

HIV pandemic, medical brain drain and economic development in sub-Saharan Africa

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Abstract

This paper analyzes the factors affecting emigration of physicians from sub-Saharan countries and the effects of this medical brain drain on number of deaths due to AIDS, life expectancy, and economic growth using country-level longitudinal data at 3-year intervals for the period 1990-2004. Data were compiled on the emigrating African physicians from the receiving 16 O.E.C.D. countries. A comprehensive longitudinal database was developed by merging the medical brain drain variables with recent data on HIV prevalence, public health expenditures, physicians' wages, and economic and demographic variables. A triangular system of equations was estimated using 5 time observations for medical brain drain rates, number of deaths due to AIDS, life expectancy, and GDP growth rates, taking into account the inter-dependence between these variables. The main findings from estimating random effects models were, first, that lower wages and higher HIV prevalence rates predicted significantly higher medical brain drain from sub-Saharan African countries. Second, higher medical brain drain rates were associated with greater number of deaths due to AIDS but the effects of medical brain drain on life expectancy were not evident in this time frame. Finally, the regressions for GDP growth rates indicated the need for taking into account the underlying trends in population; investment in the economies and life expectancy were significant predictors of GDP growth rates. Overall, the empirical results underscored the need for higher expenditures on HIV prevention and treatment, and for improving economic conditions of physicians for mitigating the adverse consequences of HIV pandemic on indicators of well-being in sub-Saharan African countries.

Keywords

AIDS deaths; economic growth; HIV; life expectancy; longitudinal data; migration; physicians; random effects models; simultaneity.

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1. Introduction

The HIV/AIDS pandemic in sub-Saharan Africa is touching all dimensions of social and economic lives of the inhabitants. In many countries, the gains in life expectancy achieved over the last several decades have been wiped out. Reductions in life expectancy are detrimental at the macro-economic level since they entail reduced economic growth (Bhargava et al., 2001). Furthermore, at the micro level, early parental deaths have created the enormous problem of young children orphaned by AIDS (USAID/UNICEF/UNAIDS, 2002, Subbarao and Coury, 2004). Orphaned children are worse off in their psychological indicators of well-being, and also in terms of school attendance that is critical for learning and for increasing the awareness of HIV transmission routes (Bhargava, 2005a). It is therefore imperative to tackle the consequences of the AIDS pandemic in sub-Saharan Africa; informed policy formulation would generally require 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 by a broader focus on issues that are of interest to researchers in biomedical and social sciences. For example, the World Health Organization has advocated anti-retroviral treatment via public clinics for patients in HIV/AIDS Stage 4 with CD4 cell count below 200 (Gutierrez et al., 2004). However, elaborate studies on the effects of anti-retroviral treatment on productivity of under-nourished populations can provide insights for enhancing the treatment strategies. In a similar vein, a recent report (Physicians for Human Rights, 2004) has emphasized the need for sub-Saharan African countries to invest greater resources in training physicians and nurses. The training of additional healthcare staff, however, is hampered by the low enrollment rates in tertiary education in sub-Saharan African countries and would benefit from strategies such as training African physicians in Asian countries (Bhargava, 2005b). Furthermore, individual-level surveys in six African countries indicate that over half the physicians would like to emigrate to developed countries for better professional opportunities and lifestyles (Awases et al., 2003). For example, the percentages of healthcare staff that were “stressed” due to caring for HIV/AIDS patients in Cameroon, Ghana, Senegal, South Africa, Uganda and Zimbabwe were 45, 38, 49, 58, 62, and 58, respectively. It is evident that health policies should be based on evidence derived from various data sources for sub-Saharan African countries.

Further, the trends underlying international migration of skilled and unskilled labor are complex and reflect many aspects of labor supply and demand conditions in developing and developed countries (Ozden and Schiff, 2006). While it has been argued that skilled migration may be detrimental for developing countries, the possible benefits include remittances from developed countries and the creation of business and information networks that can enhance economic performance in the countries of origin. In contrast, migration of physicians and nurses from developing countries is a more specific issue; the net effects on countries of origins are likely to depend on the domestic demand for healthcare services over a long time frame. In view of the AIDS pandemic, however, sub-Saharan African countries would not appear to be in a position to absorb an attrition of their scarce healthcare resources. Paradoxically, hazardous working conditions in caring for AIDS patients and the possibility of children of healthcare staff contracting HIV as they enter adolescence may exacerbate medical brain drain (Awases et al., 2003, Bhargava, 2005b).

There have been numerous studies at the household level in sub-Saharan African countries on issues of HIV/AIDS; the data have indicated that factors such as multiple sex partners and sexually transmitted infections can exacerbate HIV transmission (Caral and Holmes, 2001). Moreover, HIV prevalence rates constructed from individual-level data taking into account the survival time after contracting HIV are useful for estimating life expectancy in the countries. However, the effects of medical brain drain on indicators of well-being such as adult deaths due to AIDS, life expectancy and GDP growth rates cannot be investigated using the data from household surveys. For understanding the consequences of medical brain drain, it is necessary to analyze data at the country level. Because of the upward trends in HIV prevalence and medical brain drain rates during the last decade in sub-Saharan Africa, longitudinal data are useful for modeling the various inter-relationships. Moreover, analyses at the country level can provide insights for the design of future surveys for investigating economic and social factors underlying medical brain drain.

A major shortcoming in analyses of data at the national level is that variables reflecting medical brain drain are not available for sub-Saharan African countries in the existing databases. Fortunately, most statistical and medical agencies in the receiving O.E.C.D. countries keep longitudinal

information on immigration of physicians; information on nurses is not compiled in this detailed fashion. Furthermore, while databases such as the World Development Indicators (WDI; World Bank, 2005) contain limited information on HIV/AIDS prevalence rates, AIDS-related variables were recently expanded in a longitudinal fashion for sub-Saharan African countries by UNAIDS (2006). Lastly, one can merge the data on wages from International Labour Organization (2005) and data on public health expenditures from the World Health Organization (2006) with the economic and demographic variables in WDI to create a comprehensive longitudinal database. In this paper, models for medical brain drain rates, number of adult deaths due to AIDS, life expectancy, and economic growth rates are estimated from longitudinal data for the period 1990-2004 and alternative specifications are tested using econometric techniques.

