes the value 29.35 and is asymptotically distributed as a chi-squared variable with one degree of freedom.

Government health expenditures expressed as a percentage of GDP have positive coefficients in both specifications and are statistically significant. The data on this variable were compiled annually from 1996; the estimation method treated average expenditures as a time-invariant variable. The net enrollment in primary education is also estimated with positive and significant coefficients in both specifications in table 4. This result is not surprising, as school enrollment rates are very low, especially in rural areas of Sub-Saharan African countries, and child survival and life expectancy are likely to increase with education. The fact that the coefficient of the GDP variable is insignificant in specification 1 may seem surprising in view of the relation between GDP levels and life expectancy (Preston 1976). However, the coefficient of GDP is statistically significant in specification 2, which is a more general formulation. It is also likely that the HIV/AIDS pandemic is driving recent variations in life expectancy in Sub-Saharan Africa.

The estimated coefficients of HIV prevalence rates are significant and negative in both specifications shown in table 4. The short-run elasticity of life expectancy with respect to the HIV prevalence rate is 0.02, and the long-run elasticity is 0.07. Thus a doubling of the HIV prevalence rate would reduce life expectancy to 7 percent in the long run. The estimated coefficient for the medical brain drain rate is negative in specification 1, but not statistically significant. In the long run, the increase in the number of AIDS deaths predicted by the medical brain drain rate also implies lower life expectancy. However, the coefficients of the numbers of physicians in the home country and abroad are statistically insignificant in specification 2 after controlling for population size.

The coefficients of the lagged dependent variables are significant in both specifications but lower than those obtained for medical brain drain rates in table 2. This result may be due to the differences in availability of antiretroviral treatment across Sub-Saharan Africa; longitudinal data on the percentages of people with HIV receiving antiretroviral treatment are not available in the databases. Overall, the empirical models for adult deaths due to AIDS and for life expectancy exhibit a triangular form, although the medical brain drain rate is not a significant predictor of life expectancy. It is plausible that a combined variable for the emigration of physicians and nurses (on whom data were not available) might have had greater explanatory power because of the role of nurses in administering treatments.

## VI. CONCLUSIONS

What effect has Sub-Saharan Africa's AIDS pandemic had on the emigration of physicians? How has the medical brain drain affected life expectancy and the number of adult deaths due to AIDS?

Lower physicians' wages and higher HIV prevalence increase emigration of physicians from Sub-Saharan Africa. Empirical analyses at the country level that take into account country characteristics and unobserved heterogeneity are important for policy formulation. In particular, as is evident from the results here, physicians' wages and living standards need to be improved to better reflect the workload and risks in high HIV-prevalence environments. Some observers have suggested schemes in which developed countries would compensate Sub-Saharan African countries for the loss of their healthcare staff (Bhargava 2005a). Whether or not such schemes are adopted, it is imperative that international agencies implement pilot programs for reducing the emigration of physicians from Sub-Saharan Africa. Such policies would stop the vicious circle of higher HIV prevalence rates leading to increased emigration of physicians, which in turn lowers the quality and quantity of care for AIDS patients, increasing death rates and the numbers of orphaned children.

The medical brain drain rate is associated with an increase in the number of adult deaths after HIV prevalence rates cross the 3 percent mark. A doubling of the medical brain drain rate is associated with a 20 percent increase in adult

deaths from AIDS. These findings underscore the importance of retaining physicians in Sub-Saharan African countries, especially as antiretroviral treatment becomes more widely available.

The results from the model for life expectancy show the importance of lower HIV prevalence rates and to some extent higher government expenditures on health. Increasing life expectancy is beneficial for the welfare of children who might otherwise be orphaned by AIDS and for investments in education and training (Bhargava 2005b; Bell, Devarajan, and Gersbach 2006). The results presented here do not find a significant association between medical brain drain and life expectancy. Analyses that consider a longer-time frame may find evidence for such effects.

It would be helpful if OECD countries would compile information on the immigration of nurses, who play an important role in providing care to HIV patients. Inclusion of such data could affect some of the results presented here.

#### FUNDING

This research was supported by the International Migration and Development Research Programme of the World Bank.

#### REFERENCES

- Anderson, T.W., and C. Hsiao. 1981. "Estimation of Some Dynamic Models with Error Components." *Journal of American Statistical Association* 76(375):598–606.
- Awases, M., A. Gbary, J. Nyoni, and R. Chatora. 2003. *Migration of Health Professionals in Six Countries: A Synthesis Report*. World Health Organization, Regional Office for Africa, Brazzaville, Republic of Congo.
- Barro, R.J., and J.W. Lee. 2001. "International Data on Educational Attainment: Updates and Implications." *Oxford Economic Papers* 53(3):541–63.
- Bell, C., S. Devarajan, and H. Gersbach. 2006. "The Long-Run Economic Costs of AIDS: A Model with Applications to South Africa." *World Bank Economic Review* 20(1):55–89.
- Belperio, P., and D. Rhew. 2004. "Prevalence and Outcomes of Anemia in Individuals with Human Immunodeficiency Virus: A Systematic Review of the Literature." *American Journal of Medicine* 116(Supplement 1):27–43.
- Bhargava, A. 1991. "Identification and Panel Data Models with Endogenous Regressors." *Review of Economic Studies* 58(1):129–40.
- . 1997. "Nutritional Status and the Allocation of Time in Rwandese Households." *Journal of Econometrics* 77(1):277–95.
- . 2001. "Stochastic Specification and the International GDP Series." *Econometrics Journal* 4(2):274–87.
- . 2005a. "AIDS Epidemic and Health Care Infrastructure Inadequacies in Africa: A Socioeconomic Perspective." *Journal of AIDS* 40(2):241–42.
- . 2005b. "AIDS Epidemic and the Psychological Well-Being and School Participation of Ethiopian Orphans." *Psychology, Health and Medicine* 10(3):263–75.
- Bhargava, A., and J.D. Sargan. 1983. "Estimating Dynamic Random Effects Models from Panel Data Covering Short-Time Periods." *Econometrica* 51(6):1635–60.

