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ORIGINAL ARTICLE

Political, economic, and health system determinants of tuberculosis incidence

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Abstract

Aim Although global tuberculosis (TB) rates have decreased, multidrug-resistant strains have become a concern. Traditionally, causes of infectious diseases are determined through health and health system factors, yet socioeconomic and political variables may influence a nation's vulnerability and response to infectious disease control. This study explores relationships among political stability, economic stability, tuberculosis detection policies, health system constructs, and the incidence of tuberculosis.
Subjects and methods A retrospective, cross-sectional, observational design was employed using open-source, secondary, 2014 country-level data from the World Bank and World Health Organization. A structural equation model examined the direct and indirect effects of economic, political, and other constructs on tuberculosis incidence rates.
Results Political and economic stability, health system indicators, and detection policies all covaried. Political stability, health system indicators, and detection policies directly affected tuberculosis incidence rates, but economic stability did not. Political stability and health system indicators were negatively associated with tuberculosis incidence, while detection policies were positively associated.
Conclusions Countries with greater political stability and better health systems experienced lower TB incidence, but countries with more detection policies in place had higher TB incidence rates. Economic stability did not directly affect TB incidence, but covaried positively with political stability, indicating strong links to political stability.

Keywords Tuberculosis incidence · Political stability · Health expenditures

Introduction

While global tuberculosis (TB) rates have decreased thanks to surveillance and treatment, multidrug-resistant strains are an ever-increasing problem (WHO 2015). Many scholars argue that infectious diseases, such as tuberculosis, will re-emerge as biological warfare, international commerce, and ecological mutations increase (Abubakar et al. 2016; Bloom et al. 2017; Paules and Fauci 2017). It is therefore important to control the spread of TB and to predict and prevent outbreaks, thereby minimizing potential damage and losses. To that end, countries need to know what factors influence the incidence of infectious diseases such as TB.

Health system factors are a traditionally cited cause of infectious diseases, yet socioeconomic and political factors may influence a nation's vulnerability and response to infectious disease (Garchitorena et al. 2017; Selgelid 2016). Moreover, these factors may interact with each other so that there are direct and indirect effects on infectious disease. This research aims to examine the influence of both health and non-health determinants on TB incidence using a structural equation model (SEM) approach, which is capable of assessing more complex paths between factors contributing to infectious disease. Building on population health models and literature on determinants of infectious disease and TB, this study examines potential correlations among political stability, economic stability, tuberculosis policies, health system constructs, and the incidence of tuberculosis.

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Theoretical framework

The model of determinants of TB incidence tested here is informed by several theories of population health. Evans and Stoddart (1990) and Kindig and Stoddart (2003) divide determinants of health into those that are non-medical, such as prosperity and social environment, and those that are behavioral. The University of Wisconsin Population Health Institute (UWPHI) (2016) model divides health-influencing factors into human behaviors, clinical care, socioeconomic factors, and physical environment. Ceddia et al. (2013) call for an integration of economics and disease ecology to comprehend the emergence and spread of diseases. Goenka et al. (2014) utilize a neoclassical growth model that indicates a two-way interaction between disease transmission and the economy. From these models we theorized that TB incidence could be influenced by four categories of factors: economic stability, political stability, health system indicators, and TB detection policies. These factors will interact through complex pathways to impact TB incidence. Below we review the literature regarding each of these constructs.

Literature review

Economic stability is often measured by gross domestic product (GDP), exports, gross national income (GNI), and total reserves. Gross domestic product is the sum of value added by all producers in the economy plus product taxes (World Bank Indicators 2016). Gross national income is the value added by resident producers plus sales taxes, compensation, and property income from abroad. Total reserves include gold and foreign exchange holdings (World Bank Indicators 2016).

The literature generally presents an inverse relationship between economic stability and infectious disease (Kim and Yim 2015; Lindsay 2015; Reeves et al. 2015; Siroka et al. 2016). This relationship may exist because better economic conditions contribute to better sanitary conditions and greater healthcare access. In this sense, economic stability is also related to improved health system indicators, which become a mediator between the economic conditions and infectious disease (Kim and Yim 2015; Semenza et al. 2012). Economic stability is also associated with political stability and health system indicators, such as government health expenditures and immunization rates (Semenza et al. 2012).

In contrast, a strong economy may contribute to increased infectious disease in that it increases the exchange of goods between buyers and sellers, which creates pathways for the spread of disease (Kindig and Stoddart 2003; Ceddia et al. 2013; Institute of Medicine 2008; Perrings 2016; Tatem et al. 2006).

