Mass incarceration can explain population increases in TB and multidrug-resistant TB in European and central Asian countries

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Edited by Burton H. Singer, Princeton University, Princeton, NJ, and approved May 13, 2008 (received for review February 6, 2008)

Several microlevel studies have pinpointed prisons as an important site for tuberculosis (TB) and multidrug-resistant TB in European and central Asian countries. To date, no comparative analyses have examined whether rises in incarceration rates can account for puzzling differences in TB trends among overall populations. Using longitudinal TB and cross-sectional multidrug-resistant TB data for 26 eastern European and central Asian countries, we examined whether and to what degree increases in incarceration account for differences in population TB and multidrug-resistant TB burdens. We find that each percentage point increase in incarceration rates relates to an increased TB incidence of 0.34% (population attributable risk, 95% C.I.: 0.10–0.58%, $P < 0.01$), after controlling for TB infrastructure; HIV prevalence; and several surveillance, economic, demographic, and political indicators. Net increases in incarceration account for a 20.5% increase in TB incidence or nearly three-fifths of the average total increase in TB incidence in the countries studied from 1991 to 2002. Although the number of prisoners is a significant determinant of differences in TB incidence and multidrug-resistant TB prevalence among countries, the rate of prison growth is a larger determinant of these outcomes, and its effect is exacerbated but not confounded by HIV. Differences in incarceration rates are a major determinant of differences in population TB outcomes among eastern European and central Asian countries, and treatment expansion alone does not appear to resolve the effect of mass incarceration on TB incidence.

drug resistance | prison

Rates of tuberculosis (TB) and its multidrug-resistant (MDR) phenotype have increased markedly in eastern European and central Asian countries (1–4). TB incidence has risen from 45.2 per 100,000 in 1990 to 58.2 per 100,000 population in 2005 (5). In parallel, reported MDR TB, defined as a resistance to both rifampicin and isoniazid, has increased substantially, even allowing for improved surveillance, and now accounts for ≈25% of all treated cases in this region (6).

These aggregate figures obscure considerable geographical variations. Several central and eastern European countries (CEE), such as Poland and Slovakia, experienced declines of >50% in both incidence and mortality, whereas in Russia, these measures more than doubled from historic lows in 1991 to the highest rates in Europe at 119 per 100,000 and 22 per 100,000, respectively, in 2005 (Fig. 1). The extent to which national fortunes have differed can be seen in Table 1, which contrasts the trajectory of the five best- and five worst-performing countries, as assessed by their change in incidence and mortality relative to 1991. Both groups of countries began from similar starting points. One explanation for this recent divergence is heterogeneity in access to directly observed treatment short-course (DOTS) and treatment adherence and quality (treatment success rates). However, Table 1 also shows that these factors alone cannot account for the observed differences in population TB trends (7).

Relationship Between Incarceration and TB Spread. Prisons have been identified as a critical social vector for the transmission of TB and selection of MDR strains, primarily because of three aspects of the prison environment: (*i*) higher effective contact rate: proximity of large numbers of individuals (8) in poorly ventilated facilities for extended periods (9); (*ii*) decreased cure rate: delayed diagnosis, difficulties identifying and isolating inmates for treatment (10), "perverse" incentives among inmates to falsely start or prolong treatment (such as being excused work, receiving better treatment, or profiting from sale of drugs) (9, 11, 12), and release to community before completion of treatment with interrupted followup thereafter (13); and (*iii*) greater population susceptibility: including risk factors such as poverty (9), substance abuse (3, 14), previous unhealthy lifestyles (9), inadequate nutrition (11), and HIV infection (15).

Recent surveys of prisons in the World Health Organization's (WHO's) European region found that prisoners have 84 times higher TB prevalence than civilians (16), and that the frequency of infections that are MDR also tend to be significantly higher than in the general population (9, 17).

TB transmitted in prisons also poses risks to outside communities: prisoners may infect healthcare workers, prison guards, and their spouses and children. There is often a failure to follow up infected prisoners after their release (11, 18). Prison outbreaks have been linked directly to increased community TB incidence (19), and there is some empirical evidence that history of incarceration increases the risk that an infected individual will develop MDR (11). Thus, it is plausible to hypothesize that imprisonment could be a driver of TB epidemics (3).

Mass Incarceration in Eastern Europe and Central Asia. Incarceration rates in transition countries currently rank among the highest in the world. In Russia, 670 per 100,000 population, or nearly 1% of the population, is currently in prison, making it second only to the U.S., which imprisons 702 per 100,000 population (9). In the former Soviet Union, crime-sentencing rates rose by 75% from 1991 to 2002, which is three times faster than in CEE. This unprecedented rise in sentencing and the associated growth in the number of prisoners have been so alarming that criminologists have described these social changes as a "criminological transition" (20). Fig. 2 displays the direct log relationship between average TB incidence and incarceration rates for eastern European and former Soviet countries. Table 1 also shows

Author contributions: D.S. and M.M. designed research; D.S. and S.B. performed research; D.S., S.B., M.M., and L.K. analyzed data; and D.S., S.B., M.M., and L.K. wrote the paper.

The authors declare no conflict of interest.

This article is a PNAS Direct Submission.