The structure of this paper is as follows: Section 2 briefly describes the data compiled on medical brain drain and other variables. The analytical framework for the specification of the relationships is developed in Section 3.1, where the likely forms of inter-dependence between medical brain drain rates, number of deaths due to AIDS, life expectancy, and GDP growth rates are outlined. The empirical models are spelled out in Section 3.2, and the econometric methods necessary for estimation and testing are briefly described in Section 3.3. Section 4 presents the results from estimating random effects models for medical brain drain rates, number of adult deaths due to AIDS, life expectancy and GDP growth rates for sub-Saharan African countries at 5 time points in the period 1990-2004. Certain exogeneity hypotheses for the variables are tested to assess the validity of model assumptions. The conclusion from this study and the need for further research are summarized in Section 5.

2. The Data

While the number of physicians working in countries are available in databases such as the WDI (World Bank, 2005), the number of physicians emigrating from sub-Saharan African and other developing countries are difficult to assess without compiling data from the recipient countries. We focused on the 16 most important O.E.C.D. countries (Australia, Austria, Belgium, Canada, Denmark, France, Germany, Ireland, Italy, New Zealand, Norway, Portugal, Sweden, Switzerland, United

Kingdom and United States) where the data on foreign born physicians are available longitudinally. Further, following Carrington and Detragiache (1999) and Docquier and Marfouk (2006), we evaluate the medical brain drain in terms of stock and rates. Denoting the stock of physicians from country i working abroad by $M_{i,t}$ and the number of physicians working in the home country by $P_{i,t}$, the rate of medical brain drain for country i in time period t can be written as:

$$m_{i,t} = \frac{M_{i,t}}{P_{i,t} + M_{i,t}} \quad (1)$$

We developed an annual database from 1990 to 2004 partly because the data provided by national agencies are available for this period. For the data extracted from national censuses, we typically have two or three data points and interpolate the remaining years using a log-linear adjustment. Further, in some O.E.C.D. countries, emigrants are defined according to their country of qualification; such data were obtained from the medical associations in Canada, France, New Zealand, Norway, United Kingdom and the United States and represent approximately 67 percent of the observations in our sample. When the country of qualification could not be determined, we defined emigrants according to their country of birth. Such data were obtained from the national censuses and registers in Australia, Austria, Belgium, Denmark, Ireland and Sweden, and represent 20 percent of our sample. Finally, when the country of birth was not available, we defined emigrants according to their citizenship. This was the case for Italy, Germany, Portugal and Switzerland i.e. approximately for 13 percent of the sample. For illustrative purposes, Figure 1 plots the rates of medical brain drain in 1990 and 2000 from sub-Saharan African countries to the 16 O.E.C.D. countries.

Further, longitudinal data on HIV prevalence rates and the number of adult deaths due to AIDS in sub-Saharan African countries were recently released by UNAIDS for the period 1990-2004 (UNAIDS, 2006); these variables are much more complete than in previous data sets. The World Health Organization (2006) has compiled longitudinal information in sub-Saharan African countries on government expenditures on health for the period 1996-2004. Because of missing observations for the period 1990-1995, average government health expenditures during 1996-2004 were treated as time invariant variables in the econometric modeling. The data on wages in sub-Saharan African countries

were taken from International Labour Organization (2005) where the physicians' wages are expressed in terms of the average wage rates in the United States (see also Vujicic et al., 2004).

Next, we obtained the data on GDP series in constant dollars in 2000 from the WDI (World Bank, 2005); variables such as exports and imports of the countries were also taken from the WDI. While the WDI data set contains variables such as population, school enrollment and literacy rates, additional information on these variables was taken from the UNESCO (2005) and World Bank (2006) to reduce the numbers of missing observations. Finally, we averaged the variables in our database to create averages at 3-year intervals for the period 1990-2004 i.e. 5 time observations. Alternative data sets were created using averages at 2-year and 4-year intervals though we focus on the 3-year averages in part because of the complex stochastic properties of GDP series and also because interpolations of variables such as life expectancy can present difficulties in econometric modeling (Bhargava, 2001).

The sample means and standard deviations of selected variables at five time points (1991, 1994, 1997, 2000, and 2003) are presented in Table 1. A steady increase in HIV prevalence rates and the number of adult deaths due to AIDS is evident from the sample means. Moreover, there is an upward trend in the number of physicians emigrating from sub-Saharan African countries and in the rate of medical brain drain calculated using equation (1). The average life expectancy fell by approximately two years between 1991 and 2003. There is an increase over time in the net school enrollment rates in primary and secondary education. The physicians' wages in sub-Saharan African countries expressed in terms of U.S. wages show a slight decline over time. Lastly, the import/GDP and export/GDP ratios show an upward trend reflecting an increase in the openness to trade during the sample period.

3.1 Analytical framework for modeling the inter-relationships between HIV prevalence, medical brain drain, health indicators, and economic growth

The inter-relationships between HIV prevalence rates, medical brain drain, number of adult deaths due to AIDS, life expectancy, and economic growth estimated using country-level data are of considerable interest for policy makers. While it is often difficult to deduce the effects of disease

prevalence rates on aggregate economic indicators, the nature of HIV transmission through sexual intercourse, lags between contracting HIV and the onset of AIDS, and the likely negative impact of reduced life expectancy on economic growth have important implications for specification of macro-econometric models. It is, however, more complex to explain HIV prevalence rates at the country level since information on average number of sex partners, prevalence of sexually transmitted infections, and patterns of migrant labor are unavailable in the databases. Even so, one can analyze the effects of HIV prevalence rates on medical brain drain for sub-Saharan African countries, while allowing the possibility that HIV prevalence may be influenced by medical brain drain i.e. HIV prevalence rate is an “endogenous” variable in the system.

Further, most individuals in the rural areas of sub-Saharan African countries have limited access to even basic healthcare and a small proportion of those infected with HIV receive anti-retroviral treatment. Thus, the lags between contracting HIV and the onset of AIDS are likely to depend mainly on the natural rate of disease progression. While the survival time for individuals contracting HIV in sub-Saharan Africa is approximately 10 years (Jaffar et al., 2004), poor nutritional status and especially anemia are intertwined with HIV progression (Belperio and Rhew, 2004). These biological aspects are useful for interpreting empirical evidence from analyses of country-level data. In particular, in the 15-year period (1990-2004) for which we have longitudinal data, one would expect to see a decline in life expectancy due to the HIV pandemic in sub-Saharan Africa. Moreover, medical brain drain might increase the number of adult deaths due to AIDS especially among urban populations that are receiving some form of medical care. However, the 15-year period may not be sufficiently long for observing the adverse effects of medical brain drain on HIV prevalence rates or on life expectancy that is already low in sub-Saharan Africa due to a variety of factors.

