International Monetary Fund Programs and Tuberculosis Outcomes in Post-Communist Countries

David Stuckler[1*], Lawrence P. King[2], Sanjay Basu[3]

1 Faculty of Social and Political Sciences, University of Cambridge and King's College, Cambridge, United Kingdom, **2** Faculty of Social and Political Sciences, University of Cambridge and Emmanuel College, Cambridge, United Kingdom, **3** Department of Epidemiology and Public Health, Yale University, New Haven, Connecticut, United States of America

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Abbreviations: DOTS, directly observed therapy; EE, Eastern Europe; FSU, Former Soviet Union; IMF, International Monetary Fund; WHO, World Health Organization

* To whom correspondence should be addressed. E-mail: ds450@cam.ac.uk; after October 2008, david.stuckler@aya.yale.edu

ABSTRACT

Background

Previous studies have indicated that International Monetary Fund (IMF) economic programs have influenced health-care infrastructure in recipient countries. The post-communist Eastern European and former Soviet Union countries experienced relatively similar political and economic changes over the past two decades, and participated in IMF programs of varying size and duration. We empirically examine how IMF programs related to changes in tuberculosis incidence, prevalence, and mortality rates among these countries.

Methods and Findings

We performed multivariate regression of two decades of tuberculosis incidence, prevalence, and mortality data against variables potentially influencing tuberculosis program outcomes in 21 post-communist countries for which comparative data are available. After correcting for confounding variables, as well as potential detection, selection, and ecological biases, we observed that participating in an IMF program was associated with increased tuberculosis incidence, prevalence, and mortality rates by 13.9%, 13.2%, and 16.6%, respectively. Each additional year of participation in an IMF program was associated with increased tuberculosis mortality rates by 4.1%, and each 1% increase in IMF lending was associated with increased tuberculosis mortality rates by 0.9%. On the other hand, we estimated a decrease in tuberculosis mortality rates of 30.7% (95% confidence interval, 18.3% to 49.5%) associated with exiting the IMF programs. IMF lending did not appear to be a response to worsened health outcomes; rather, it appeared to be a precipitant of such outcomes (Granger- and Sims-causality tests), even after controlling for potential political, socioeconomic, demographic, and health-related confounders. In contrast, non-IMF lending programs were connected with decreased tuberculosis mortality rates (−7.6%, 95% confidence interval, −1.0% to −14.1%). The associations observed between tuberculosis mortality and IMF programs were similar to those observed when evaluating the impact of IMF programs on tuberculosis incidence and prevalence. While IMF programs were connected with large reductions in generalized government expenditures, tuberculosis program coverage, and the number of physicians per capita, non-IMF lending programs were not significantly associated with these variables.

Conclusions

IMF economic reform programs are associated with significantly worsened tuberculosis incidence, prevalence, and mortality rates in post-communist Eastern European and former Soviet countries, independent of other political, socioeconomic, demographic, and health changes in these countries. Future research should attempt to examine how IMF programs may have related to other non-tuberculosis–related health outcomes.

The Editors' Summary of this article follows the references.

Introduction

A major barrier to effective tuberculosis control has been the capacity of health systems to detect and adequately treat infected persons [1–4]. The World Health Organization (WHO) has promoted a policy of expanding directly observed therapy (DOTS) for tuberculosis control, which critically depends upon the availability of doctors, nurses, community health-care workers, and associated laboratory and hospital infrastructure. In resource-poor settings, international donations and financial lending play a crucial part in determining how such programs will expand and how successful they might be [5–7].

The International Monetary Fund (IMF) provides a major source of capital for financially ailing countries, including capital used for health program development. Like most international lending institutions, the IMF seeks to ensure that it will recover its loans from borrowers. To reduce the risk of loan defaults, the IMF requires a set of strict "conditionalities" on its lending, which include economic programs that countries must agree to comply with in order to receive funds. According to the IMF, the objective of these programs is to achieve macroeconomic stability and economic growth: "Our primary objective is growth. In my view there is no longer any ambiguity about this. It is toward growth that our programs and their conditionality are aimed" [8].

Whether these IMF programs have impacted health and health infrastructure has been a source of ongoing controversy. In the mid-1980s, a UNICEF report (*Adjustment with a Human Face*) suggested that IMF structural adjustment programs had disenfranchised poor populations [7]. A decade later some academics and NGOs suggested that the conservative inflationary targets of IMF programs (being set often lower than 5%) were undermining infectious disease control efforts, particularly in the context of HIV/AIDS and tuberculosis epidemics [9–15]. Such targets constrained public health and social spending, for example by reducing public social expenditure and placing caps on public wage bills, and led to restructured health-care financing and delivery, often via privatizing health services [9,10,12]. (The World Bank and IMF do not advise governments to reduce social expenditures; however, the officials are fully aware that in practice adjustment policies often translate into reduced investment in health, education, and social services in order to meet economic benchmarks) [16]. Linkages between the IMF and health have been hypothesized for a variety of health-related issues, including the emigration of health personnel [11,13], reduction of surveillance and disease testing [14–16], scalebacks of social safety nets [10,12], declining sustainability of subsistence economies [8,14,17], urbanization and migration patterns [14,16,18], and increased impoverishment and inequality [6,7,9,16]. More recently, the Center for Global Development convened a working group of leading economists from the IMF and World Bank, as well as public health experts, to assess the IMF's effect on the health sector (*Does the IMF Constrain Health Spending in Poor Countries?)* [5]. The final report concluded that "in a number of ways IMF actions have unduly constrained countries' policy choices and that it needs to do more to help explore a broader range of policy options" (page 56, [5]). However, to our knowledge, these hypothesized effects of IMF programs on health and health infrastructure have yet to be tested with empirical data [5,16].

The post-communist Eastern European (EE) and former Soviet Union (FSU) countries provide a quasi-natural experimental setting for studying the relationship between IMF programs and infectious disease control. Nearly every EE/FSU country during the early- to mid-1990s participated in an IMF program for the first time, and country participation in relatively similar IMF programs occurred in different periods, for different loan sizes, and for varying durations (table I in Text S1). We studied how these different IMF programs impacted upon differences in tuberculosis incidence, prevalence, and mortality trends among EE/FSU countries. Tuberculosis was the subject of interest because of the extensive longitudinal data available to study the disease in EE/FSU countries, and because tuberculosis incidence and prevalence is an indicator of societal health [19]. Existing medical and public health literature has suggested a relationship between IMF programs and infectious disease outcomes, and the effect is hypothesized to be mediated via the health system, to which tuberculosis outcomes are sensitive [10]. During the 1990s, EE/FSU countries experienced significant and increasing variations in their tuberculosis burdens: in the FSU, tuberculosis mortality rates doubled from 1991 to 2002 (from 6.2 to 13.3 per 100,000 population), while mortality in the EE started from a similar level but alternatively fell by roughly 40% (from 5.6 to 3.2 per 100,000 population) (see also table I and II in Text S1). In parallel, among FSU countries the average outstanding IMF debt was $850 million for an average of 10.3 y in 1989–2005, compared to $270 million among EE countries for an average exposure time of 5.5 y. The country with the greatest proportional tuberculosis mortality rate drop over this period, Slovenia, was the only one that did not partake in an IMF program. Today, tuberculosis rates in the FSU countries rank among the worst in the world, and the WHO notes that FSU is the only region lagging behind on Millennium Development Goal number 6 target to "halt and reverse" the spread of tuberculosis [1].