Political stability is frequently measured using the World Bank's Worldwide Governance Indicators: voice/accountability, violence/terrorism, government effectiveness, regulatory quality, rule of law, and control of corruption (Andreas 2015; Apodaca 2004; Kaufmann et al. 2009; Neumayer 2002). The literature generally describes a negative relationship between political stability and infectious disease (Canetti et al. 2014; Ostrach and Singer 2012; WHO 2014a), including TB (Dudnyk et al. 2015; Eldholm et al. 2016). As citizen voice increases, civil liberties increase, and disease incidence decreases. Political violence contributes to the spread of disease (WHO 2014a), and political corruption is associated with decreased life expectancy (Siverson and Johnson 2014).

There is an interplay between economics and politics, since social and economic factors are controlled and regulated by federal governments (Kindig and Stoddart 2003; UWPHI 2016) and because political violence exacts a heavy cost on societies in the form of treatment, lost productivity, and infrastructure rebuilding (WHO 2014a). Indeed, the literature indicates that political stability is positively associated with economic stability (Aisen and Veiga 2013; Polachek and Sevastianova 2012). Political stability also shows a relationship with health system indicators, such as water and sanitation (Ostrach and Singer 2012).

In this study we are interested in *health system indicators* that are most related to the incidence of TB, such as tuberculosis detection rates, HIV prevalence, immunizations, health expenditures, and access to good water and sanitation. Research demonstrates a negative relationship between various health system indicators and TB incidence (WHO 2015; Ceddia et al. 2013; Siverson and Johnson 2014; Sloan and O'Dempsey 2015). Health expenditures have been found to have a positive effect on health (Kringos et al. 2013; Moreno-Serra and Smith 2012; Sisko et al. 2014) and a negative effect on disease (Karanikolos et al. 2013). The evidence is quite strong that better water and sanitation are linked to better health outcomes (Gooenka, Liu and Nguyen 2014; Grimes et al. 2014; Lopez et al. 2015; Sahoo and Dash 2012; Vittecoq et al. 2014).

While numerous TB detecting policies exist, the World Health Organization (WHO) recommends Xpert MTB/RIF (*Mycobacterium tuberculosis*/resistance to rifampicin) as the gold standard for diagnostic accuracy and cost-effectiveness (WHO 2014b). The literature indicates that when specific TB-detecting policies are developed, more cases of tuberculosis are identified and treated, thereby eventually reducing incidence rates (Lönnroth et al. 2015). This is theorized to be due to the need for rules, protocols, and policies to direct people's behaviors.

Other factors found to influence disease incidence are population density, precipitation, and refugee populations (Bloom and Fink 2014; De Vries et al. 2014; Diaz et al. 2010; Leblebicioglu and Ozaras 2015). To reduce infectious disease, population growth should be stable and density low (Lopez et al. 2015). Climate, temperature, and precipitation greatly impact disease outbreaks (Bloom and Fink 2014). Tropical climates tend to harbor infectious diseases since the warm, moist air stimulates microbial growth (Bloom and Fink 2014).

Conceptual model

From the theoretical framework and literature review above, we constructed the conceptual model of TB incidence visually represented in Fig. 1. Political stability and economic stability impact TB incidence both directly and indirectly through health system indicators. Political and economic stabilities also iteratively interact with each other. TB detection policies impact TB incidence as well as health system indicators (thus also affecting TB through this mediator). Political and economic stability, health system indicators, and TB detection policies are latent constructs, each comprised of 4–6 observed variables. TB incidence is an observed variable, which is also impacted by three observed control variables: population density, annual precipitation, and the refugee population in the country.

Research methods

Research design

This study employs a retrospective, cross-sectional design of country-level secondary data. The model in Fig. 1 corresponds to the following research questions tested through SEM: How are a country's:

(1) political and economic stabilities associated with health system indicators and TB incidence?
(2) health system indicators associated with TB incidence?
(3) TB detection policies associated with TB incidence?
(4) political and economic stabilities associated with each other?

Sample and data sources

The sample size for this study is 264 countries, defined as both independent nations and economies that have separate socio-economic statistics. Data are from open-source databases from the World Bank and WHO for the year 2014.

Measures

Table 1 in the results section lists the observed variables that comprised the four latent constructs, three control variables, and endogenous observed variable. Table 3 in the Appendix presents their full operational definitions, data sources, and data year.