While macro-econometric analyses are useful for understanding the broad effects of HIV prevalence rates on economic activity, it is helpful to outline the pathways through which HIV prevalence can depress economic activity (e.g. Bell et al., 2006). Thus, for example, in developed countries with anti-retroviral treatment available to HIV-infected members of the labor force, even high HIV prevalence rates may not significantly lower productivity. By contrast, in developing

countries, work absenteeism is likely to be a salient feature of HIV-positive individuals not receiving anti-retroviral treatment. However, the effects of HIV prevalence rates on aggregate indicators of economic activity may be dampened in sub-Saharan Africa if individuals are mainly engaged in household tasks and work on their own farms; such work can be substituted in the short run by other household members (Bhargava, 1997). While it is important to investigate the effects of HIV prevalence and medical brain drain rates on economic growth, it is plausible that in a relatively short time frame, the effects of HIV prevalence on GDP growth rates operate primarily through reduced life expectancy that hampers investments in education and training (Bhargava et al., 2001).

The preceding discussion suggests that the inter-relationships between HIV prevalence, medical brain drain, number of adult deaths due to AIDS, life expectancy, and GDP growth 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 and GDP levels in the countries and also by the HIV prevalence rates that increase the risks in work environment. Second, HIV prevalence rates and medical brain drain are likely to increase number of adult deaths due to AIDS and reduce life expectancy in the countries. Third, the model for GDP growth rates should take into account the effects of life expectancy and possibly HIV prevalence rates, and incorporate economic factors such as investment levels in the economies and the openness to trade.

Because we have longitudinal data at 5 time points for estimating econometric models for outcomes such as medical brain drain rates, number of adult deaths due to AIDS, life expectancy, and GDP growth rates, the simultaneous equations system is a “block triangular” one i.e. the triangular system of equations itself contains longitudinal observations that are in a triangular form due to the time ordering (see below). Appropriate techniques for efficiently estimating all the equations simultaneously are not as yet available in the econometrics literature. Instead, one can estimate each model separately using longitudinal estimation methods that take into account potential endogeneity of variables such as HIV prevalence rates. Moreover, the models for medical brain drain rates, number of adult deaths due to AIDS, and life expectancy should be dynamic in nature since the past realization of these variables are critical for explaining the respective current levels. The models for GDP growth

rates can be specified along the lines of Barro and Sala-i-Martin (1995) though one needs to treat variables such as the lagged GDP levels and life expectancy as endogenous (Bhargava et al., 2001). It is also useful to model the aggregate and per capita GDP growth rates partly because of the possible effects of the HIV/AIDS pandemic on population growth.

3.2 The empirical models

The first equation in the simultaneous equations system is the model for the rate of medical brain drain from sub-Saharan African countries given by:

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

The initial observations on medical brain drain rate and the lagged dependent variables are treated as endogenous variable in the system i.e. correlated with the errors u_{it} (Anderson and Hsiao, 1981, Bhargava and Sargan, 1983, see below). Moreover, HIV prevalence rate is treated as an endogenous variable and the exogeneity assumptions are tested via likelihood ratio tests. Also, a dynamic model for HIV prevalence rate is estimated to investigate the possible “reverse causality” i.e. if higher medical brain drain rate predicts higher HIV prevalence. The errors u_{it} ’s can be decomposed in a random effects fashion as:

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

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

Second, the empirical models for number of adult deaths due to AIDS and for life expectancy in sub-Saharan African countries are quite similar. For brevity, we write the model for number of deaths due to AIDS as:

$$\begin{aligned}
(\text{Deaths due to AIDS})_{i,t} = & b_0 + b_1 \ln(\text{Population})_i \\
& + b_2 \ln(\text{Prop. labor force with secondary +tertiary education})_{i,t} \\
& + b_3 \ln(\text{GDP per capita})_{i,t} + b_4 \ln(\text{HIV prevalence rate})_{i,t} \\
& + b_5 \ln(\text{Medical brain drain rate})_{i,t} + b_6 \ln(\text{Deaths due to AIDS})_{i,t-1} \\
& + u_{2i,t} \quad (i=1,\dots,N; t=2,3,4,5) \quad (4)
\end{aligned}$$

In equation (4), the total population in the countries is accounted for and medical brain drain and HIV prevalence rates are treated as endogenous variables. Also, an interaction term between HIV prevalence and medical brain drain rates is included in an extended version of this model (Specification 2, Table 3). Further, in the model for life expectancy, Specification 2 (Table 4) replaced the medical brain drain rate by the numbers of physicians at home and those working abroad. The net percentages of school enrollment in primary education is a regressors in the model for life expectancy, since even a few years of primary education were associated with lower child mortality levels in sub-Saharan Africa (Bhargava and Yu, 1997).

The final equation in the system for GDP growth rates is given by:

$$\begin{aligned}
(\text{GDP growth rate})_{i,t} = & c_0 + c_1 \ln(\text{Prop. labor force with secondary +tertiary education})_{i,t-1} \\
& + c_2 \ln(\text{Investment/GDP})_{i,t-1} + c_3 \ln(\text{Imports/GDP})_{i,t-1} + c_4 \ln(\text{Export/GDP})_{i,t-1} \\
& + c_5 \ln(\text{Population})_{i,t-1} + c_6 \ln(\text{Life expectancy})_{i,t-1} + c_7 \ln(\text{GDP})_{i,t-1} \\
& + u_{3i,t} \quad (i=1,\dots,N; t=2,3,4,5) \quad (5)
\end{aligned}$$

The model in equation (5) is in the spirit of the work by Barro and Sala-i-Martin (1995) in that the lagged values of the explanatory variables are included as explanatory variables; life expectancy and GDP levels are treated as endogenous variables (Bhargava et al., 2001). Note that the export/GDP and import/GDP ratios are included instead of the trade/GDP ratio since the coefficients of export and import ratios may not sum up to one (Bhargava, 2006). We also estimate the model for per capita GDP growth rates omitting the population variable from the explanatory variables in equation (5). In fact, the model for per capita GDP growth rates is a special case of the model in equation (5) with the restriction that the coefficient of population $c_5=1$. A statistical test is used to discriminate between these two specifications. Lastly, as alluded to above, HIV prevalence and medical brain drain rates

were not significant predictors of the GDP growth rates and hence are excluded from the model in equation (5).