Figure 1 compares average trends in tuberculosis mortality rates for EE/FSU countries participating in IMF programs and countries that were not participating from 1991 to 2003. Countries involved in IMF programs experienced significantly different trajectories in tuberculosis mortality rates than countries that were not under these programs. In this study, we examine the relationship revealed by this figure, by further characterizing the relationship between IMF lending programs and tuberculosis incidence, prevalence, and mortality trends among the post-communist EE and FSU countries.

Methods

Four sets of health outcomes data were used in the analysis, all of which are from the WHO. Tuberculosis incidence, prevalence, mortality, and DOTS population coverage levels and treatment success rates were obtained from the WHO Global Tuberculosis Database [20,21]; HIV and AIDS prevalence data were obtained from the WHO/UNAIDS Global HIV database [22]. IMF data were from the World Bank World Development Indicators (WDI) [23]. Control variables were from the WHO European Health For All Database 2007

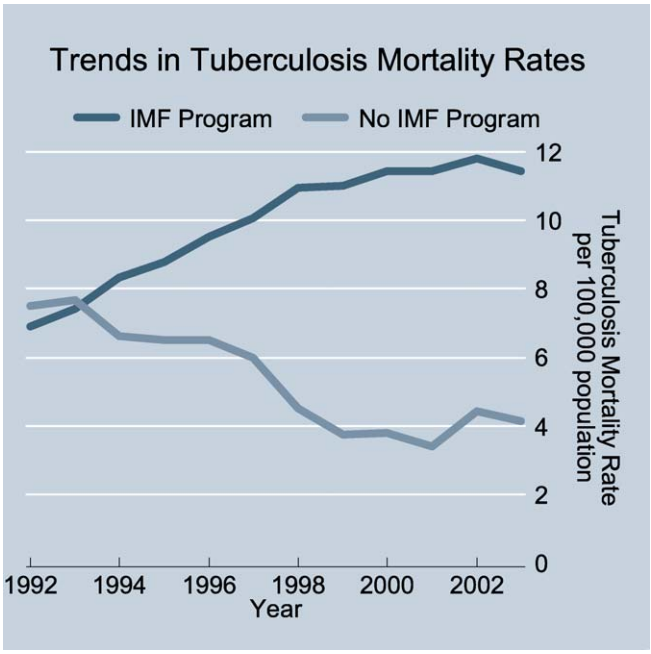

Figure 1. Trends in Tuberculosis Mortality Rates in Post-Communist European Countries, By Region

Data sources: authors' calculations, WHO Global Tuberculosis Database 2007 [20], and World Bank World Development Indicators 2005 edition.
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edition, WDI, and UNICEF TransMONEE database [24]. Data sources are further described in Text S2.

Despite evidence of underreporting in homicide and suicide data, in particular for the North Caucuses, the consensus among scholars of mortality data in transition has been that they are sufficiently reliable to permit comparative studies [25–30]. Nonetheless, we coped with data monitoring and quality through the use of several techniques. First, we introduced a set of dummy variables for each country, which holds time-varying effects, such as the strength of national surveillance systems, that are national in scope constant within nations (though see the paragraph on detection biases, below). These variables also correct for factors that differ across countries but remain fixed over time, such as membership in the former Soviet Union or proximity to Western Europe as well as initial transition conditions and country predispositions to higher mortality. This conservative modeling approach isolated how changes within individual countries impacted upon their tuberculosis mortality profiles [31], rendering the available data suitable to answer our research question.

Selection bias may be an issue for assessing the effect of IMF programs on tuberculosis incidence and mortality rates. Participating in an IMF program may have been an act of financial desperation, reflecting "how sick the country was to begin with," which could be linked to higher tuberculosis mortality rates irrespective of taking the IMF programs' "medicine." We controlled for this "sick patient" possibility using a lag of the change in overall log gross domestic product (GDP) in our main models as well as other observed financial health measures in a series of robustness checks. Our controls for differences between countries also net out potential unobserved selection biases relating to country predispositions to undertake IMF programs. Lastly, we modeled the hazard of participating in an IMF program for each country, and used this constructed variable to explicitly control for potential unobserved selection bias ("Heckman-type" selection model or "control function" approach, see the discussion in Text S7) [32–34].

We considered the impact of detection bias. If IMF programs damaged public health capacity, they would be expected to lead to underreporting of tuberculosis outcomes, which would have reduced the likelihood of observing evidence to support this hypothesis. On the other hand, if IMF programs improved public health infrastructure, then they could have led to improved surveillance, revealed by increasing tuberculosis rates followed by eventual declines in tuberculosis rates. We tested the relationship between IMF programs and public health spending and resources in order to characterize the relationship between IMF programs and actual increases in tuberculosis rates, to determine whether detection biases may have occurred. We also used controls for DOTS treatment success and DOTS population coverage, measures of quality and quantity of tuberculosis treatment, to offset differences in tuberculosis infrastructure. Lastly, we used a set of period effects to control for secular trends in the mortality data that may have occurred as a result of changes in detection capacity.

Several variables were introduced as controls, to examine the independent association of IMF programs with tuberculosis outcomes. We controlled for overall economic development; democratization, which has been theorized to exert positive effects on health [35] and captures political changes in each country; the occurrence of military or ethnic conflict, which has been shown to adversely impact disease incidence and mortality surveillance [21]; urbanization, which may facilitate the transmission of tuberculosis but also provide access to better health-care services, and serves as a proxy for overall social development; population dependency ratios, which reflect the stage of demographic transition and population age-structure; and population education levels, which captures the stock of human capital.

