The impact of corruption on multidrug-resistant tuberculosis: a quantitative assessment

To the Editors:

Multidrug-resistant tuberculosis (MDR-TB) is among the most preoccupying aspects of the pandemic of antimicrobial resistance. In 2008, an estimated 440,000 cases of MDR-TB emerged globally and caused 150,000 deaths [1]. MDR-TB is globally distributed, but significant variations in prevalence have been observed in different geographical regions.

The emergence of antimicrobial resistance is a complex problem driven by numerous interconnected factors, many of which are linked to the use of antimicrobials [2]. According to CAMINERO [3], at a community level four main groups of potential factors associated with the selection of resistance and the generation of MDR-TB under epidemic conditions exist: 1) non-implementation of DOTS (Directly Observed Treatment Short course) and DOTS expansion strategies; 2) inadequate supply or poor quality of drugs; 3) patients' inadequate drug intake; and 4) other factors such as the magnitude of HIV infection.

Corruption is a complex problem which threatens the impact of public investments, healthcare access and services, equity and outcomes [4]. There is mounting evidence on the negative effects of corruption on the health and welfare of citizens and on the consequences of corruption in multiple health areas or processes, especially in the regulation of product quality and the distribution and use of drugs. More globally, corruption was shown to affect all domains of life from education to economic performance [5] and it could also impact on health outcomes.

Due to a strong overlap between corruption consequences and potential MDR-TB drivers, it was argued in the literature that corruption may have a deep impact on drug resistance, particularly on MDR-TB prevalence in some parts of the world [6]. However, quantitative data at a country level on this subject are very poor. Accordingly, data on MDR-TB prevalence, the potential current risk factors of MDR-TB prevalence and current corruption levels were gathered.

National MDR-TB data in 2008 were compiled from estimations calculated by the 2010 global report of the World Health Organization (WHO) [7]. The studied indicator was the percentage of MDR-TB among new TB cases. The national corruption level was assessed using the 2008 Corruption Perception Index (CPI) compiled by Transparency International, which orders the countries of the world according to "the degree to which corruption is perceived to exist among public officials and politicians" [8]. This index ranges from 0 to 10 with a higher score meaning less (perceived) corruption.

To reflect the economic level and development level of studied countries, the Gross Domestic Product (GDP) per capita, the dependency ratio, the literacy rate and the percentage of rural population in 2008 were used [9]. The National health and medical level circa 2008 was assessed using the public health expenditure per capita, HIV prevalence, the national TB case detection rate, the DOTS population coverage and the TB treatment success rate, which were obtained from the World Bank and WHO [9].

Logarithm transformations of the percentage of MDR among new TB cases in 2008 were used in this study as the outcome variables. Data on 190 countries were provided. For each studied factor, unweighted univariate linear regressions were then performed. In order to identify the dominant factors in those that were statistically significant in univariate regression ($p<0.2$), significant variables were included in a multivariate linear regression model. To determine the final multivariate model, a backward stepwise linear regression was then used to simultaneously adjust for various variables of interest. Statistical significance was set at $p<0.1$. As a step towards stabilising the residual variation in regression analysis, logarithmic transformations of the data on health expenditure per capita and GDP per capita were used. Homoscedasticity was verified graphically and the model including corruption was compared to the model without corruption using the adjusted R^2. All statistical analyses were conducted using R 2.12.0 (R-project).

In 2008, the percentage of MDR-TB among new TB cases varied from 0 to 22.3% with a world median at 1.9%. For percentage of MDR among new TB cases, the final multivariable model (adjusted $R^2=0.068$) included only the following significant variables: TB treatment success rate ($p=0.034$) and CPI score ($p=0.001$), which were both negatively correlated with the percentage of MDR among new TB cases. Others variables were not as significantly associated with the studied outcome, both in univariate and multivariate regressions. Incorporation of the CPI in the model increased the adjusted R^2 from 0.013 to 0.068 (+5.5%). The coefficient for the CPI ($\beta= -0.0635$) in the final multivariate model would mean that a decrease in one point of the CPI (*i.e.* a more important perceived corruption) would increase the log of percentage of MDR among new TB cases by 0.0635.

After verification, the homoscedasticity and normal assumptions were shown to be respected in the final linear model. A simultaneous bubble plot for the CPI, the TB treatment success rate and the percentage of MDR among new TB cases are shown in figure 1.