3.2 The econometric framework

The methodology used for estimation of dynamic and static random effects models where some explanatory variables are endogenous was developed in Bhargava and Sargan (1983) and Bhargava (1991). Let the dynamic model be given by

$$y_{it} = \sum_{j=1}^m z_{ij} \gamma_j + \sum_{j=1}^{n_1} x_{1ij} \beta_j + \sum_{j=n_1+1}^n x_{2ij} \beta_j + \alpha y_{i,t-1} + u_{it} \quad (6)$$

where, the z 's are time invariant variables, x_1 and x_2 are, respectively, exogenous and 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 i.e. is included in x_{2ij} 's; unobserved factors affecting HIV prevalence rates may be influenced by the country-specific random effects (δ_i) in equation (2). It is helpful to re-write the dynamic model in a simultaneous equations framework i.e. by defining a "reduced form" for the initial observations and a system of (T-1) "structural" equations for remaining time periods (Bhargava and Sargan, 1983):

$$y_{i1} = \sum_{j=0}^m z_{ij} \zeta_j + \sum_{j=1}^T \sum_{k=1}^T v_{jk} x_{ijk} + u_{i1} \quad (i=1, \dots, N) \quad (7)$$

and

$$\begin{matrix} B & Y' & + & C_z & Z' & + & C_x & X' & = & U' \\ (T-1) \times T & T \times N & & (T-1) \times (m+1) & (m+1) \times N & & (T-1) \times nT & nT \times N & & (T-1) \times N \end{matrix} \quad (8)$$

Here, Y , Z and X are, respectively, 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)×T lower triangular matrix of coefficients:

$$B_{ii} = \alpha, B_{i,i+1} = -1, B_{ij} = 0 \text{ otherwise} \quad (i=1, \dots, T-1; j=1, \dots, T) \quad (9).$$

The matrices C_z and C_x contain coefficients of time invariant and time varying regressors, respectively; the matrix U contains the error terms.

The profile log-likelihood functions of the model in equation (2) can be optimized using the numerical scheme such as E04 JBF from Numerical Algorithm Group (1991). Assuming that the number of countries (N) is large but the number of time observations fixed, the asymptotic standard errors of the parameters are obtained by approximating second derivatives of the function at the maximum. Furthermore, the random effects decomposition in equation (3) can be tested in this framework using likelihood ratio tests. Given 5 time observations, under the null hypothesis of the random effects decomposition, the likelihood ratio statistic is distributed for large N as a Chi-square variable with 12 degrees of freedom.

Further, in short panels, it is reasonable to assume that a variable such as the HIV prevalence rates in equation (2) are correlated only with the country-specific random effects δ_i i.e.

$$x_{2ijt} = \lambda_j \delta_i + x_{2ijt}^* \quad (10)$$

where x_{2ijt}^* are uncorrelated with δ_i , and δ_i are randomly distributed variables with zero mean and finite variance as in equation (3). This correlation pattern was invoked by Bhargava and Sargan (1983) and endogenous variables of the type in equation (10) have been referred to as “special” endogenous variables. The advantage in invoking (10) is that deviations of the x_{2ijt} 's from their time means:

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

where

$$\bar{x}_{2ij} = \frac{\sum_{t=1}^T x_{2ijt}}{T} \quad (j=n_1+1, \dots, n; i=1, \dots, N) \quad (12),$$

can be used as $[(T-1)n_2]$ additional instrumental variables to facilitate identification and estimation of the parameters (Bhargava and Sargan, 1983). Moreover, exogeneity hypotheses can be tested using likelihood ratio tests. Given 5 time observations, the likelihood ratio statistic for testing correlation between the random effects (δ_i) and the time means of HIV prevalence rates in equation (2) is distributed as a Chi-square variable with 5 degrees of freedom.

For static models such as that for GDP growth rates in equation (5), one can invoke more general assumptions on the form of endogeneity for variables such as GDP levels and life expectancy with the 5 time observations available. First, endogenous variables (x_2) may be correlated with the errors u_{it} in a general way i.e. x_2 are fully endogenous; x_{2jt} must be treated as different variables in each time period.

Let X_1 and X_2 be, respectively, the $n_1 \times 1$ and $n_2 \times 1$ vectors containing the exogenous and endogenous time varying variables ($n_1+n_2=n$), and let Z be the $m \times 1$ vector of time invariant variables. We can write a reduced form equation for the fully endogenous variables X_2 as:

$$X_{2it} = \sum_{j=1}^T F_{ij} X_{1ij} + F_t^* Z_i + U_{2it} \quad (13),$$

where F_{ij} ($t=1, \dots, T; j=1, \dots, T$) and F_t^* ($t=1, \dots, T$) are, respectively, $n_2 \times n_1$ and $n_2 \times m$ matrices of reduced form coefficients; U_{2it} is the $n_2 \times 1$ vector of errors.

The reduced form equation (13) is a general formulation for correlation between the time varying endogenous variables and errors u_{3it} affecting model (5). For example, lagged GDP levels may be correlated with the errors in a general way in the models for growth rates and should be treated as fully endogenous variables (Bhargava et al., 2001). However, due to the small number of time observations, it may be difficult to achieve identification of the model parameters under the general correlation pattern. In our estimation, efficient Three Stage Least Squares type instrumental variables estimators are used to estimate the model parameters in equations (5), assuming the correlation patterns for x_{2it} in equations (10) and (13), and without restricting the variance covariance matrices of the errors. While one can also use “fixed” effects estimators (with indicator variables for each country) to circumvent certain endogeneity problems, the increase in the number of parameters with sample size leads to the problem of “incidental parameters” (Neyman and Scott, 1948).

Lastly, in the spirit of Wald (1947), one can sequentially test exogeneity assumptions using statistics based on instrumental variables estimates because the correlation pattern for special endogenous variables in (10) is a special case of the general formulation (13) (Bhargava, 1991). The sequential Chi-square test for exogeneity would first test the validity of the special correlation pattern (10). If, as in the model for growth rates, two time varying variables are postulated to be endogenous with four time observations available for the estimation, then under the null hypothesis, the first test statistic is asymptotically distributed as a Chi-square variable with 24 degrees of freedom. If the null hypothesis cannot be rejected, then we can test if the time means of the endogenous variables (x_2) in equation (10) are uncorrelated with the random effects δ_i . The test statistic for the second set of hypotheses is asymptotically distributed as a Chi-square variable with 8 degrees of freedom.