Thus, we specify the following log-linear regression model:

$$\begin{aligned}\text{Log Tuberculosis}_{it} = {} & \alpha + \beta_1 \text{IMF}_{it} + \beta_2 \text{GDP}_{it} + \beta_3 \text{GDP}_{\text{Cit}-1} \\ & + \beta_4 \text{DEM}_{it} + \beta_5 \text{WAR}_{it} + \beta_6 \text{URBAN}_{it} \\ & + \beta_7 \text{DEP}_{it} + \beta_8 \text{EDUC}_{it} + \mu_i + \eta_t + \varepsilon_{it}\end{aligned} \quad (1)$$

In Equation 1, i is country and t is year. IMF is a dummy variable for whether a country was receiving IMF funding; GDP is logged per capita in constant USD for the year 2000; GDPc is the lag of GDP change; DEM is an index of democratization from the Freedom House democracy indicators database [36]; WAR is a dummy variable for whether a country experienced military or ethnic conflict; URBAN is the percentage of the country's population living in urban settings; EDUC is the percentage of the population that has received tertiary education; μ and η are sets of dummy variables that control for country and period effects, as described above. We subsequently add further variables to test the associations of the duration of exposure to IMF programs and the size of IMF loans with tuberculosis outcomes. We also performed Granger- and Sims-causality

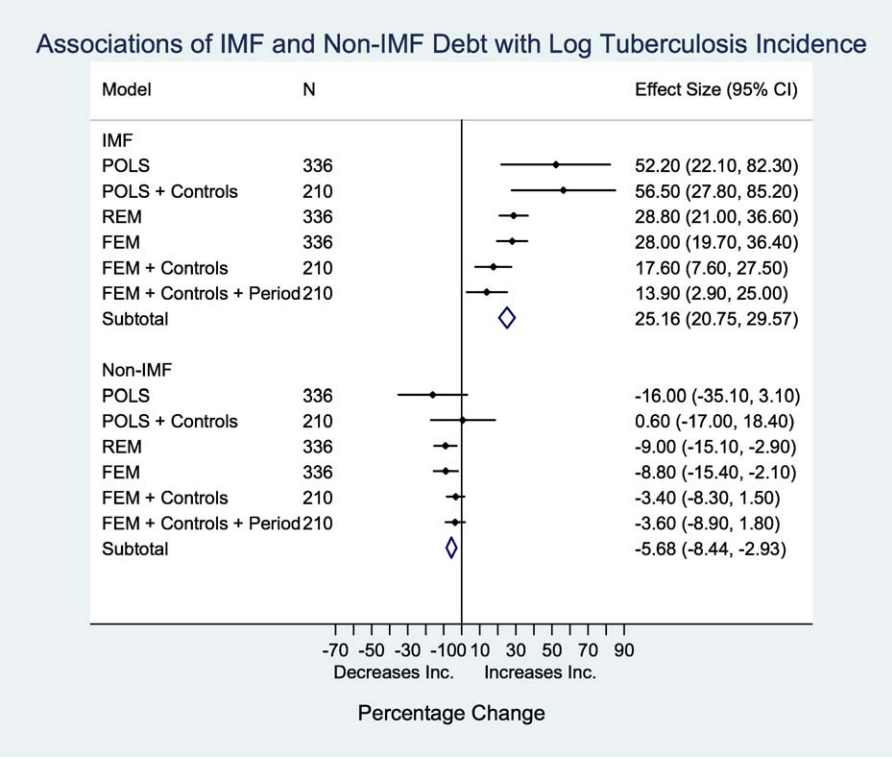

Figure 2. Forest Plot: Effects of IMF and Non-IMF Debt on Log Tuberculosis Incidence Results

Plot is based on six separate regression models using various controls and functional forms. Weighting used for aggregation calculated based on confidence intervals provided in STATA's standard metan module. Controls include either IMF or non-IMF program, change in log GDP, level of log GDP per capita, democratization index, dummy for occurrence of military or ethnic conflict, population dependency ratios, percentage of the population with tertiary education, and urbanization rates. CI, 95% confidence interval; FEM, fixed effects model, which uses a set of country dummies; POLS, pooled OLS model; REM, random effects model. "Period" refers to a set of year dummies.

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tests, which use the longitudinal nature of the data to test (i) whether IMF programs preceded and/or were contemporaneous with tuberculosis outcomes ("precedence") and (ii) whether the future values added predictive value beyond these measures as a negative check on our findings (based on the principle that the future does not cause the past) (see Text S4 for more details) [37,38]. Data were analyzed using xtreg with the fe and cluster options in STATA version 9.2.

Results

Associations of IMF Programs with Tuberculosis Outcomes

Figures 2–4 present the results of the 18 regression models for tuberculosis incidence, prevalence, and mortality rates with and without control variables. IMF program participation was associated with increases in tuberculosis incidence, prevalence, and mortality by 13.9%, 13.3%, and 16.6%, respectively. Since the results do not significantly differ across incidence, prevalence, and mortality rates (joint F-test, $p < 0.001$), the rest of the analysis proceeds using mortality rates because those data have been established as the most valid and reliable, although parallel results were found for incidence and prevalence (see tables I and II in Text S3).

Table 1 presents the results of the basic model for tuberculosis mortality rates with the full set of control variables. IMF program participation was significantly associated with increases in tuberculosis mortality rates from between 16% to 24% on average. Tuberculosis mortality rates rose by an average of 2.2 deaths per 100,000 from 1992 to 2002 in the post-communist countries; the absolute association of the IMF programs corresponds to 1.6 additional tuberculosis deaths per 100,000. Hence, participation in IMF programs appears to be connected with more than half of the increase in tuberculosis mortality rates observed in this cohort of countries. This relationship holds even after correcting for a broad set of potential confounders, including a country's level of economic development, potential financial desperation, socio-demographic factors, tuberculosis infrastructure, and HIV/AIDS.

Both WHO tuberculosis treatment indices—DOTS success rates and DOTS population coverage—had no significant associations with short-term tuberculosis mortality rates when accounting for the other explanatory variables, including IMF program lending. Adding HIV prevalence to the model did not significantly alter the coefficient describing the impact of IMF lending on tuberculosis mortality (model 2), although we did find evidence (similar to prior microlevel studies) that greater HIV prevalence was associated with tuberculosis mortality increases. Given the delay between rising HIV prevalence and associated increases in tuberculosis incidence, prevalence, and mortality [39], the finding that HIV prevalence did not impact upon the lending coefficient supports the hypothesis that IMF conditionalities worsened tuberculosis mortality rates by damaging infrastructure related to preventing mortality. Using AIDS