The economic stability construct includes measures of gross domestic product (GDP), exports, gross national income (GNI), and total reserves. The political stability construct consists of measures of voice and accountability, degree of absence from violence and terrorism, control of corruption, regulatory quality, and rule of law. The health system indicator construct consists of tuberculosis case detection, measles immunizations, DTP immunizations, health expenditures, improved water sources, and improved sanitation facilities. The TB detection policies construct is measured by the presence or absence of national guidelines for the use of Xpert MTB/RIF (*Mycobacterium tuberculosis*/resistance to rifampicin) as the initial diagnostic test for the diagnosis of TB in four types of people. The endogenous variable—TB incidence—was an observed variable. Three observed variables—population density, precipitation, and refugee populations—served as controls for the endogenous variable

Data analyses

Data preparation and imputation The World Bank and WHO data were merged into a single Excel spreadsheet and then imported into IBM® SPSS®. Missing data analyses removed 35 countries that had 20% or more missing data, decreasing the sample size to 229 countries. Remaining missing data were imputed using linear interpolation in IBM® SPSS®.

Univariate analyses and distribution transformations Since SEM assumes normality for all observed variables, skewness and kurtosis ratios and the Shapiro-Wilk test were employed to test normality. Variables with skewness values outside the ± 1 range and/or kurtosis values outside the ± 3 range were transformed to optimize normality. Further analysis indicated that logarithmic transformations improved population density, refugee population, GDP per capita, exports % of GDP, GNI/capita, total reserves, TB incidence rates, and immunizations, while square root transformations improved case detection rates, DTP immunizations, and measles immunizations. Following these transformations, normality tests and descriptive statistics were within acceptable ranges.

Correlation analysis was performed to determine whether the observed variables for each construct were correlated to one another and to TB incidence rates. For the most part there were strong correlations, which indicated that the latent constructs, measurement model, and structural model were on the right track.