4. 1 Empirical results from the model for medical brain drain rates

The results from estimating the model in equation (2) for medical brain drain rates are presented in Table 2. Specification 1 treats the HIV prevalence rate as an exogenous variable and does not restrict the variance covariance matrix of the errors in the simple random effects fashion (equation (3)). In Specification 2, the variance-covariance matrix is restricted to be that of the random effects model and the ratio of between to within variance and the within variance are also estimated. Specification 3 treats the HIV prevalence rates as an endogenous variable that is correlated with the country-specific random effects. First, one can discriminate between these three specifications using likelihood ratio tests. The likelihood ratio statistic for testing Specification 2 against Specification 1 is 42.32 and it is distributed as a Chi-square variable with 12 degrees of freedom. Since the 5% critical level is 21.0, the test rejects the null hypothesis of the simple random effects decomposition. The likelihood ratio statistic for testing the exogeneity of the HIV prevalence rate assumes the value 11.38 that is close to the 5% critical limit 11.10. Thus, the null hypothesis is rejected though 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; we focus on the results from Specification 3 in the discussion.

Second, the coefficient of the variable measuring wages of physicians in sub-Saharan African countries in terms of those in the U.S. is significant at the 5% level in Specifications 1 and 3. Thus, countries with higher physician wages experience lower emigration rates. These findings support the responses of physicians from sub-Saharan African countries (Awases et al., 2003) where percentages of health professionals reporting higher salaries as a motivation for emigration in Cameroon, Ghana, South Africa, Uganda and Zimbabwe were, 68, 85, 78, 84, and 77, respectively. Third, the percentages of net enrollment in secondary education in the country are positive and significant predictors of the medical brain drain rates, with the estimated short run elasticity 0.12. This is not surprising since higher enrollments in secondary education entail higher expenditures on education; physicians graduating from such environments are likely to have better emigration prospects.

Fourth, the HIV prevalence rate is a significant predictor of medical brain drain in all three specifications in Table 2; the short run elasticity 0.07 is robust across the three specifications.

Moreover, the coefficient of the lagged dependent variable is estimated to be 0.93 in Specification 3 so that the long-run impacts of the explanatory variables are approximately 14 times higher than the respective short run coefficients. Thus, the long run elasticity of medical brain drain rate with respect to HIV prevalence is close to unity; a doubling of HIV prevalence rate implies a doubling of the medical brain drain rate in the long run. This is a rather large effect with important policy implications especially since the average number of physicians per 1,000 of population is only 0.15 in sub-Saharan Africa (Table 1). Furthermore, as more HIV-infected individuals get sick with AIDS and require care, it would be necessary to have higher ratios of physicians to the population.

Fifth, the large estimated coefficients of the lagged dependent variable also suggest that emigration patterns in sub-Saharan African countries are getting well-established presumably due to the stable demand from O.E.C.D. countries for physicians trained in specific countries. Also, while Specification 2 is rejected in favor of Specification 1 by the likelihood ratio test, the estimated between to within variance ratio is not significant in Specification 2 which may be due to the relatively small number of countries in the sample. Lastly, a model similar to that in equation (2) was estimated for HIV prevalence rates with medical brain drain rate as an explanatory variable in order to investigate the possible “reverse causality”. However, coefficients of the medical brain drain rate were not significant in any of the specifications thereby supporting our model formulation and exogeneity assumptions.

4. 2 Empirical results from the models for numbers of adult deaths due to AIDS and life expectancy in the countries

Table 3 reports the results from the model for the numbers of adult deaths due to AIDS in sub-Saharan African countries for two specifications; Specification 2 includes an interaction term between medical brain drain and HIV prevalence rates, since higher HIV prevalence rates can exacerbate the effects of medical brain drain on adult deaths due to AIDS. The constraints on the variance covariance matrix implied by the random effects decomposition are rejected in both specifications. Moreover, the exogeneity hypotheses for the medical brain drain and HIV prevalence rates are rejected; Specifications 1 and 2 treat these variables as endogenous.

The results from the two specifications show the importance of HIV prevalence rates for the number of adult deaths due to AIDS. While the short run elasticity from Specification 1 is 0.54, the long run elasticity is close to one. In view of the lack of anti-retroviral treatment for the vast majority of HIV-infected individuals during our sample period 1990-2004, it is not surprising to find large long-run effects of HIV prevalence rates on adult deaths in sub-Saharan Africa. The medical brain drain rate is a significant predictor of the number of deaths due to AIDS in Specification 1, with the short and long run elasticities 0.1 and 0.2, respectively. Although most HIV-positive individuals in sub-Saharan Africa do not receive anti-retroviral treatment, even basic care such as the treatment for tuberculosis that accompanies HIV progression is likely to be enhanced by access to physicians in the country. Thus, at an aggregate level, medical brain drain from sub-Saharan African countries appears to decrease the survival time of HIV-positive individuals.

Further, in Specification 2 of Table 3, the interaction term between medical brain drain and HIV prevalence rates is significant indicating that the effects of medical brain drain are likely to depend on HIV prevalence rates in the countries. While the effects of medical brain drain rate on the number of deaths due to AIDS become positive after HIV prevalence rates cross 1 percent, it is difficult to precisely estimate the standard errors in non-linear models with modest sample sizes. Nevertheless, the empirical results from Specifications 1 and 2 suggest the importance of devising economic and other incentives for reducing medical brain drain especially as HIV prevalence rates cross certain thresholds in sub-Saharan African countries.

Table 4 reports the results for the model for life expectancy in sub-Saharan African countries for two specifications; Specification 2 replaces medical brain drain rate by the numbers of physicians in the home country and those abroad. The exogeneity hypotheses for medical brain drain rate in Specification 1 and that 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, since the likelihood ratio statistic assumes the value 29.35 and is asymptotically distributed as a Chi-square variable with one degree of freedom.

The government health expenditures expressed as a ratio to the GDP are estimated with positive coefficients in both specifications and are statistically significant. As noted above, the data on this variable were compiled annually from 1996 and the estimation method treated the 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 is perhaps not surprising since 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 coefficient of the GDP variable is insignificant in Specification 1 that may seem surprising in view of the relationship between GDP levels and life expectancy (Preston, 1976). However, the coefficient of GDP is statistically significant in Specification 2 that is a more general formulation. Also, it is likely that recent variations in life expectancy in sub-Saharan Africa are driven to a considerable extent by the HIV/AIDS pandemic.

The coefficients of HIV prevalence rates are estimated with negative signs in both specifications and are significant. The short and long elasticities of life expectancy with respect to HIV prevalence rate are 0.022 and 0.07, respectively. Thus, life expectancy would fall in the long run by 7% with the doubling of the HIV prevalence rates. Because these results are from the data corresponding to the onset of the HIV epidemic, HIV prevalence rates might have a greater impact on life expectancy as the chances of death increase in the absence of anti-retroviral treatment. The medical brain drain rate is estimated with a negative sign in Specification 1 but is not statistically significant. In the long run, the increased numbers of AIDS deaths predicted by medical brain drain rate (Table 2) imply lower life expectancy. Also, the coefficients of the numbers of physicians in the home country and abroad controlling for population size are statistically insignificant in Specification 2.