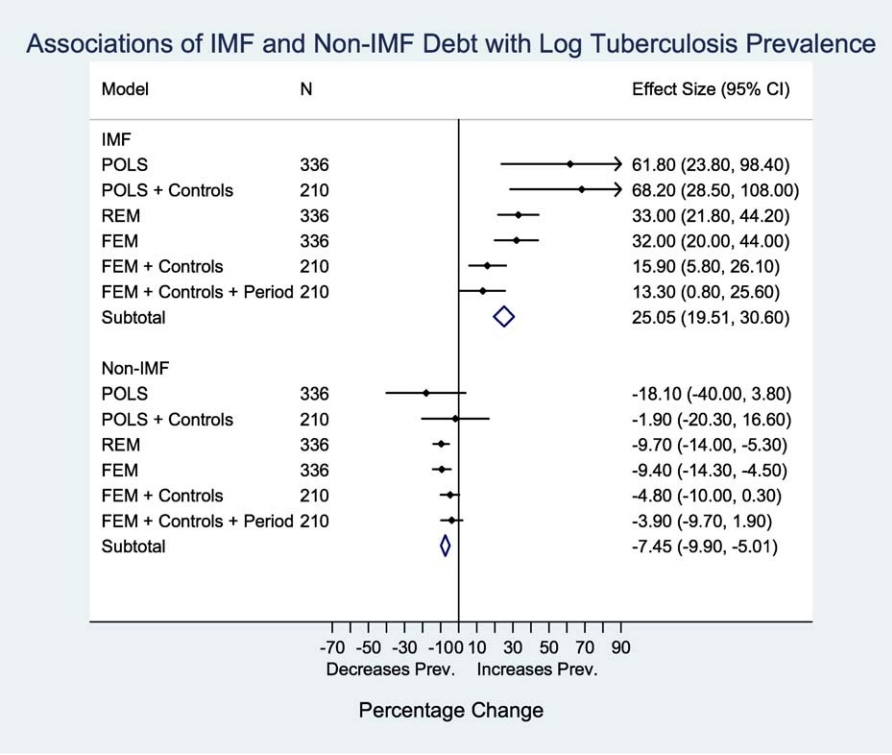

Figure 3. Forest Plot: Effects of IMF and Non-IMF Debt on Log Tuberculosis Prevalence

Results based on six separate regression models using various controls and functional forms. Weighting used for aggregation calculated based on confidence intervals provided in STATA's standard metan module. Controls include either IMF or non-IMF program, change in log GDP, level of log GDP per capita, democratization index, dummy for occurrence of military or ethnic conflict, population dependency ratios, percentage of the population with tertiary education, and urbanization rates. CI, 95% confidence interval; FEM, fixed effects model, which uses a set of country dummies; POLS, pooled OLS model; REM, random effects model. "Period" refers to a set of year dummies.

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prevalence rates, log HIV cases, or log AIDS cases as alternative measures did not change the results (unpublished data).

We further tested the temporal patterns of the IMF's associations with tuberculosis mortality rates in Table 2 using a dynamic model specification that included both leads and lags of the dummy for IMF participation. If our results were possibly confounded by factors causing countries to take up IMF programs and increasing tuberculosis mortality rates (such as an ensuing financial crisis or other unobserved country "sickness"), then the periods prior to the start of an IMF program would likely have associations with increased tuberculosis rates. As shown in Table 2, we find that the periods prior to IMF program participation did not have a significant association with tuberculosis mortality rates (using a joint F-test, see Text S4 and [40] for details and additional specifications). On the other hand, once the IMF program is started, the negative associations endure for at least 4 y.

It may be the case that external debt is correlated with higher tuberculosis mortality, and that the observation associated with IMF programs is driven by reliance on donor monies and not specifically on the IMF programs. We test whether non-IMF lending, including credit from official and private sources and which did not involve the same set of economic conditionalities as the IMF programs, was associated with the relationships we observed with the IMF variables. As shown in Table 3, the regression revealed no evidence that the level of non-IMF lending had any association with tuberculosis mortality rates. However, we found that the dummy for non-IMF lending, shown in Figure 4, was significantly associated with reduced tuberculosis mortality (−7.6%, 95% confidence interval, −1.0% to −14.1%).

Next, we evaluated different indicators of exposure to IMF programs to determine whether the total amount of IMF credit affected the observed outcomes. Larger debts may exert a stronger effect on tuberculosis mortality, because the IMF might have stricter standards on countries for making progress in implementing conditionalities for whom default would have greater consequences. The results of this study provided evidence for a dose-response relationship of increasing IMF loans: each 1% increase in IMF credit was associated with increased tuberculosis mortality rates by 0.9%.

We also used a count variable for the number of years a country was exposed to IMF programs. Since longer exposure would correspond to greater institutional reforms, a higher count would lead to greater effects on tuberculosis mortality. We found that each extra year of exposure to an IMF program was associated with increased tuberculosis mortality by 4.1%.

Lastly, to further confirm that causality runs from the IMF programs to worse mortality, and not vice versa (that is, to confirm that the IMF did not loan more funds as a result of observing whatever factors may have worsened tuberculosis mortality), we tested the effects of exiting from an IMF

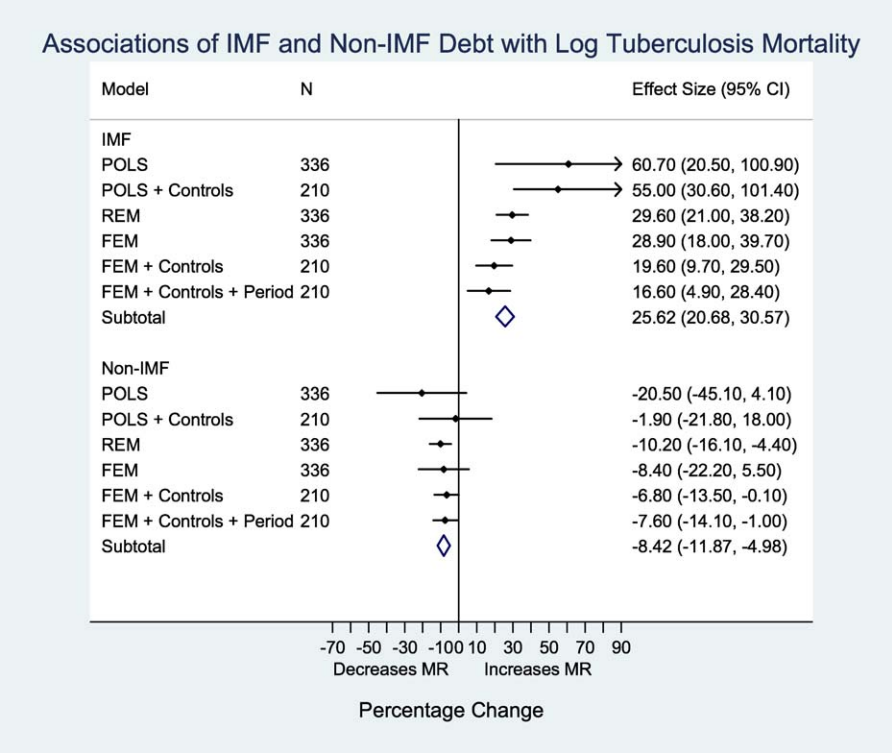

Figure 4. Forest Plot: Effects of IMF and Non-IMF Debt on Log Tuberculosis Mortality Rates

Results based on six separate regression models using various controls and functional forms. Weighting used for aggregation calculated based on confidence intervals provided in STATA's standard metan module. Controls include either IMF or non-IMF program, change in log GDP, level of log GDP per capita, democratization index, dummy for occurrence of military or ethnic conflict, population dependency ratios, percentage of the population with tertiary education, and urbanization rates. CI, 95% confidence interval; FEM, fixed effects model, which uses a set of country dummies; POLS, pooled OLS model; REM, random effects model. "Period" refers to a set of year dummies.