- Bhargava, A., and J. Yu. 1997. "A Longitudinal Analysis of Infant and Child Mortality Rates in Developing Countries." *Indian Economic Review* 32(2):141–53.
- Bhargava, A., D. Jamison, L. Lau, and C. Murray. 2001. "Modeling the Effects of Health on Economic Growth." *Journal of Health Economics* 20(3):423–40.
- Caral, M., and K. Holmes. 2001. "The Multicentre Study of Factors Determining the Different Prevalences of HIV in Sub-Saharan Africa." *AIDS* 15(Supplement 4):S1–S132.
- Carrington, W., and E. Detragiache. 1999. "How Extensive Is the Brain Drain?" *Finance and Development* 36(2):46–49.
- Cohen, D., and M. Soto. 2007. "Growth and Human Capital: Good Data, Good Results." *Journal of Economic Growth* 12(1):51–76.
- Docquier, F., and A. Bhargava. 2007. "The Medical Brain Drain: A New Panel Data Set on Physicians' Emigration Rates (1991–2004)." ([http://www.ires.ucl.ac.be/csssp/home\\_pa\\_pers/docquier/filepdf/mbd1\\_description.pdf](http://www.ires.ucl.ac.be/csssp/home_pa_pers/docquier/filepdf/mbd1_description.pdf)).
- Docquier, F., and A. Marfouk. 2006. "Measuring International Migration by Educational Attainment in 1990–2000, Release 1.1." In C. Ozden, and M. Schiff, eds., *International Migration, Remittances, and the Brain Drain*. Washington, D.C.: World Bank.
- Gutierrez, J., B. Johns, T. Adam, S. Bertozzi, T. Edejer, R. Greener, C. Hankins, and D. Evans. 2004. "Achieving the WHO/UNAIDS Antiretroviral Treatment 3 by 5 Goal: What Will It Cost?" *Lancet* 364(9428):63–64.
- ILO (International Labour Organization). 2005. "Laborsta Internet: Occupational Wages and Hours of Work." Geneva. (<http://laborsta.ilo.org>).
- Jaffar, S., A. Grant, J. Whitworth, P. Smith, and H. Whittle. 2004. "The Natural History of HIV-1 and HIV-2 Infections in Adults in Africa: A Literature Review." *Bulletin of World Health Organization* 82(66):462–69.
- Neyman, J., and E. Scott. 1948. "Consistent Estimates Based on Partially Consistent Observations." *Econometrica* 16(1):1–32.
- Numerical Algorithm Group. 1991. *Numerical Algorithm Group Mark 13*. Oxford, United Kingdom: University of Oxford.
- Ozden, C., and M. Schiff. 2006. *International Migration, Remittances, and the Brain Drain*. Washington, D.C.: World Bank.
- Physicians for Human Rights. 2004. *An Action Plan to Prevent Brain Drain: Building Equitable Health Systems in Africa*. Boston, Mass.: Physicians for Human Rights. (<http://physiciansforhumanrights.org/library/report-2004-july.html>).
- Preston, S. 1976. *Mortality Patterns in National Populations*. New York: Academic Press.
- Subbarao, K., and D. Coury. 2004. *Reaching Out to Africa's Orphans: A Framework for Publication*. Africa Region Human Development Series. Washington, D.C.: World Bank.
- UNAIDS (Joint United Nations Programme on HIV/AIDS). 2006. HIV Data. Geneva. ([www.unaids.org/en/hiv\\_data/default.asp](http://www.unaids.org/en/hiv_data/default.asp)).
- UNESCO (United Nations Educational, Scientific, and Cultural Organization). 2004. Statistics for Downloading. Institute for Statistics, Montreal. (<http://www.uis.unesco.org>).
- USAID, UNICEF, and UNAIDS (U.S. Agency for International Development, United Nations Children's Fund, and Joint United Nations Programme on HIV/AIDS). 2003. *Children on the Brink 2002*. New York: United Nations Children's Fund.
- Vujcic, M., P. Zurn, K. Diallo, O. Adams, and M. Dal Poz. 2004. "The Role of Wages in the Migration of Health Care Professionals from Developing Countries." *Human Resources for Health* 2 (3) doi:10.1186/1478-4491. (<http://www.human-resources-health.com/content/2/1/3>).
- World Bank. 2005. *World Development Indicators*. Washington, D.C.
- . 2006. EDSTATS Database. Washington, D.C. (<http://devdata.worldbank.org/edstats/>).
- WHO (World Health Organization). 2006. "Core Health Indicators." Geneva. ([http://www3.who.int/whosis/core/core\\_select.cfm](http://www3.who.int/whosis/core/core_select.cfm)).