The coefficients of the lagged dependent variables are significant in both specifications but are lower than those obtained for medical brain drain rates in Table 2. This may in part be due to the differences in the availability of anti-retroviral treatment in sub-Saharan African countries; longitudinal data on percentages of HIV-infected individuals receiving anti-retroviral treatment are not available in the databases. Overall, the empirical models for adult deaths due to AIDS and life

expectancy exhibit a triangular form though the medical brain drain rate was not a significant predictor of life expectancy in the countries. Even so, it is plausible that if we had data on emigration of nurses, then the combined variable for emigration of physicians and nurses might have had greater explanatory power because of the important role played by nurses in administering various treatments.

4. 3 Empirical results for aggregate and per capita GDP growth rates

The results from estimating static random effects models for aggregate and per capita GDP growth rates are presented in Table 5. In these formulations, the variance covariance matrix of the errors is unconstrained and there is greater flexibility in invoking the more general form of endogeneity assumptions for lagged GDP levels and life expectancy, as in equation (13). The Chi-square statistics with 24 degrees of freedom test the null hypothesis that GDP levels and life expectancy are fully endogenous variables. Since the test statistics assume the values 45.90 and 63.86, respectively, in the models for aggregate and per capita GDP growth rates, the null hypotheses are rejected at the 5% significance level. Thus, it is not necessary to test further the null hypotheses that country-specific random effects are correlated with GDP levels and life expectancy; these two variables are treated as fully endogenous in the estimation.

In the model for aggregate and per capita GDP growth rates, the ratio of investment to GDP is estimated with a positive sign that is statistically significant. However, the import and export ratios to GDP are not statistically significant in these models. The coefficient of life expectancy is positive in both models but it reached statistical significance only in the model for aggregate GDP growth rates. These differences presumably result from the fact that the coefficient of the population variable is restricted to be one in the model for per capita GDP growth rates. In fact, the coefficient of the population variable is not significantly different from zero thereby showing a preference for modeling the aggregate GDP growth rates.

Overall, the results for GDP growth rates in Table 5 reflect a fair amount of internal variation in the 3-year GDP growth rates which may have led to the statistical insignificance of variables such as

imports and exports and HIV prevalence and medical brain drain rates. However, the results show the importance of greater investments and higher life expectancy in sub-Saharan African countries for enhancing economic growth; life expectancy, in turn, is lowered by HIV prevalence and the number of deaths due to AIDS increased with medical brain drain. The preference for Specification 1 for aggregate GDP growth rates may be in part due to the fact that population growth is likely to be affected by HIV pandemic. However, for analyzing the effects of the HIV/AIDS pandemic on population growth, a longer time frame than the 15-year period for which we have the data would be useful. Lastly, while one can estimate models for per capita GDP *levels*, missing observations on capital stock series for sub-Saharan African countries and the complex stochastic properties of the GDP series are likely to hamper the analyses.

5. Conclusion

The purpose of this paper was to analyze the effects of the HIV pandemic in sub-Saharan Africa on the emigration of physicians and the consequences of medical brain drain for the number of adult deaths due to AIDS, life expectancy and GDP growth rates. Because longitudinal data on emigration of physicians are not available in databases, we compiled the variables from the records of 16 major O.E.C.D. countries. Moreover, by utilizing the most recent data on HIV prevalence rates and physicians' wages, we were able to put together a comprehensive longitudinal data set for the period 1990-2004 and model the various inter-relationships using econometric techniques.

The main findings from estimating the model for medical brain drain rates were that lower physicians' wages and higher HIV prevalence increased emigration of physicians from sub-Saharan countries. While there were earlier hints of this phenomenon in the responses of physicians in 6 African countries (Awases et al., 2003), empirical analyses at the country level taking into account a range of country characteristics and the unobserved heterogeneity are important for policy formulation. In particular, it is evident from our results that physicians' wages need to be increased so that they are commensurate with the workload and risks in a high HIV-prevalence environment. While schemes such as developed countries compensating sub-Saharan African countries for the loss of

healthcare staff on the basis of opportunity costs in developed countries have been proposed (Bhargava, 2005b), it is imperative that international agencies implement alternative pilot programs for reducing the emigration of physicians in the wake of the HIV/AIDS pandemic.

Further, the results from the model for numbers of adult deaths due to AIDS indicated that a doubling of the medical brain drain rate implies a 20 percent increase in adult deaths due to AIDS. This again underscores the importance of retaining physicians in sub-Saharan African countries especially as anti-retroviral treatment is available to higher proportions of HIV-infected individuals. The results from the model for life expectancy showed the importance of higher governmental expenditures on health and of lower HIV prevalence rates. Increasing the life expectancy is beneficial for raising welfare of children that might otherwise be orphaned by AIDS (Bhargava, 2005a), and for individuals' investments in their education and training. While the medical brain drain rate was not significantly negatively associated with life expectancy, future analyses may find significant effects if the data cover a longer time frame and if the emigration of physicians continues unabated. It would also be helpful if O.E.C.D. countries compile information on emigration of nurses, since nurses play an important role in providing care to HIV patients receiving anti-retroviral and other treatments.

Lastly, the results for GDP growth rates indicated the importance of greater investments in the economies and of life expectancy in sub-Saharan countries. With the progression of HIV/AIDS, worker absenteeism is likely to be a major hindrance in industrialized sectors unless workers receive anti-retroviral treatment. Because the costs of anti-retroviral treatment continue to fall for developing countries, manufacturing and other firms would benefit from lower worker absenteeism achieved via anti-retroviral treatment for infected workers. The productivity of workers in subsistence activities, however, is low so that public programs should assign high priority to rural populations that are often too poor to afford anti-retroviral treatment. Individual-level studies on the effects of anti-retroviral treatment and food supplementation on the labor productivity of under-nourished individuals will shed light on the cost-effectiveness of alternative treatment schemes in sub-Saharan Africa.