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program. In the periods after a country leaves the IMF program, tuberculosis mortality rates drop by 31% on average, after correcting for economic changes, sociodemographic variables, and variations in tuberculosis infrastructure (see also tables I and II in Text S6). Similarly, although we identified a significant relationship between greater IMF lending and increased tuberculosis mortality rates, we found no relationship between the changes in IMF lending and the preceding period's change in tuberculosis mortality rates, meaning that IMF loans did not increase as a result of observing worsening tuberculosis mortality (tables I–III in Text S4 further describe the results of "Granger-causality" tests).

Table 1. Associations of IMF Lending Programs with Log Tuberculosis Mortality Rates

Covariate	Model 1	Model 2	Model 3	Model 4
Dummy for IMF lending program	0.17** (0.06)	0.24*** (0.06)	0.17* (0.07)	0.17* (0.08)
DOTS success rate	—	—	−0.00 (0.00)	—
DOTS population coverage	—	—	—	0.00 (0.00)
Log GDP per capita	−0.20 (0.12)	−0.09 (0.16)	−0.30 (0.53)	0.14 (0.45)
Change in log GDP	0.01** (0.00)	0.01* (0.09)	0.01 (0.11)	0.00 (0.00)
Freedom House democracy index	−0.01 (0.02)	0.00 (0.02)	0.00 (0.02)	−0.00 (0.02)
Military conflict	0.17 12)	0.28 (0.16)	—	—
Population dependency ratio	−0.03 (0.04)	−0.02 (0.03)	−0.04 (0.03)	−0.02 (0.03)
Percentage of population with tertiary education	−0.00 (0.01)	−0.01 (0.01)	−0.00 (0.00)	−0.01 (0.01)
Percentage of population urban	−0.07 (0.05)	−0.06 (0.04)	−0.18* (0.06)	−0.10* (0.05)
Log HIV prevalence	—	0.06** (0.02)	0.02 (0.02)	0.02 (0.02)
Number of country-years	210	188	98	137
Number of countries	21	20	18	20
Within-R^2/total-R^2	0.55/0.94	0.60/0.95	0.57/0.99	0.44/0.97

Constant estimated but not reported; robust standard errors in parentheses clustered by country. Models include dummy variables for each country and period. DOTS is the main WHO program for controlling tuberculosis. Tuberculosis data are from the WHO Global Tuberculosis Database [20].

*, $p < 0.05$; **, $p < 0.01$; ***, $p < 0.001$ (two-tailed tests).

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Table 2. Dynamic Association of IMF Lending Programs with Log Tuberculosis Mortality Rates

Covariate	Association with Log Tuberculosis Mortality Rates
4 y before IMF	−0.06 (0.03)
3 y before IMF	0.02 (0.03)
2 y before IMF	−0.00 (0.03)
1 y before IMF	0.04 (0.05)
Current period start IMF	0.05 (0.04)*
1 y after IMF	0.10 (0.05)*
2 y after IMF	0.08 (0.03)*
3 y after IMF	0.10 (0.03)*
4 y after IMF	0.11 (0.04)*

Constant estimated but not reported; robust standard errors in parentheses clustered by country to reflect nonindependence of sampling and robustness to serial correlation. Models include dummy variables for each country and period as well as controls used in the basic specification in Equation 1. Tuberculosis data are from the WHO Global Tuberculosis Database [20]. Further details of the Sims-causality test and alternative specifications are provided in Text S4. Joint F-test on future lags, $F(4, 20) = 1.28$, $p = 0.31$.
*, $p < 0.001$ (two-tailed tests).
doi:10.1371/journal.pmed.0050143.t002

Table 3. Associations of IMF Lending Programs with Log Tuberculosis Mortality Rates

Covariate	Effect on Log Tuberculosis Mortality Rates
Log IMF credit	0.009 (0.003)***
Log non-IMF credit	0.001 (0.008)
Years exposed to IMF program	0.041 (0.010)***
Exit from IMF program	−0.307 (0.060)***

Constant estimated but not reported; robust standard errors in parentheses clustered by country. Results presented from four separate regression models, which include dummy variables for each country and period as well as controls used in the basic specification in Equation 1. Tuberculosis data are from the WHO Global Tuberculosis Database [20].
***, $p < 0.001$ (two-tailed tests).
doi:10.1371/journal.pmed.0050143.t003

Before proceeding to attempt to identify some possible macrolevel mechanisms that explain these associations, we conducted a series of robustness checks and regression diagnostics. Figure 5 presents a representative added-variable plot to identify potential outliers. First we removed potential outliers from this regression (liberally defined by standardized residuals greater than the absolute value of 2). The results were strengthened ($\beta = 5.3$), but were statistically indistinguishable from our original estimate ($\beta = 4.1$). We next removed regions where data quality has been suggested to be misreported, such as the Central Asian countries. Again, the results were consistent. We attempted to sequentially include a broad set of additional variables used to capture macroeconomic health, including inflation, hyperinflation, changes in real wages, changes in monetary emissions, and unemployment rates. We also added variables for macroeconomic policies implemented including price and trade liberalization and foreign direct investment inflows. Adding these additional controls for how sick the patient might have been did not change the results (Table 4 and Text S8). Other estimation modules, including xtregar and xtpcse (which attempt to explicitly estimate serial correlation) were used, and the results were consistent. We also re-ran these robustness checks without controls for country and period effects. In all cases, the coefficients on the IMF programs were even larger ($\beta = 0.29$ in Figure 4), which emphasizes that our reported estimates are conservative.

Association of IMF Programs with Tuberculosis Infrastructure

One explanation for the above results is that the associations of IMF programs with tuberculosis mortality rates may be driven by reductions in state capacity, which leads to drops in tuberculosis prevention and treatment capacity. We examine this hypothesis using a variety of dependent variables known to be associated with tuberculosis control success from previous studies. By comparison, we test the associations of a non-IMF debt regime.

Table 5 shows the results from a series of separate regression models using a variety of dependent variables that may mediate the observed relationship between IMF programs and tuberculosis mortality. IMF programs are linked to a significant 8% drop in government spending as a percentage of GDP, a 7% drop in the number of physicians per capita, and an average of 42% lower DOTS population coverage (Text S5 provides a preliminary path-analysis).

We also test whether IMF programs were associated with short-term increases in HIV prevalence. If the pathway linking IMF programs to increased tuberculosis mortality was through HIV prevalence, then we should find a direct relationship between IMF programs and increased HIV prevalence. Instead, we find no association between IMF programs and HIV prevalence; together with our previous results, this indicates that the association of IMF programs with tuberculosis mortality was mediated by other mechanisms.

Among all countries, IMF debt has a more negative association than non-IMF debt in terms of these pathways (Table 5). We did not find any significant associations with non-IMF debt, although the coefficients for non-IMF debt were generally in the direction of improved tuberculosis control, suggesting that additional capital independent of IMF programs may have provided an important source of funding for strengthening health systems.

