INCIDENCE OF TUBERCULOSIS AND ITS DETERMINANTS: A SYSTEMS GMM ANALYSIS

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Abstract

In this study, the authors used dynamic panel specifications on an unbalanced panel of 112 countries using annual data from 1990 to 2005. These specifications support the influence of basic education on lowering the incidence of infectious disease. The lagged values of the dependent variable were also found to be significant in all systems GMM specifications, thereby supporting the contagious nature of the disease. Though a considerable amount of aid has been directed towards infectious disease control (controlling the spread of communicable diseases), the achievement of these health goals remains rather questionable among recipient economies. The policy implications of this study are that aid could be diverted towards strengthening systems by investing in both health and human infrastructure.

Introduction

Over the decades, developing countries have seen a shift both in the amount of aid and the purpose for which it is disbursed. The emphasis changed from structural adjustments in the 1980s to conditionality in 1990s, to more recent decades witnessing donor financing towards social services such as health and education [1]. This move has been along the lines of meeting the new global priority, the Millennium Development Goals (MDGs), where the emphasis is on improving human infrastructure. The Millennium Development Goals (MDGs) are eight international development goals broken down into twenty-one quantifiable targets that are measured by sixty indicators. They have been adopted by 189 nations and signed by 147 heads of state and governments. These goals respond to the world's development challenges and are agreed to be achievable by the year 2015. They include fighting infectious diseases such as tuberculosis and AIDS, reducing child mortality, improving maternal health, reducing extreme poverty, and developing a global partnership for development, to name a few.

In this study, the authors looked at health-aid to see if it could lower a specific infectious disease, called tuberculosis—one of the most widespread infectious diseases in developing countries and which results in a large number of deaths in the economically productive age group of 15-59 years. Standard linear mean regression was used on annual level data to explore the dynamic nature of the relationship and to see if by exploiting this dynamic nature any significant impact of health-aid on this specific infectious disease could be found. Of particular interest was the impact of disaggregated health-aid on the incidence of tuberculosis. Analogous to the growth literature, which uses an institutional quality index, the authors used primary schooling completion rate as a proxy to measure human infrastructure which is a key prerequisite for improving health standards/ outcomes of developing countries. Longitudinal data analysis methods were used on an unbalanced panel of 112 developing countries from 1990-2005. These dynamic panel model specifications (systems GMM) account for issues of serial correlation, heteroscedasticity and endogeneity among some of the explanatory variables in the estimations. These specifications confirm that, among the covariates considered, education does play an important role in lowering the incidence of infectious diseases. It was also found that there is a significant lagged effect of the incidence of tuberculosis, which basically supports the contagious nature of the disease. Unfortunately, health-aid was consistently found to be ineffective.

Related Research

Thiele et al. [2] used a Tobit regression analysis to test if sectorally disaggregated data on aid by purpose does have a significant impact on meeting MDGs for a sample of 140 recipient countries. The findings indicated that while aid has been effective in fighting infectious diseases like HIV/ AIDS, it has not helped lower the incidence of tuberculosis or malaria, nor has it helped increase primary education levels. They attribute part of this failure to insufficient targeting of aid. Momota et al. [3] used a two-period overlapping-generations model to examine how the spread of infectious diseases (e.g., HIV, Malaria, syphilis) influences individual preventive behavior (i.e., health investment) and resource allocation. That study also examined how one-shot foreign (medical) aid influences the welfare of individuals in recipient countries. The findings suggest that agents' preventive behavior induces the cyclical spread of infectious diseases. They also found that one-shot medical aid may likely suppress the spread of the disease at a given time but, given the cyclical nature of the disease in developing economies, people need to be more vigilant. Finally, then, they

found one-shot foreign aid to be undesirable. Martin et al. [4] developed a theoretical model that generates the optimal budget allocation to maximize social welfare for 23 programs of care (namely, infectious diseases, cancer, circulation) administered by the English Primary Care Trust. Using an instrumental variable method, they empirically tested two large programs of care: cancer and circulation. The findings suggested that healthcare spending can improve health outcomes. Shiffman [5] and Landis [6] both compared donor funding priorities to the burden of diseases. Shiffman's study indicated that funding does not correspond to the burden of the disease and identified funding towards infectious diseases like respiratory infections and malaria to be highly insufficient. Landis extended his work to all diseases and concluded that while health areas such as basic healthcare and infrastructure, health education and personnel development have witnessed a decline in allocations, infectious diseases such as HIV/AIDS have received a larger share of the resources. Both papers concluded that funding patterns do not reflect the needs of the developing world and suggest an increased need for funding communicable disease control.