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TABLE 1

*Sample means and standard deviations of selected variables for sub-Saharan countries at 3-year intervals for the period 1991-2004*¹

Year :	1991		1994		1997		2000		2003	
Variable :	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
HIV prevalence, %	2.98	3.72	5.037	5.592	6.594	7.047	7.073	7.907	7.085	8.096
No. of AIDS Deaths	3960.82	7777.64	10253.64	16672.51	19713.29	28002.43	30245.11	40974.4	36963.61	54538.9
No. Physicians/1000	0.153	0.241	0.153	0.219	0.158	0.235	0.160	0.239	0.162	0.240
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	0.094	0.113	0.096	0.115	0.097	0.113	0.103	0.113	0.111	0.117
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	1134.56	749.14	1179.60	818.13	1292.17	876.92	1400.12	906.38	1415.34
GDP pc growth rate,%	1.670	1.547	1.950	2.125	4.176	8.232	2.810	2.864	3.632	3.743
Population ('000)	11536	16747	12511	18310	13515	19799	14539	21223	15581	22692
Literacy rate, %	50.76	19.73	53.73	19.72	56.76	19.62	59.70	19.46	62.57	19.21
School enroll prim, %	58.11	25.01	60.20	25.41	61.00	23.31	62.57	20.98	67.00	19.71
School enroll sec., %	19.11	15.95	20.64	17.34	22.06	18.22	23.91	18.72	25.58	18.62
Prop (sec+tert) educat	0.132	0.102	0.148	0.117	0.160	0.126	0.170	0.129	0.180	0.137
Govt HealExp/GDP,%	4.315	1.314	4.679	1.416	4.835	1.747	4.872	1.786	4.981	1.747
Physicians wages/USA	0.124	0.133	0.104	0.110	0.098	0.106	0.082	0.072	0.083	0.074
Investment/GDP, %	18.98	9.67	20.93	11.19	21.77	13.64	21.36	13.57	20.04	13.45
Import/GDP, %	38.98	21.74	43.16	22.41	44.13	27.14	45.29	28.28	45.88	28.27
Export/GDP, %	25.88	17.63	28.92	17.36	30.90	20.58	32.38	22.43	33.00	22.22

¹ There were at most 47 countries in the sample at each time point.

TABLE 2 Maximum likelihood estimates from dynamic random effects models for 3-yearly medical brain drain rates of physicians from sub-Saharan African countries explained by socioeconomic variables and HIV prevalence rates for the period 1991-2004 ¹

Explanatory variables:	Dependent variable: Medical brain drain rate					
	Specification 1		Specification 2		Specification 3 ²	
	Coefficient	SE	Coefficient	SE	Coefficient	SE
Constant	-0.420*	0.138	-0.633*	0.173	-0.431*	0.141
Ln (Physicians wages/USA ratio)	-0.035*	0.019	-0.049*	0.052	-0.034*	0.019
Ln (% School enrollment secondary)	0.116*	0.044	0.171*	0.037	0.122*	0.022
Ln (GDP per capita)	-0.034	0.032	-0.051*	0.021	-0.036*	0.009
Ln (HIV prevalence)	0.078*	0.017	0.070*	0.017	0.071*	0.020
Lagged dependent variable	0.934*	0.025	0.890*	0.022	0.930*	0.017
(Between/within) variance ratio	-		0.104	0.076	-	
Within variance	-		0.049		-	
2 x (maximized log-likelihood function)	522.22		479.90		579.37	
Chi-square test for random effects decomposition (12 d.f.)	-		42.32*		-	
Chi-square test for exogeneity of HIV prevalence rate (5 d.f.)	-		-		11.38*	

¹ There were 39 countries with 5 time observations at 3-yearly intervals for the period 1991-2004 in the estimation; slope coefficients and standard errors are reported; ² HIV prevalence rate is treated as an endogenous variable; * P<0.05.

TABLE 3 Maximum likelihood estimates from dynamic random effects models for the number of adult deaths due to AIDS in sub-Saharan African countries at 3-yearly intervals explained by socioeconomic variables and HIV prevalence and medical brain drain rates for the period 1991-2004 ¹

Dependent variable: Number of adult deaths due to AIDS				
Explanatory variables:	Specification 1 ²		Specification 2 ²	
	Coefficient	SE	Coefficient	SE
Constant	-2.833*	0.422	-41212*	0.165
Ln (Population)	0.450*	0.017	0.480*	0.006
Ln (Prop. with second+tert education)	-0.045	0.027	-0.005	0.026
Ln (GDP per capita)	-0.014	0.025	-0.072*	0.025
Ln (HIV prevalence)	0.542*	0.039	0.778*	0.038
ln (Medical brain drain rate)	0.095*	0.019	-0.059*	0.023
ln (Medical brain drain) x ln (HIV prevalence)	-		0.049*	0.008
Lagged dependent variable	0.510*	0.012	0.498*	0.001
2 x (maximized log-likelihood function)	1243.35		1258.20	
Chi-square test for exogeneity of medical brain drain and HIV prevalence rates (10 d.f.)	104.03*		116.63*	

¹ There were 39 countries with 5 time observations at 3-yearly intervals for the period 1991-2004 in the estimation; slope coefficients and standard errors are reported; ² Medical brain drain and HIV prevalence rates are treated as endogenous variables * P<0.05.

TABLE 4 Maximum likelihood estimates from dynamic random effects models for life expectancy in sub-Saharan African countries at 3-yearly intervals explained by socioeconomic variables and HIV prevalence and medical brain drain rates for the period 1991-2004 ¹

Dependent variable: Life expectancy				
Explanatory variables:	Specification 1 ²		Specification 2 ²	
	Coefficient	SE	Coefficient	SE
Constant	1.117*	0.005	1.012*	0.004
ln (% Government health expenditure/GDP)	0.040*	0.003	0.029*	0.003
ln (% School enrollment primary)	0.022*	0.009	0.022*	0.002
ln (GDP per capita)	0.001	0.007	0.009*	0.004
ln (HIV prevalence)	-0.027*	0.003	-0.026*	0.004
ln (Medical brain drain rate)	-0.005	0.003	-	
ln (Physicians in home country)	-		-.0001	0.003
ln (Physicians abroad)	-		0.0001	0.002
Lagged dependent variable	0.662*	0.002	0.700*	0.001
2 x (maximized log-likelihood function)	1558.80		1588.15	
Chi-square test for exogeneity of medical brain drain rate or physicians abroad (5 d.f.)	16.64*		24.46*	