We then tested the relationships of IMF and non-IMF debts with incarceration rates, which have been identified by numerous studies as important drivers of localized tuberculosis epidemics [40,41]. Only non-IMF debt was linked to greater incarceration rates at $p < 0.05$, which suggests that incarceration may not have been one of the major pathways linking IMF programs to the adverse associations with tuberculosis outcomes.

Controlling for Selection Bias

Despite the robustness tests used in this assessment, and strong evidence supporting the mechanism proposed to explain how IMF conditionalities affect tuberculosis mortality, there may still remain potential for our results to have been driven by some aspect of the changing environment that we have not controlled for. We can address the issue of unobserved selection bias directly by constructing, and conditioning upon, a variable of the hazard for entering into an IMF program, generated from a first step bivariate probit

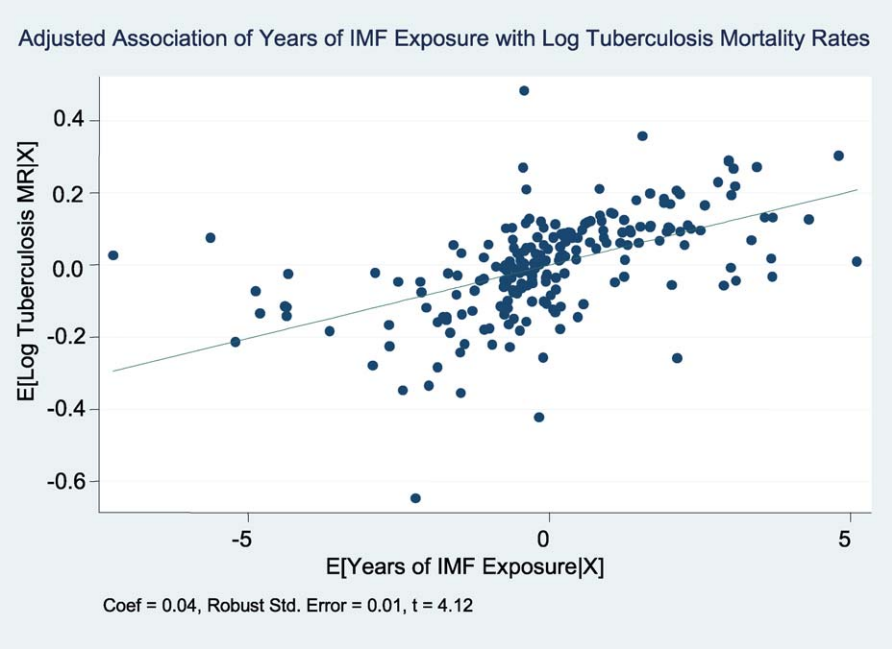

Figure 5. Adjusted Association of Years of IMF Exposure on Log Tuberculosis Mortality Rates
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model (a "Heckman-type" selection model or "control function" approach, Table 6 and Text S7) [32–34]. Once we add controls for potential selection bias associated with IMF lending, the negative association of IMF programs magnifies to 35% at $p < 0.001$. The coefficient on the variable for the hazard of participating is significant, but in the opposite direction of the "sick patient" criticism (–8.9%, $p < 0.01$). Stated otherwise, the factors that predisposed countries to take on IMF programs are linked to lower rates of tuberculosis mortality. This method of controlling for selection bias has an inherently counterfactual interpretation: the countries that started IMF programs, apart from the IMF programs themselves, would have experienced improved tuberculosis outcomes, net of our controls.

Discussion

Our results show that IMF economic reform programs are strongly associated with rises in tuberculosis mortality rates in post-communist Eastern European and FSU countries, even after correcting for potential selection bias, tuberculosis surveillance infrastructure, levels of economic development, urbanization, and HIV/AIDS. We estimated an increase in tuberculosis mortality rates when countries participate in an IMF program, which was much greater than the reduction that would have been expected had the countries not participated in an IMF program. On the other hand, we estimated a decrease in tuberculosis mortality rates associated with exiting an IMF program. Both the duration and amount of IMF lending have an estimated dose-response

Table 4. Additional Sample and Specification Robustness Checks

Variables	Covariates	Coefficient of Control	Coefficient of IMF Program	Number of Country-Years
Economic	**Log inflation**	0.02 (0.02)	0.31*** (0.08)	162
	Lag of hyperinflation (inflation > 30%)	0.02 (0.05)	0.16*** (0.06)	210
	Real wage	−0.003 (0.003)	0.15* (0.06)	203
	Log unemployment rates	0.01 (0.05)	0.15*** (0.06)	200
	Change in money supply (M2)	−0.0006 (0.0024)	0.25*** (0.07)	161
	Dummy for bank crisis	−0.07 (0.06)	0.17*** (0.06)	210
	Foreign direct investment as a percentage of GDP	−0.01 (0.00)	0.17** (0.06)	210
Policy	**EBRD index of price liberalization**	−0.04 (0.03)	0.17*** (0.06)	210
	EBRD index of foreign exchange and trade liberalization	0.04 (0.03)	0.18** (0.04)	197

Robust standard errors in parentheses, clustered by country to reflect nonindependence of sampling and for robustness to serial correlation. Models also control for change in log GDP per capita, level of log GDP per capita, democratization index, dummy for occurrence of military or ethnic conflict, population dependency ratios, percentage of the population with tertiary education, urbanization rates, as well as country- and period-fixed effects. See Text S8 for more details. EBRD, European Bank for Reconstruction and Development; GDP, gross domestic product.

**, $p < 0.01$; ***, $p < 0.001$.

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Table 5. Macro-Pathways of IMF Programs' Associations with Tuberculosis Outcomes

Covariate	Government Expenditures as a Percentage of GDP	Log Incarceration Rates	DOTS Coverage	Log Physicians per Capita	Log HIV Prevalence
Dummy for IMF lending program	−7.50** (2.21)	0.04 (0.04)	−0.42*** (0.10)	−0.07* (0.03)	0.19 (0.42)
Dummy for non-IMF lending	0.69 (0.73)	0.06* (0.02)	0.06 (0.03)	−0.01 (0.02)	0.10 (0.15)

Constant estimated but not reported; robust standard errors in parentheses clustered by country. Results presented from five separate regression models. Models include dummy variables for each country and period as well as controls used in the basic specification, except for DOTS coverage due to unavailable data. DOTS is the WHO program for controlling tuberculosis. Tuberculosis data are from the WHO Global Tuberculosis Database [20]. Further path-analytic models that estimate the relationship between the putative intermediary pathways and tuberculosis outcomes are presented in Text S5.

*, $p < 0.05$; **, $p < 0.01$; ***, $p < 0.001$ (two-tailed tests).