Data

The sample in this current study covered 112 developing countries spanning the years from 1990 to 2005. Annual level data were used though the number of observations varied across specifications depending on the control variables used. The dependent variable was incidence of tuberculosis per 1000 people. The independent variables used in this study were as follows:

- GDP per 1000 people, measured in constant 2005 U.S. dollars
- Primary schooling completion rate, which was used as a proxy for education and existing human infrastructure
- Density per square kilometer
- Government health expenditure per 1000 people, measured in constant 2005 U.S. dollars
- The GINI index which measures the level of income inequality and which is also an important factor that may contribute to the further worsening of the health outcomes among developing economies
- Health-aid per 1000 people, measured in constant 2005 U.S. dollars
- The number of physicians per 1000 people

Physician stock was used as a proxy for the existing health infrastructure. Several period dummies were used to check if the implementation of the Millennium Development Goals or the changes in donor financing towards health-related issues have had a significant impact in lowering the incidence of tuberculosis.

The health-aid term was considered in order to check for the diminishing effects of health-aid. Interconnecting the health-aid term with physician stock or government health expenditure also helped us determine whether the existing amounts of physician stock or government health expenditure would improve the effectiveness of health-aid in reducing the incidence of tuberculosis. In system GMM estimation, the number of instruments grows quickly with the number of time periods and covariates. To control for the rapid growth of instruments, the maximum number of lags of the dependent variable and lags of the endogenous variables (used as instruments) was limited to one.

Health-aid is an important covariate of interest. Ideally speaking, it would be best to use only that component of health-aid that is disbursed specifically for tuberculosis control. However, due to the lack of data at this level, data on health-aid—aid that is specifically directed towards health outcomes—was used. Following the conventional practice of aid-growth-poverty literature, a one-period lag of health-aid was used to subdue any possible endogeneity effect. The variables and data sources are listed in Table 1.

Table 1. Variables and Sources [7], [8]

Variable	Source
Incidence of tuberculosis (per 100,000 people)	WDI, 2007
GDP per capita	WDI, 2007
Health-aid	OECD, CRS
Primary completion rate, total (%)	WDI, 2007
Physicians (per 1000 people)	WDI, 2007
Population, total	WDI, 2007
Population density (per square km.)	WDI, 2007
GINI index	WDI, 2007
Health expenditure per capita	WDI, 2007

Note that period averages were not taken; rather, annual level data were used to examine the dynamic nature of the interrelationship between health-aid and the incidence of tuberculosis.

Descriptive Statistics

Table 2 represents the summary statistics. On average there are about 2 instances of tuberculosis that are reported per 1000 people per year. The incidence of tuberculosis is as high as 11 cases per 1000 people in some developing countries. Though these numbers do not seem large, the fact remains that a large number of deaths in productive ages occur due to this communicable disease; furthermore, there could be some level of misreporting/lack of reporting. The availability of physicians, on average, is very low. The maximum number of available physicians per 1000 people among these sample countries is about 8 physicians. Governments of developing economies spend a substantial amount on the health needs of the population. The GINI index measures inequality in income distribution and is expressed in terms of a percentage. The higher the percentage, the greater the level of inequality. The average density is about 106 people per square kilometer. The average primary completion rate is about 66%. On average, about $1,280 (in constant 2005 U.S. dollars) per year of health-aid is disbursed per 1000 people.