Ecological studies have their limitations (*i.e.* bias and confounding) [10]. Furthermore, this study was limited to a 1-yr period (2008), used only one kind of corruption measure to assess the overall country corruption level and, due to the lack of objective data, was based on rough estimations made by the WHO. In addition, further studies have to be performed to: 1) identify the exact temporal pattern of studied variables and their possible lag effect on MDR-TB level; 2) confirm this trend using other MDR-TB level indicators; and 3) calculate more precisely the

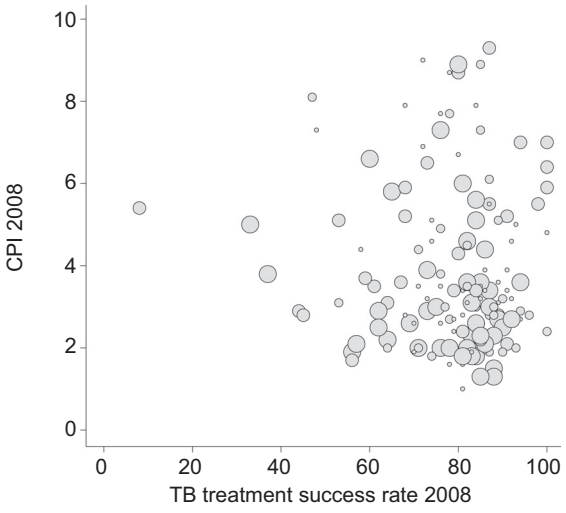

FIGURE 1. Bubble plot of the percentage of multidrug-resistant tuberculosis (MDR-TB) among new TB cases according to the Corruption Perception Index (CPI) score and the TB treatment success rate in 2008. For a given country, the greater the bubble size the greater its percentage of MDR among new TB cases.

overall impact of corruption on MDR-TB. However, the data used in this analysis is the only data available to study the problem at this scale and the study has the merit of approaching a controversial problem from an innovative angle.

The linear regression analysis presented here, after taking into account known significant predictors of MDR-TB level (TB treatment success rate), seems to point towards a significant pejorative link between perceived corruption and the percentage of MDR-TB among new TB cases at a national level. In this model, a decrease in CPI of one point (*i.e.* a more important perceived corruption) was associated with an increase in the logarithm transformation of the percentage of MDR-TB of 0.0635. The adjustment of the final model was poor (pseudo R^2=0.068) meaning that only 6.8% of the data variability was captured by the model. Incorporation of CPI in the final model led to a 5% increase of the pseudo R^2. According to this result, it could be hypothesised that ~5% of MDR-TB rate variability could be explained by corruption.

This study is a first step in the quantification of the current global impact of corruption on MDR-TB in human populations and shows that possibly ~5% of the inter-country variability of the percentage of MDR among new TB cases could be related to corruption, a total that largely exceeds the effect of health-related factors significantly associated with the outcome in the analysis (TB management strategies). But still, because the equation corruption equals death is seldom explicit, corruption only seems like a nuisance. In practice, governments still treat health and corruption as separate components rather than integral components of the same strategy. To address these obstacles, policies and interventions supported by governments must integrate initiatives that recognise how they are interrelated to fight and efficiently contain the burden of MDR-TB.

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REFERENCES

1 Dye C, Williams BG, Espinal MA, *et al*. Erasing the world's slow stain: strategies to beat multidrug-resistant tuberculosis. *Science* 2002; 295: 2042–2046.
2 Byarugaba DK. A view on antimicrobial resistance in developing countries and responsible risk factors. *Int J Antimicrob Agents* 2004; 24: 105–110.
3 Caminero JA. Multidrug-resistant tuberculosis: epidemiology, risk factors and case finding. *Int J Tuberc Lung Dis* 2010; 14: 382–390.
4 Vian T. Review of corruption in the health sector: theory, methods and interventions. *Health Policy Plan* 2008; 23: 83–94.
5 Abed GT, Gupta S, eds. Governance, Corruption, & Economic Performance. Washington, International Monetary Fund, 2002.
6 Cohen JC, Mrazek M, Hawkins L. Tackling corruption in the pharmaceutical systems worldwide with courage and conviction. *Clin Pharmacol Ther* 2007; 81: 445–449.
7 World Health Organisation. Multidrug and Extensively Drug-Resistant TB (M/XDR-TB): 2010 Global Report on Surveillance and Response. Geneva, World Health Organisation, 2010.
8 Transparency International. www.transparency.org Last updated 2012. Date last accessed: January 4, 2011.
9 The World Bank. http://data.worldbank.org Last updated 2012. Date last accessed: January 4, 2011.
10 Morgenstern H. Uses of ecologic analysis in epidemiologic research. *Am J Public Health* 1982; 72: 1336–1344.

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