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relationship with tuberculosis mortality rates: each additional year of participation in an IMF program was associated with increases in tuberculosis mortality rates by 4.1%, and each 1% increase in IMF lending was associated with increases in tuberculosis mortality rates by 0.9%. Debt to non-IMF lenders was found to have a slightly favorable association with tuberculosis mortality rates.

The robust results observed help to account for puzzling differences in why countries such as Russia, which was exposed to the IMF's economic program for 13 y (corresponding to a ~50% higher level in tuberculosis mortality rates) did so much worse than Slovenia, which did not undertake an IMF program. Similarly, Russia's level of DOTS coverage in 2003 was only 25%, whereas in Slovenia DOTS coverage had reached 100% already by 1996. Clearly, IMF programs are not the only explanation for variations in tuberculosis control, but these results offer a partial account of the ultimate correspondents of cross-country differences.

Our findings were robust to a broad set of socioeconomic measures. However, there are several important limitations to our analysis. First, as with all cross-country analysis, the potential exists for ecologic fallacies, though we have employed a number of well-accepted statistical tests for causal inference that strongly support the link between IMF policies and tuberculosis outcomes. The mechanism we hypothesize for the IMF's relationship to tuberculosis outcomes is plausible, given the numerous studies suggesting such a relationship between IMF conditionalities and infectious disease outcomes [6,7,9–18]. We also applied statistical methods less frequently used in epidemiology both to examine the nature of selection bias (Heckman) and to describe temporal causality (Granger and Sims) in a manner that could be applied to future epidemiological studies [37,38].

Another limitation to our findings is the potential for detection biases arising from temporal variations in tuberculosis surveillance within countries. However, our results are robust to a wide variety of health measures that can reasonably be expected to serve as proxies for the observed changes. If IMF programs did somehow lead to improved tuberculosis surveillance, net of controls, they might have lead to artifactual short-term increases in tuberculosis rates. Yet all of our evidence points to the contrary: IMF programs were linked to reduced government spending, less health resources per capita, and decreased tuberculosis treatment coverage. This suggests that IMF programs damaged health surveillance infrastructure, and any residual detection bias in our models rendered our conclusions conservative. It would be appropriate to further investigate the relationship between IMF policies and other diseases and their related infrastructure, as this analysis is restricted to tuberculosis outcomes and program variables. While our preliminary analysis suggests a weak negative connection between IMF programs and life expectancy levels more generally (unadjusted Pearson's $R = -0.18$, $p < 0.01$) that was similarly observed for non-IMF debt albeit less significant (unadjusted Pearson's $R = -0.09$, $p = 0.11$), we cannot rule out that IMF programs are not associated with some health improvements in other ways we have not examined in this study.

Another limitation to our study is that the implementation of IMF conditionalities themselves were not directly observed, but rather reflected by entry into and exit from IMF program participation, the size of the IMF loan, and the duration of exposure to IMF lending. While IMF programs typically involve a similar set of economic reforms, the specific package is likely to vary across countries. However,

Table 6. Associations of IMF Programs with Log Tuberculosis Mortality Rates, Adjusted for Selection Bias

Covariate	Association with Log Tuberculosis Mortality Rates
Dummy for IMF lending program	0.35 (0.08)***
Risk of participating in IMF programs (hazard rate, θ^a)	−0.09 (0.04)**

Robust standard errors in parentheses clustered by country. Models include dummy variables for each country and period as well as controls used in the basic specification in Equation 1 augmented with log HIV rates.

[a]θ, the hazard of participation in an IMF program, also referred to as the Inverse Mills Ratio, is calculated as ϕ/Φ if under an IMF program, and $-\phi/1-\Phi$ if not under an IMF program from the probit model in table I of Text S7. For more details of this method see Heckman 1979 or more recently Heckman 2004, or Przeworski 2003 [32–34] and Text S7. The system of equations is thus:

$$TB_{it} = \alpha + \gamma IMF_{it} + \beta X_{it} + \theta\lambda_{it} + \upsilon_i + \eta_t + \varepsilon_{it}$$

$$IMF_{it} = \alpha + \beta X_{it} + \zeta W_{it} + \mu_{it}$$

Here X is the set of controls used in the main Equation 1, and W is a vector of variables that have been suggested to affect the probability of country participation in an IMF program by previous studies: lag of dummy for non-IMF debt, size of the largest titular nationality, lag of number of countries participating in IMF programs, and lag of foreign direct investment (percent of GDP) [34]. These covariates enter the probit model but are excluded from the main regression [32–34] and are jointly significant at $p < 0.05$. Results are robust to varying the set of variables included in the Z-vector. First-step probit results are reported in table I of Text S7. Further details of Heckman's selection method, applied as a control function approach, are described in Text S7.

**, $p < 0.01$; ***, $p < 0.001$.

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given the similar set of economic distortions in post-communist countries, the IMF economic reform programs were much more homogenous than those implemented in more diversified economic contexts [42]. Analyzing the unique EE/FSU setting that enjoyed relatively strong public health programs restricts our ability to generalize the results to low-income countries with weaker health infrastructure. Subsequent research should focus on resolving which specific policy components of the IMF programs drove the adverse tuberculosis outcomes identified in this study.

Although our findings support the hypothesis that the adverse associations of IMF programs with tuberculosis outcomes are constituted by reductions in tuberculosis control infrastructure, more research is needed to specify the mechanisms in greater detail and compare their relative magnitude. Some possible mediating factors include abridged access to, or decreased quality of, tuberculosis care that may arise from shifting the burden of treatment costs onto patients, or from privatizing health care services that may exclude marginalized groups [6,43–45]. It is likely that our results reflect the distributional consequences of IMF programs for societies, especially since previous studies have suggested that IMF programs have disproportionately hurt the poor [46,47]. To analyze whether IMF programs have increased poverty in the EE/FSU context, however, is beyond the scope of our current study. Future research should also attempt to resolve how tuberculosis program outcomes observed in this study might be affected by reforms to IMF programs.

The Center for Global Development report on whether IMF programs constrain health spending notes "So humility is required when pronouncing on the appropriate macro framework unless country-specific evidence on such relationships is available. In practice, policy choices must inevitably be made under considerable uncertainty and need to take account of the implied costs of different types of potential mistakes. For example, risks to macroeconomic stability have to be weighed against foregone opportunities for additional public spending" (page 6, [5]). This study begs the same question, but in the opposite direction: can the foregone opportunities for health expenditure and the toll of human lives be justified by the macroeconomic stability the IMF might have created? Our regressions give us further insight to this issue. The IMF has argued that "Wealthier is Healthier," (to quote Pritchett and Summers [48]); that is, by promoting economic development, public health will be improved. We can ask how much wealthier a country has to be as a result of an IMF lending program in order to offset the tuberculosis associations identified here. The coefficient on country income per capita reveals that each 10% increase in GDP is associated with decreases in tuberculosis by close to 2.5%. Since an IMF program is connected with an increase in tuberculosis by 17%, this means that per capita income would have to nearly double to offset the rise in tuberculosis. Unfortunately, no EE/FSU country has come near that level of growth. The results presented here suggest that while macroeconomic stability might spare some lives, the magnitude needed to offset the tuberculosis-related harms is implausible at present. On the other hand, the World Bank has recently shown that reducing tuberculosis in EE/FSU countries would boost economic growth and has urged countries to fully implement the Global Plan to Stop TB (see [49] and www.stoptb.org).