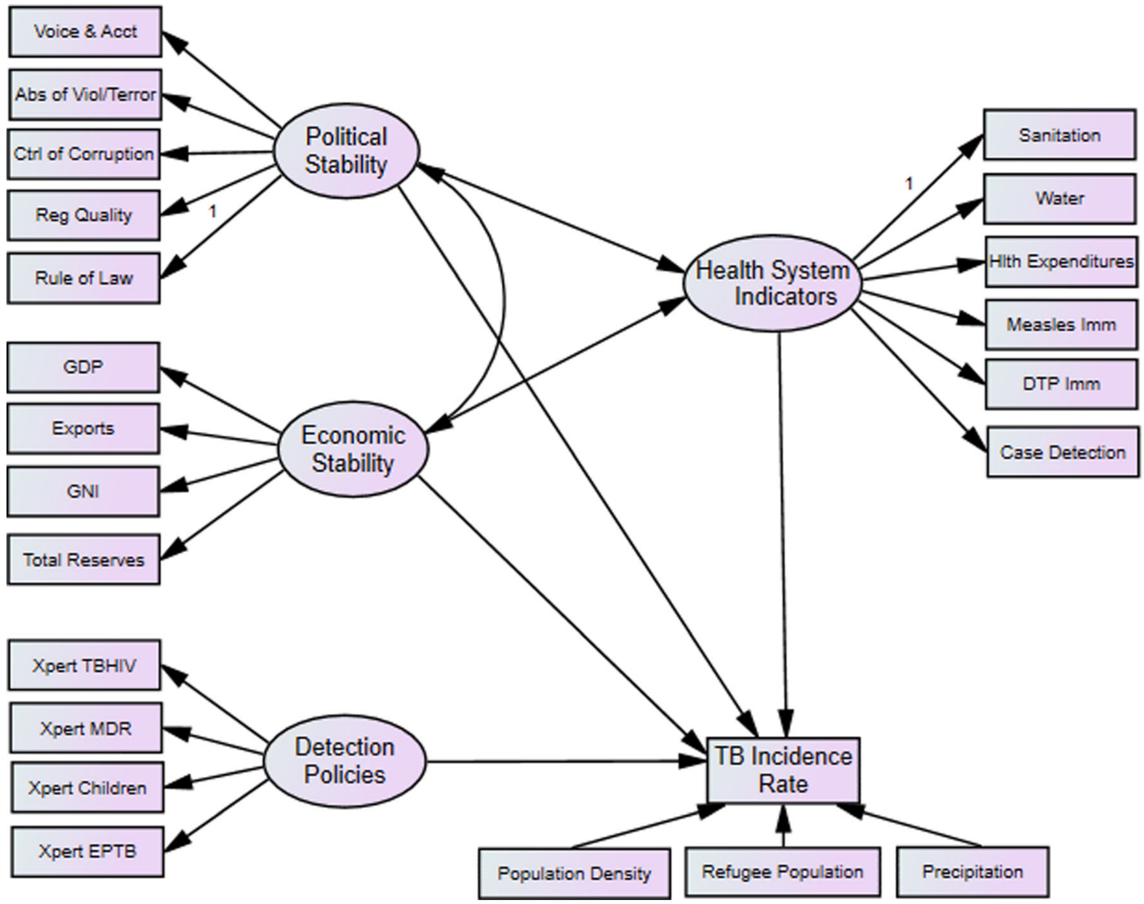

Fig. 1 Initial conceptual model of determinants of TB incidence

Measurement model and reliability analyses The measurement model and reliability analyses were conducted to ensure that the latent variables measured their intended construct. A confirmatory factor analysis (CFA) was run on each of the political stability, economic stability, health system indicator, and detection policy constructs, and a covariance analysis was run on all constructs together. All CFAs showed good fit for each latent variable, without any need to remove an observed variable. The covariance measurement model showed that those constructs continued to have good fit in the presence of all other constructs. Cronbach's alpha reliability scores ranged from 0.749 for economic stability to 0.949 for political stability.

Structural equation model SEM was used to capture the complex relationships among political, economic, health system, and TB incidence and to deal with probable interactions and covariance between factors influencing TB incidence. We used the conceptual model in Fig. 1 for the initial structural model, which was run via maximum likelihood estimation in AMOS. The initial model fits were poor, with insignificant paths from political stability to health system indicators and from economic stability to health system indicators. The health system indicator construct was then eliminated as a mediator and was covaried among political stability, economic stability, and TB detection policies. Also, the TB incidence control variables (population density, etc.) were removed (one by one) to obtain a good model fit. Finally, economic stability was not significantly related to TB incidence rates so this path was removed.

Results

Descriptive statistics for the imputed but not transformed variables are presented in Table 1. All of the observed measures for the "political stability" construct had mean scores close to 50, half way between a possible low of 0 and high of 100. Means of the observed measures for "economic stability" were reasonable for each of the different measures. For health system indicators, the average percentage of population immunized was 71–89% depending upon the type of immunization. The average percentage of GDP spent on health was 7%. On average, 84% of the population in a country

Table 1 Descriptive statistics post-linear imputation ($N = 229$)

Indicator variable	Minimum	Maximum	Mean (or percent)	SD
Political stability indicators (scale of 1–100)				
Voice and accountability	0.00	100.00	48.79	28.15
Absence of violence/terrorism	0.00	99.03	48.33	27.98
Control of corruption	0.00	100.00	47.79	28.39
Regulatory quality	0.00	100.00	48.32	28.31
Rule of law	0.00	100.00	48.16	28.49
Economic stability indicators				
GDP $ per capita	255	116,613	14,059	20,024
Exports % GDP	6.13	95.62	42.34	29.18
GNI $ per capita	250	103,620	13,787	19,301
Total reserves, millions of $	63	3,900,039	73,639	325,887
Health system indicators				
TB case detection %	0.00	190.00	71.10	24.58
DTP immunizations %	24.00	99.00	88.54	12.53
Measles immunizations %	22.00	99.00	87.78	12.77
Health expenditures % GDP	1.48	17.14	6.94	2.81
Water % population with access	28.20	100.00	83.99	17.98
Sanitation % population with access	6.70	100.00	72.83	28.16
TB policy indicators (percent of countries with the policy)				
Xpert TBHIV	NA	NA	(59.74)	NA
Xpert MDR	NA	NA	(68.18)	NA
Xpert Children	NA	NA	(49.35)	NA
Xpert EPTB	NA	NA	(40.90)	NA
Population density #/sq. km	1.87	19,073.07	367.87	1883.82
Refugee population %	0	7.24	4.02	0.11
Precipitation mm/year	51.00	3240.00	1134.39	737.79
TB incidence rates/ 1000 population	0.71	852.00	114.85	NA

had access to water, while 73% had access to sanitation. Several of these health system indicators, in particular TB immunizations, had wide ranges of values, and some countries had very low minimum values on one or more indicator. TB policy adoption ranged from 68% of the countries adopting Xpert MDR to 45% of the countries adopting Xpert EPTB. Control variables had wide ranges. TB incidence rates also had a wide dispersion with an average of 115/1000 population.