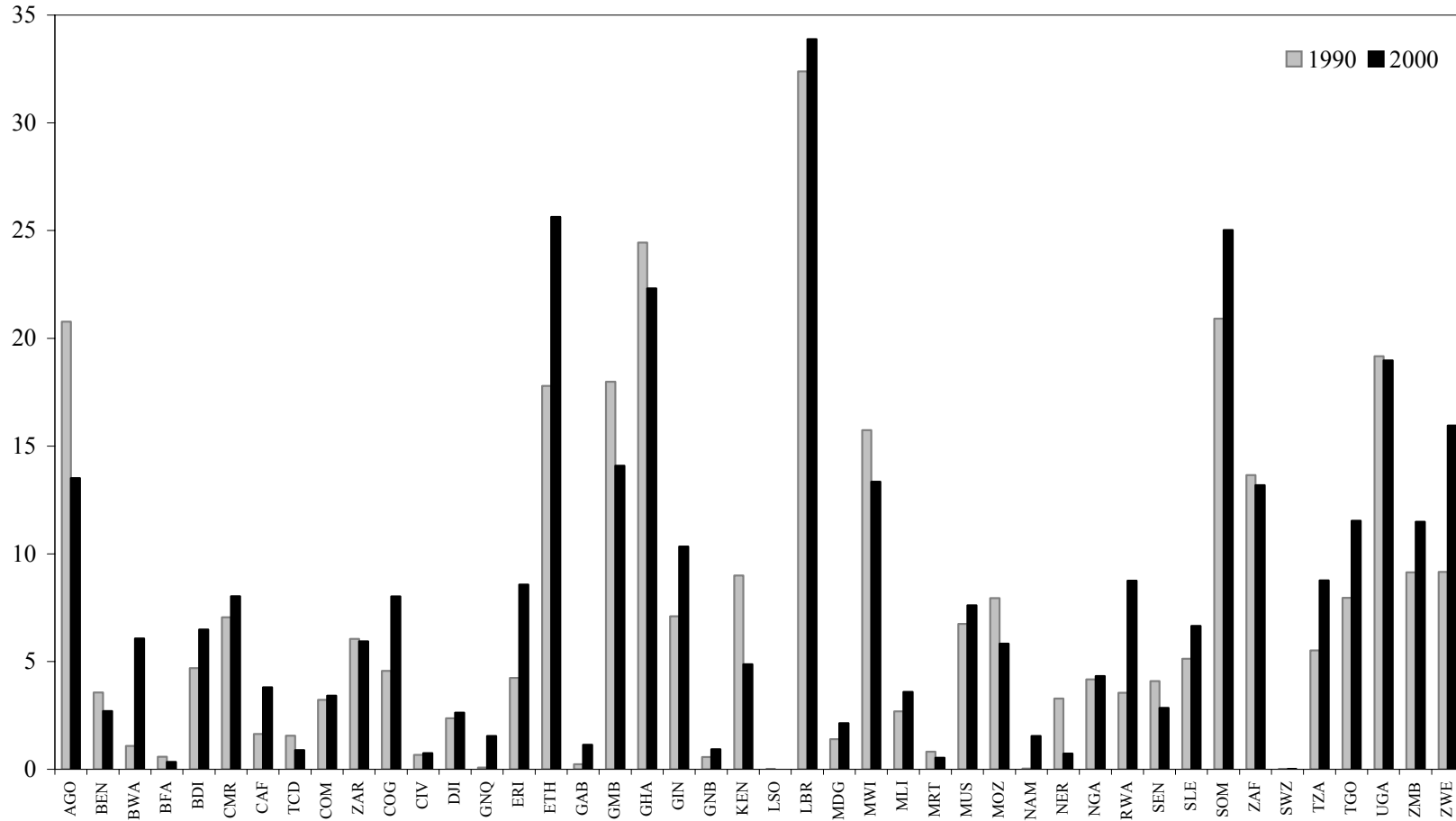
¹ There were 39 countries with 5 time observations at 3-yearly intervals for the period 1991-2004 in the estimation; slope coefficients and standard errors are reported; ² Medical brain drain rate (or number of physicians abroad) is treated as an endogenous variable. * P<0.05.

TABLE 5 Efficient estimates from static random effects models for aggregate and per capita GDP growth rates at 3-year intervals in sub-Saharan African countries explained by socioeconomic variables and life expectancy ^{1,2}

Explanatory variables :	Dependent variable: GDP growth rates			
	Aggregate GDP growth rates		Per capita GDP growth rates	
	Coefficient	SE	Coefficient	SE
Constant	-0.332	0.210	-0.165	0.127
Ln (Proportion with second+tert education) ₋₁	-0.003	0.008	-0.002	0.006
ln (Investment/GDP) ₋₃	0.025*	0.012	0.023*	0.010
ln (Imports/GDP) ₋₃	0.003	0.018	0.006	0.012
ln (Export/GDP) ₋₃	-0.002	0.013	-0.011	0.011
ln (Population) ₋₃	0.013	0.008	-	
ln (Life expectancy) ₋₃	0.081*	0.037	0.025	0.034
ln (GDP) ₋₃	-0.011	0.010	0.003	0.010
Chi-square test for exogeneity of life expectancy and GDP levels (24 d.f.)	45.90*		63.86*	
Chi-square test for special form of exogeneity of life expectancy and GDP levels (8 d.f.)	2.38		3.11	

¹ There were 45 countries with 4 time observations at 3-yearly intervals for the period 1991-2004 in the estimation; slope coefficients and standard errors are reported; ² Life expectancy and GDP levels are treated as endogenous variables * P<0.05.

Figure 1: Medical brain drain rates from sub-Saharan Africa for the years 1990 and 2000



Source: Authors' calculations.

Country codes (ISO): AGO=Angola; BEN=Benin; BWA=Botswana; BFA=Burkina Faso; BDI=Burundi; CMR=Cameroon; CAF=Central Afr Rep; TCD=Chad; COM=Comoros; ZAR=Congo Dem Rep; COG=Congo Rep; CIV=Cote d'Ivoire; DJI=Djibouti; GNQ=Equat. Guinea; ERI=Eritrea; ETH=Ethiopia; GAB=Gabon; GMB=Gambia, The; GHA=Ghana; GIN=Guinea; GNB=Guinea-Bissau; KEN=Kenya; LSO=Lesotho; LBR=Liberia; MDG=Madagascar; MWI=Malawi; MLI=Mali; MRT=Mauritania; MUS=Mauritius; MOZ=Mozambique; NAM=Namibia; NER=Niger; NGA=Nigeria; RWA=Rwanda; SEN=Senegal; SLE=Sierra Leone; SOM=Somalia; ZAF=South Africa; SWZ=Swaziland; TZA=Tanzania; TGO=Togo; UGA=Uganda; ZMB=Zambia; ZWE=Zimbabwe