Table 2. Sample Summary Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Tuberculosis	723	2.26	1.84	0.05	11.41
Govt. Health expenditure	347	15.15	1.18	12.51	18.01
Physician	723	0.66	0.93	0.01	7.88
Health-aid	723	7.16	1.62	1.45	12.59
Density	723	3.886	1.33	0.42	7.07
GDP	723	17.91	1.08	15.89	21.13
Education	723	65.79	28.37	10.78	143.67
GINI	291	43.37	8.00	28.15	62.35

Estimation Method and Statistical Tests

Given the longitudinal nature of the data set used in this study, the authors used panel data estimation techniques. Panel data analysis endows regression analysis with both spatial and temporal dimensions; i.e., cross-sectional and periodic observations of the set of variables. The system GMM estimators proposed by Arellano & Bover [9] and Blundell & Bond [10], [11] were used in order to explore the effect of our main variable, interest (health-aid), on the incidence of tuberculosis. Even if the lagged dependent variable and the error terms are uncorrelated, the introduction of the lagged dependent variable makes random- and fixed-effect estimates inconsistent because the lagged dependent variable would be correlated with the transformed errors [12]. To overcome this problem, the systems GMM estimation technique was used. This technique was first introduced by Arellano & Bover [9] and developed by Blundell & Bond [10], [11], and accounts for the bias introduced by the lagged dependent variable. To understand this method, let us consider a dynamic panel data model of the form shown in Equation (1):

$$Y_{it} = \alpha_i + \delta Y_{it-1} + X_{it}'\beta_k + \varepsilon_{it} \quad (1)$$

where $u_{it} = \alpha_i + \varepsilon_{it}$

Here, Y_{it} is the dependent variable (incidence of tuberculosis per 1000 people) for country *i* at time *t*. X_{it} is the set of relevant macroeconomic covariates such as health-aid per 1000 people, government health expenditure per 1000 people, gross domestic product per 1000 people, education, physician stock per 1000 people, density per square kilometer, the GINI index, interaction terms and period dummies. And where β is the *k x 1* parameter vector associated with the independent variables defined above; α_i represent the special effects for each country and which are considered to be constant over time, *t* , and are specific to individual units [13]; and, u_{it} is the i.i.d. (independently identically distributed) error term. This specification uses more moment conditions, whereas lagged differences are used as instruments for level equations and lagged levels are used as instruments for difference equations.

In this study, two important tests were conducted to serve as a check for the validity of the estimators [14], [15]. The first was the Autocorrelation test where the null hypothesis is not a second-order serial correlation in the error term of the first-differenced equation which requires that

$$E[\Delta u_{it} \Delta u_{it-2}] = 0$$

Another test for the validity of the instrument is Sargan's [16] test of over-identifying restrictions which requires that

$$E[W'\Delta u\ ] = 0$$

Stated another way, the instruments are uncorrelated with first difference errors, where *W* is the instrument matrix [17]. If the null hypothesis is rejected, it implies that either the number of instruments must be reduced or a more appropriate set of instruments must be found. Thus, in both of the tests, the null hypothesis had to be accepted. The con-

sistency of system GMM estimators depends on the validity of the instruments and the absence of second-order serial autocorrelation.

Results

The results of the estimation procedure for the systems GMM estimator are reported in Table 3. Also included in this table are the two-step robust estimator coefficients, the *p* values corresponding to the Sargan test, and the second-order autocorrelation tests.

Table 3. Systems GMM Estimation

Tuberculosis	1	2	3	4
Tuberculosis (Lag 1)	0.97*** (14.92)	0.88*** (11.73)	0.98*** (26.18)	0.94*** (23.62)
Physician	0.02 (0.85)	-0.02 (-0.61)	0.02 (0.31)	0.03 (1.05)
GDP	-0.09 (-0.75)	-0.06 (-0.38)	-0.07 (-0.71)	
GINI	0.001 (0.35)	-0.001 (-0.25)	0.003 (0.70)	0.003 (0.79)
Density		-0.04 (-0.61)		
Education	-0.004** (-2.22)	-0.004* (-1.90)	-0.003* (-1.67)	-0.003* (-1.89)
Health-aid (Lag1)	-0.01 (-0.51)	0.002 (0.14)	0.06 (0.60)	0.20 (1.63)
Health-aid (Lag1)			-0.01 (-0.73)	
Govt.Health Expenditure (Lag 1)	-0.12 (-0.67)	-0.18 (-1.19)	0.01 (0.06)	0.02 (0.18)
Health-aid * Physician (Lag 1)			0.001 (0.15)	
Health-aid * Govt.Health Expenditure (Lag 1)				-0.01* (-1.72)
Constant	1.71 (1.22)	2.38 (1.09)	1.65 (1.29)	-0.99 (-0.46)
Sargan	0.8606	0.8173	0.7169	0.8532
2Order Auto-correlation	0.6879	0.5410	0.9099	0.5810
t statistics are reported in the parenthesis				
*significant at 10%, **significant at 5%, ***significant at 1%				