The path parameter statistics are presented in Table 2, and the final structural model is presented in Fig. 2. The first part of Table 2 shows the path parameter statistics for the constructs as they related to the observed variables comprising the construct. All observed items were significantly related to the construct. Figure 2 and Table 2 show that in this final model all four constructs covaried with each other. Political and economic stability and health system indicators covaried in the same direction (positive coefficients), while political and economic stability and health system indicators all covaried in the opposite direction from TB detection policies (negative coefficients). Political stability, health system indicators, and detection policies had direct effects on tuberculosis incidence rates, but economic stability did not. Both political stability and health system indicators were negatively associated with tuberculosis incidence rates. The detection policy pathway was positively associated with tuberculosis incidence rates.

Goodness-of-fit indices for the final model revealed that it exhibited an adequate fit, with a likelihood ratio of 2.526, goodness of fit index (GFI) of 0.857, and root mean square error of approximation (RMSEA) of 0.082. Relative goodness of fit statistics all fell within acceptable parameters (IFI =0.940, NFI =0.905, and CFI =0.940). Parsimonious goodness of fit was acceptable with an adjusted goodness of fit index (AGFI) statistic of 0.808.

Table 2 Final structural equation model and path parameter statistics

Path parameter	Unstandardized regression coefficient	SE	CR	*P* value	Standardized regression coefficient
Rule of law← political stability	1.000				0.999
Regulatory quality← political stability	0.899	0.029	30.563	***	0.904
Control of corruption← political stability	0.925	0.025	36.712	***	0.933
Absence violence/terrorism← political stability	0.764	0.041	18.836	***	0.785
Voice and accountability← political stability	0.765	0.042	18.421	***	0.778
Total reserves← economic stability	1.000				0.383
GNI per capita← economic stability	1.580	0.256	6.164	***	0.949
Exports← economic stability	0.295	0.067	4.376	***	0.448
GDP per capita← economic stability	1.649	0.266	6.196	***	0.994
Case detection← health system	1.000				0.402
DTP immunizations← health system	0.749	0.140	5.335	***	0.556
Measles immunizations← health system	0.815	0.148	5.502	***	0.599
Health expenditures← health system	1.610	0.417	3.863	***	0.317
Water← health system	26.948	4.409	6.112	***	0.830
Sanitation← health system	47.688	7.615	6.262	***	0.937
Xpert EPTB← TB detection policies	1.000				0.667
Xpert EPTB← TB detection policies	1.209	0.100	12.101	***	0.793
Xpert EPTB← TB detection policies	1.134	0.105	10.750	***	0.810
Xpert EPTB← TB detection policies	1.375	0.120	11.414	***	0.943
TB incidence rates← political stabilty	−0.005	0.001	−3.721	***	−0.215
TB incidence rates← TB detection policies	0.284	0.106	2.688	**	0.132
TB incidence rates← health system	−0.669	0.126	−5.323	***	−0.569

Unstd. = Unstandardized; SE = standard error; CR = critical ratio

**$p \leq 0.01$; ***$p \leq 0.001$

Discussion

Main findings

We find that the greater the political stability and the better the health system of a country, the lower the tuberculosis incidence is, but that countries with more Xpert detection policies in place have higher tuberculosis incidence rates, perhaps due to the fact that countries with better detection policies actually detect more TB, thus increasing their TB incidence rates in the short run. Economic stability did not directly affect the incidence of TB, but it covaried positively with political stability, indicating that it is strongly linked to political stability, being stronger when the political situation is stable and weaker when the political situation is unstable.

As demonstrated by this research, the problem of infectious disease does not exist in isolation: it is interconnected to other challenging problems such as politics, economics, the health system, and infectious disease policies, which do not have simple or quick-fix solutions. Instead of focusing primarily on population health contributors to disease, it is important, if not more important, for future global health research and policy-makers to examine the "up-stream" effects. If these "up-stream" conditions can be improved or corrected, then the "downstream" consequences of disease could perhaps be prevented and there may be large cost savings, increased workforce productivity, and an improvement in population health.

What is already known on this topic and what this study adds

The role of political stability, a non-health determinant, and factors such as citizen voice, violence and terrorism, and government corruption have seldom been studied in tandem with economic constructs, tuberculosis policies, and health system indicators. Furthermore, many studies have linked health and non-health determinants in terms of infectious disease, but none have studied the direct and indirect pathways leading to tuberculosis. This study revealed a direct relationship between political stability and tuberculosis incidence, which highlights the importance of political stability for lowering the incidence of infectious disease.