The results of this analysis suggest that the IMF should take into account the potential impact of its programs on tuberculosis control systems. Although in recent years the IMF has begun to play a direct role in supporting tuberculosis and HIV/AIDS control efforts via poverty reduction programs [50,51,13], the IMF should critically evaluate the indirect effects of its economic programs on tuberculosis control efforts. Securing health systems that are robust to tuberculosis should be a first-order concern for international financial institutions when attempting to create the conditions needed for sustainable economic development.

Supporting Information

Alternative Language Abstract S1. Translation of the Abstract into Russian by Zinaida Zagdyn

Found at doi:10.1371/journal.pmed.0050143.sd001 (37 KB DOC).

Text S1. Entry to and Exit from IMF Programs and Tuberculosis Patterns in Post-Communist Countries, 1989–2003

Found at doi:10.1371/journal.pmed.0050143.sd002 (105 KB DOC).

Text S2. Summary Statistics, Empirical Sample

Found at doi:10.1371/journal.pmed.0050143.sd003 (49 KB DOC).

Text S3. Associations of IMF Lending Programs with Log Tuberculosis Incidence and Prevalence Rates

Found at doi:10.1371/journal.pmed.0050143.sd004 (66 KB DOC).

Text S4. Granger-Causality tests

Found at doi:10.1371/journal.pmed.0050143.sd005 (60 KB DOC).

Text S5. Preliminary Path-Analyses

Found at doi:10.1371/journal.pmed.0050143.sd006 (36 KB DOC).

Text S6. EE/FSU Countries Not Participating in an IMF Program and Percentage Change in Tuberculosis Mortality Rates (Based on Logs), Empirical Sample

Found at doi:10.1371/journal.pmed.0050143.sd007 (119 KB DOC).

Text S7. Further Details of Selection Model Methods

Found at doi:10.1371/journal.pmed.0050143.sd008 (66 KB DOC).

Text S8. Further Details about the Additional Sample and Specification Robustness Checks

Found at doi:10.1371/journal.pmed.0050143.sd009 (24 KB DOC).

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Author contributions. DS formulated the study question and project design and performed the statistical analysis. LPK and SB contributed to the study design and analysis. DS, LPK, and SB contributed to the writing of the manuscript.

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Editors' Summary

Background. Tuberculosis—a contagious, bacterial infection—has killed large numbers of people throughout human history. Over the last century improvements in public health began to reduce the incidence (the number of new cases in the population in a given time), prevalence (the number of infected people), and mortality rate (number of people dying each year) of tuberculosis in several countries. Many authorities thought that tuberculosis had become a disease of the past. It has become increasingly clear, however, that regions impacted by health and economic changes since the 1980s have continued to face a high and sometimes increasing burden of tuberculosis. In order to boost funding and resources for combating the global tuberculosis problem, the United Nations has set a target of halting and reversing increases in global tuberculosis incidence by 2015 as one of its Millennium Development Goals. Yet one region of the world—Eastern Europe and the former Soviet Union—is not on track to achieve this goal.

Why Was This Study Done? To achieve these targets, the World Health Organization (WHO) and tuberculosis physicians' groups promote the expansion of detection and treatment efforts against tuberculosis. But these efforts depend on the maintenance of good health infrastructure to fund and support health-care workers, clinics, and hospitals. In countries with significant financial limitations, the development and maintenance of these health system resources are often dependent upon international donations and financial lending. The International Monetary Fund (IMF) is a major source of capital for resource-deprived countries, but it is unclear whether its economic reform programs have positive or negative effects on health and health infrastructures in recipient countries. There are indications, for example, that recipient countries sometimes reduce their public-health spending to meet the economic targets set by the IMF as conditions for its loans. In this study, the researchers examine the relationship between participating in IMF lending programs of varying sizes and durations by 21 post-communist Central and Eastern European and former Soviet Union countries and changes in tuberculosis incidence, prevalence, and mortality in these countries during the past two decades.

What Did the Researchers Do and Find? To examine how participation in IMF lending programs affected tuberculosis control in these countries, the researchers developed a series of statistical models that take into account other variables (for example, directly observed therapy programs, HIV rates, military conflict, and urbanization) that might have affected tuberculosis control. Participation in an IMF program, they report, was associated with increases in tuberculosis incidence, prevalence, and mortality rate of about 15%, which corresponds to hundreds of thousands of new cases and deaths in this region. Each additional year of participation increased tuberculosis mortality rates by 4.1%; increases in the size of the IMF loan also corresponded to greater tuberculosis mortality rates. Conversely, when countries left IMF programs, tuberculosis mortality rates dropped by roughly one-third. The authors' further statistical tests indicated that IMF lending was not a positive response to worsened tuberculosis control but precipitated this adverse outcome and that lending from non-IMF sources of funding was associated with decreases in tuberculosis mortality rates. Consistent with these results, IMF (but not non-IMF) programs were associated with reductions in government expenditures, tuberculosis program coverage, and the number of doctors per capita in each country. These findings associated with mortality were also found when analyzing tuberculosis incidence and prevalence data.

What Do These Findings Mean? These findings indicate that IMF economic programs are associated with significantly worsened tuberculosis control in post-communist Central and Eastern European and former Soviet Union countries, independent of other political, health, and economic changes in these countries. Further research is needed to discover exactly which aspects of the IMF programs were associated with the adverse effects on tuberculosis control reported here and to see whether IMF loans have similar effects on tuberculosis control in other countries or on other non–tuberculosis-related health outcomes. For now, these results challenge the proposition that the forms of economic development promoted by the IMF necessarily improve public health. In particular, they put the onus on the IMF to critically evaluate the direct and indirect effects of its economic programs on public health.

Additional Information. Please access these Web sites via the online version of this summary at http://dx.doi.org/10.1371/journal.pmed.0050143.

- This study is further discussed in a *PLoS Medicine* Perspective by Murray and King
- The US National Institute of Allergy and Infectious Diseases provides information on all aspects of tuberculosis, including a brief history of the disease
- The US Centers for Disease Control and Prevention provide several fact sheets and other information resources about tuberculosis
- The World Health Organization provides information (in several languages) on efforts to reduce the global burden of tuberculosis, including information on the Stop TB Strategy and the 2008 report on global tuberculosis control—surveillance, planning, financing
- Detailed information about the International Monetary Fund is available on its Web site
- An article that asks "Does the IMF constrain health spending in poor countries?" (with a link to a response from the IMF) is provided by the Center for Global Development