Across all specifications, the coefficients corresponding to the lagged values of the dependent variable and primary levels of education were found to have a significant impact on the incidence of tuberculosis. It was also found that the lagged values of the dependent variable turned out to be positive and significant, which supports the contagious nature of a communicable disease like tuberculosis. Additional findings suggested that the education variable turned out to be negative and significant in almost all specifications. Thus, given the basic nature of the disease (communicable), basic levels of education can substantially help lower the incidence of tuberculosis. This could be attributed to factors like better awareness of the nature of the disease and better understanding of detection and prevention measures that could help avoid the possible spread of infectious diseases—for example, exposing oneself to sunlight and better cross ventilation helps kill germs. The period dummies used in this study always turned out to be insignificant in all specifications.

Improving nutritional intake and living conditions (hygiene and sanitary conditions) could further improve the results of the health outcomes. Education, then, acts as a prerequisite in laying the foundation for an improved, healthy lifestyle and also helps us perform better during the productive ages which will have a direct impact on our earning capacities. The complementarity between health-aid and government health expenditure seen in our fourth specification indicates the need for greater coordinated efforts between donor countries and recipient governments in order to have a successful impact on health outcomes. Thus, the overall conclusion of the systems GMM confirms that health-aid by itself does not help lower the incidence of tuberculosis. Government efforts may help in improving health outcomes along with health-aid, but not by itself. Primary completion rate, however, was found to help lower the incidence of tuberculosis across all specifications. Finally, donors could channel some of the funds towards developing the human infrastructure and strengthen the health infrastructure.

Summary

Over the last decade there has been a decisive move on the part of donors to finance social services such as health and education, with a substantial amount of aid going towards infectious disease control. This study looked at the impact of health-aid and other covariates like primary completion rate (used as proxy for education) on the incidence of tuberculosis. Also considered were the effects of dynamic panel specifications on an unbalanced panel of 112 countries using annual data from 1990 to 2005. These specifications supported the influence of basic education on lowering the incidence of infectious disease. It was also found that the lagged values of the dependent variable were significant in all of the systems GMM specifications, thereby confirm-

ing the contagious nature of the disease. The health-aid variable never seemed to have a significant impact on the incidence of tuberculosis. Though a considerable amount of aid has been directed towards infectious disease control (controlling the spread of communicable diseases), the achievement of these health goals remains questionable among recipient economies. According to MacKellar [18], there is room for improvement in the process of preparing poverty-reduction strategies through the allocation of official development assistance.

The failure of health-aid to have the desired impact could be attributed to various factors. The weak health systems among developing countries can be considered as an important determinant of the ineffectiveness of health-aid. Lack of coordinated efforts on the part of donor countries and the recipient economies in meeting desired goals could also be a factor. Martin et al. [4] emphasize promoting program budgeting as it enables policy makers to make informed decisions about where their limited budgets are best spent. Shiffman [5] indicated that there needs to be a more balanced allocation of resources. Since, by their nature, these diseases are highly contagious, some amount of the health-aid could be diverted towards educating the general population on early detection, causes, treatment/prevention measures, nutritional aspects, hygiene and sanitation, improving living conditions, etc., which could help lower the incidence of tuberculosis to a large extent. This also ties in with the work by Momota et al. [3] which emphasized that one-shot medical aid would no doubt suppress the disease level during the next time period; however, when the pattern of the disease is cyclical, and in spite of a large aid package, one-shot aid is not desirable. Basic levels of education play a key role in lowering the incidence of tuberculosis; hence, both donors and recipient governments could direct a part of the funds towards meeting basic educational standards across the population at large. From a policy perspective, aid could be diverted towards developing the human infrastructure and strengthening the health infrastructure.

A major drawback of this analysis lies in the fact that there is limited data on aid going specifically towards tuberculosis control. More efforts could be undertaken to collect more detailed data on communicable diseases, which could help in a more meaningful analysis of the issue. Since such data issues were encountered in this study, health-aid data were used as the closest approximation. Future work could focus on other infectious diseases like HIV, malaria, etc.

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