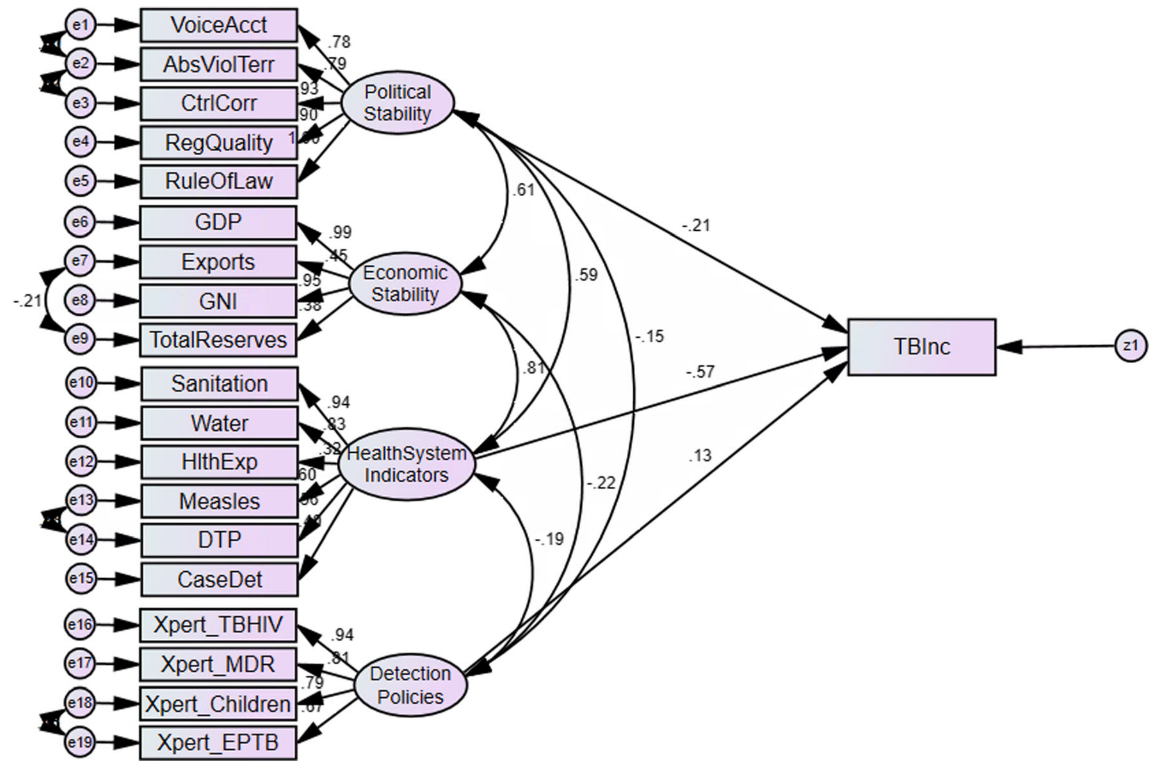

Fig. 2 Final structural model of determinants of TB incidence

Although the previous literature finds an inverse relationship between economic factors and infectious disease, including tuberculosis (Kim and Yim 2015; Lindsay 2015: Reeves et al. 2015; Siroka et al. 2016), this study did not. However, even though economic stability did not have a direct effect on TB incidence, it was found to covary with the political situation and therefore plays a strong role through that avenue. In terms of the relationship between health system indicators and infectious disease, the literature indicated that health system indicators often have an impact on infectious disease via population and individual health (Kringos et al. 2013; Sisko et al. 2014; Karanikolos et al. 2013).

This study revealed a direct pathway between health system indicators and tuberculosis incidence rates. Regarding TB policies' impact on TB incidence, the evidence shows that these policies have substantially reduced tuberculosis (Lönnroth et al. 2015), but no research has examined this at the country level. This study showed a direct positive pathway between detection policies and tuberculosis incidence rates in the short run, which may lead to lower rates in the long run.

Limitations

The primary constraint of this study was the limited sample size due to the number of countries in the world and that a few countries had to be eliminated because of missing values. Because of this, it was challenging to have enough observed variables to arrive at a good measurement model, and it may have resulted in omitted variable bias.

Another limitation was the reliability of the measures, which were not always uniformly defined, were self-reported to the WHO, and were updated irregularly as countries corrected and updated previously submitted data. For example, TB data varied because of national differences in diagnosis, testing, and reporting (US-Mexico Border Health Commission 2003). Therefore, the data may not represent exactly the same measure across countries.

As far as internal validity, it is possible that the study did not measure what the researcher intended. For example, in Mexico TB cases are mostly diagnosed clinically, which may result in false-positive diagnoses. This is in contrast to a more accurate method of diagnosis, such as confirmatory TB tests, which determines diagnosis in countries such as the USA. Also, because it was cross sectional, this study did not have temporal ordering, so causal inferences cannot be made. Furthermore, while this study indicated direct path relationships between the constructs and the dependent variable, the results should not be reduced to a simple explanation. In reality, this is a very complex problem, comprised of many interdependencies and with no simple solution.

Finally, because these are results at the most macro (country) level, they cannot be generalized to regions or localities within the country at the micro-level. There may be large differences and disparities within the country.

Future research

Regarding research design, future studies should explore why the latent construct of economic stability was not directly related to TB incidence rates. The construct may have required additional or different observed variables to be significant in the model. For a more causal interpretation, future research could utilize a growth curve model to analyze longitudinal data. This would provide the ability to determine whether countries that implement WHO's Xpert policies have lower TB incidence in the long run. Future research could specifically examine provinces or states within individual countries or a group of countries such as the high-burden TB nations.

Regarding measures, future research could incorporate other latent constructs and measures pertaining to climate and the environment, population and demographics, individual behaviors, barriers to care, and policies and laws. Other TB detection policies could be used, such as the Directly Observed Treatment Short Course (DOTS), which is a cost-effective, efficient strategy for TB control (WHO 2016).

Compliance with ethical standards

This retrospective study did not involve human participants or animals and was exempted by the University of Central Florida IRB. No external funds were used in the research, and the authors have not and will not receive honoraria or other financial gain from the research. In sum:

Ethical approval This article does not contain any studies with human participants or animals performed by any of the authors.

Informed consent For this type of study formal consent is not required.

Conflict of interest The authors declare no conflicts of interest.

Appendix

Table 3 Study measures, definitions, and sources

Constructs and observed variables	Definition and measurement	Source and year
Political stability		
Voice and accountability	"Extent to which a country's citizens are able to participate in selecting their government as well as freedom of expression, freedom of association, and a free media"* (data are compiled from numerous representative and non-representative indexes and surveys) Measured in "percentile rank terms from 0 to 100, with higher values corresponding to better governance performance"*	World Bank's Worldwide Governance Indicators, 2014
Absence of violence/ terrorism	"Likelihood of political instability and/or politically motivated violence, including terrorism"* (Data are compiled from numerous representative and non-representative indexes and surveys) Measured in "percentile rank terms from 0 to 100, with higher values corresponding to better governance performance"*	
Control of corruption	"Extent to which public power is exercised for private gain, including both petty and grand forms of corruption as well as "capture" of the state by elites and private interests"* (data are compiled from numerous representative and non-representative indexes and surveys) Measured in "percentile rank terms from 0 to 100, with higher values corresponding to better governance performance"*	
Regulatory quality	"Extent to which a country's government is able to formulate and implement sound policies and regulations that permit and promote private sector development"* (data are compiled from numerous representative and non-representative indexes and surveys) Measured in "percentile rank terms from 0 to 100, with higher values corresponding to better governance performance"*	

Table 3 (continued)

Constructs and observed variables	Definition and measurement	Source and year
Rule of law	"Extent to which agents have confidence in and abide by the rules of society, and in particular the quality of contract enforcement, property rights, the police, and the courts as well as the likelihood of crime and violence"* (data are compiled from numerous representative and non-representative indexes and surveys) Measured in "percentile rank terms from 0 to 100, with higher values corresponding to better governance performance"*	
Economic stability		
Gross domestic product (GDP)	Per capita "sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products"** Measured in current US dollars $/ country's population	
Exports	"The value of all goods and other market services provided to the rest of the world. They include the value of merchandise, freight, insurance, transport, travel, royalties, license fees, and other services, such as communication, construction, financial, information, business, personal, and government services. They exclude compensation of employees and investment income (formerly called factor services) and transfer payments"** Measured as % of a country's total GDP	World Bank's World Development Indicators, 2014
Gross national income (GNI)	"Per capita gross national income, converted to US dollars using the World Bank Atlas method, divided by the midyear population. GNI is the sum of value added by all resident producers plus any product taxes (less subsidies) not included in the valuation of output plus net receipts of primary income (compensation of employees and property income) from abroad"** Measured in current US dollars $/ country's population	
Total reserves	"Holdings of monetary gold, special drawing rights, reserves of IMF members held by the IMF, and holdings of foreign exchange under the control of monetary authorities. The gold component of these reserves is valued at year-end (December 31) London prices"** Measured in "percent of total external debt, current US dollars $"**	
Health system indicators		
Sanitation	"Percentage of the population using improved sanitation facilities. Improved sanitation facilities are likely to ensure hygienic separation of human excreta from human contact. They include flush/pour flush (to piped sewer system, septic tank, pit latrine), ventilated improved pit (VIP) latrine, pit latrine with slab, and composting toilet"** Measured as % of population with access	World Bank's World Development Indicators, 2013 or 2014
Water	"Percentage of the population using an improved drinking water source. The improved drinking water source includes piped water on premises (piped household water connection located inside the user's dwelling, plot or yard), and other improved drinking water sources (public taps or standpipes, tube wells or boreholes, protected dug wells, protected springs, and rainwater collection)"** Measured as % of population with access	
Health expenditures	"Sum of public and private health expenditure; covers provision of health services (preventive and curative), family planning activities, nutrition activities, and emergency aid designated for health but does not include provision of water and sanitation"** Measured as % of a country's total GDP	
Measles immunizations	"Percentage of children ages 12–23 months vaccinated for measles."** Adequate immunization is 1 dose Measured as % of children ages 12–23 months who are adequately immunized	

Table 3 (continued)

Constructs and observed variables	Definition and measurement	Source and year
DTP immunizations	"Percentage of children ages 12–23 months vaccinated for diphtheria, pertussis (or whooping cough)."** Adequate immunization is 3 doses Measured as % of children ages 12–23 months who are adequately immunized	
TB case detection	Number of new and relapse tuberculosis cases (all forms) notified to WHO in a given year, "divided by WHO's estimate of the number of incident tuberculosis cases for the same year" Measured as % detected	
Detection policies		
Xpert TBHIV	"Absence or presence of national guidance that indicates the use of Xpert MTB/RIF as the initial diagnostic test for the diagnosis of TB in all people suspected of having TB"*** Dummy coded: 0 = absence (no national guidance in place), 1 = presence (national guidance in place)	World Health Organization, 2014
Xpert MDR	"Absence or presence of national guidance that indicates the use of Xpert MTB/RIF as the initial diagnostic test for the diagnosis of drug-resistant TB among people at risk"*** Dummy coded: 0 = absence (no national guidance in place), 1 = presence (national guidance in place)	
Xpert Children	"Absence or presence of national guidance that indicates the use of Xpert MTB/RIF as the initial diagnostic test for the diagnosis of TB in children suspected of having TB"*** Dummy coded: 0 = absence (no national guidance in place), 1 = presence (national guidance in place)	
Xpert EPTB	"Absence or presence of national guidance that indicates the use of Xpert MTB/RIF as the initial diagnostic test for the diagnosis of extra-pulmonary TB using selected specimens"*** Dummy coded: 0 = absence (no national guidance in place), 1 = presence of national guidance	
TB incidence rate	"Estimated number of new and relapse tuberculosis cases arising in a given year, expressed as the rate per 100,000 population. All forms of TB are included, including cases in people living with HIV"** Measured per 1000 population	World Bank's World Development Indicators, 2014
Controls		
Population density	"Midyear population divided by land area in square kilometers; counts all residents regardless of legal status or citizenship—except for refugees not permanently settled in the country of asylum"** Measured as #/sq. km	World Bank's World Development Indicators, 2014
Refugee population	"People who are recognized as refugees under the 1951 Convention Relating to the Status of Refugees or its 1967 Protocol, the 1969 Organization of African Unity Convention Governing the Specific Aspects of Refugee Problems in Africa, people recognized as refugees in accordance with the UNHCR statute, people granted refugee-like humanitarian status, and people provided temporary protection"** Measured as % of refugees [(#/ country's population)*100]	
Precipitation	"Long-term average in depth (over space and time) of annual precipitation in the country. Precipitation is defined as any kind of water that falls from clouds as a liquid or a solid"** Measured in millimeters per year	

Data Definition and Measurement Sources:

*World Bank's Worldwide Governance Indicators. Data set available from http://info.worldbank.org/governance/wgi/index.aspx#home

**World Bank's World Development Indicators. Data set available from http://databank.worldbank.org/data/reports.aspx?source=world-development-indicators.

***World Health Organization. Data set available from http://www.who.int/tb/country/data/download

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