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This article contains supporting information online at www.pnas.org/cgi/content/full/0801200105/DCSupplemental.

Table 1. Best and worst TB performers in eastern European and central Asian countries, 1991–2005

Transition country	Indicator	Year			
		1991	1996	2001	2005
Best performers: Slovakia, Slovenia, Macedonia, Croatia, Poland	TB incidence (per 100,000 population)	52.0	45.8	31.6	25.8
	TB mortality (per 100,000 population)	8.6	7.4	4.8	4.0
	DOTS population coverage, %	0.0	40.0	52.2	85.0
	DOTS treatment success rates, %	0.0	80.0	83.5	85.3*
	Incarceration rates (per 100,000 population)	539.3	471.8	433.6	459.8†
Worst performers: Russia, Moldova, Estonia, Uzbekistan, Latvia	TB incidence (per 100,000)	42.8	77.6	100.4	92.4
	TB mortality (per 100,000)	6.6	11.8	15.6	13.6
	DOTS population coverage, %	0.0	20.4	49.6	82.4
	DOTS treatment success rates, %	0.0	63.0	67.5	66.3*
	Incarceration rates (per 100,000 population)	277.9	523.1	742.3	647.2†

*The latest available data are from 2004.

†The latest available data are from 2002. Best- and worst-performing countries are based upon greatest and lowest proportional changes in TB incidence and are limited by the availability of data. TB and DOTS data are from the WHO Global Tuberculosis Database 2007 (5). Incarceration rates are from the UNICEF TransMonee Database 2005 (21). Missing values for DOTS population coverage and treatment success in 1991 were coded as zero. All data are further described in *SI Appendix 1*.

a closer association between TB incidence and mortality and incarceration rates, compared with measures of treatment quantity and quality. Among the "worst five performers," a 2.5-fold increase in TB incidence from 1991 to 2001 corresponds to a roughly equivalent increase in incarceration rates, whereas the best-performing countries have seen a fall in incarceration rates, albeit less than the decline in TB.

In this article, we empirically evaluate whether "mass incarceration," defined as the rapid growth of the prison population, can in part account for the divergence in TB incidence and MDR TB prevalence among transition countries, using longitudinal data from 1991 to 2002. Although several microlevel studies have pinpointed prisons as an important reservoir for TB and MDR TB in transition countries (1, 22–24), to date no comparative analyses have examined this hypothesis at a macrolevel or among countries. At a population level, TB incidence and transmission can occur (*i*) within the general population, (*ii*) from the general population to the prison population, (*iii*) within the prison population, and (*iv*) from the prison population to the general population. Does the rise in incarceration rates, which increase the prominence of the population-to-prison, intraprison, and prison-to-population TB pathways play a significant role in determining a population's overall TB burden? Such a hypothesis linking mass incarceration to population TB rises can be tested only at the population level, and the eastern European and central Asian countries provide a unique setting for this experiment, which the rest of our study aims to accomplish.

Longitudinal TB Results. Table 2 presents the results of the cross-national model from 1991 to 2002. Each percentage increase in the sentencing rate is associated with a 0.34% increase in TB incidence (all forms of TB; 95% C.I.: 0.10–0.58%, $P < 0.01$). The average increase in the number of persons sentenced for the average country during this period jumped from 282 per 100,000 to 452 per 100,000, a 60% increase. Based on our model, the net effect of this rise was a 20.5% increase in TB incidence. Given that the overall percentage rise in TB for the average country was 35.5% during this period, incarceration can thereby on average account for nearly three-fifths of the entire TB rise observed during this period, after controlling for other reasonable explanatory variables, including a broad set of economic, policy, and demographic measures.

Several of the main control variables have important effects. The coefficient on log Gross Domestic Product (GDP) per

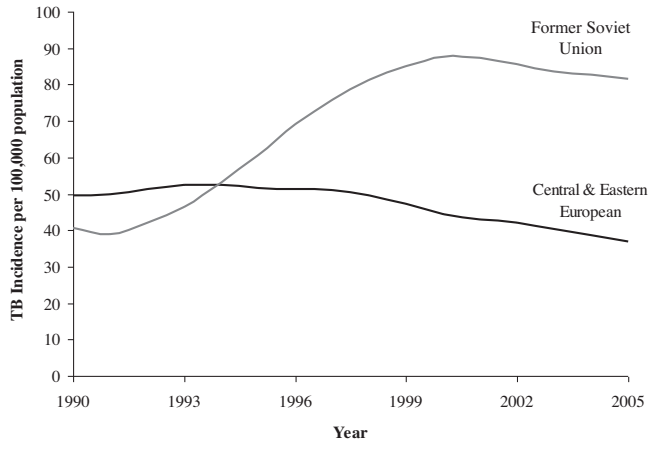

Fig. 1. Trends in TB incidence in eastern European and central Asian countries, 1990–2005. Former Soviet Union (FSU) countries include Armenia, Azerbaijan, Belarus, Estonia, Georgia, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Moldova, Russia, Turkmenistan, Ukraine, Uzbekistan; Central and Eastern European non-FSU countries include Albania, Bosnia, Bulgaria, Croatia, Czech Republic, Hungary, Macedonia, Poland, Romania, Slovakia, and Slovenia [WHO Global Tuberculosis Database 2007 (5)].

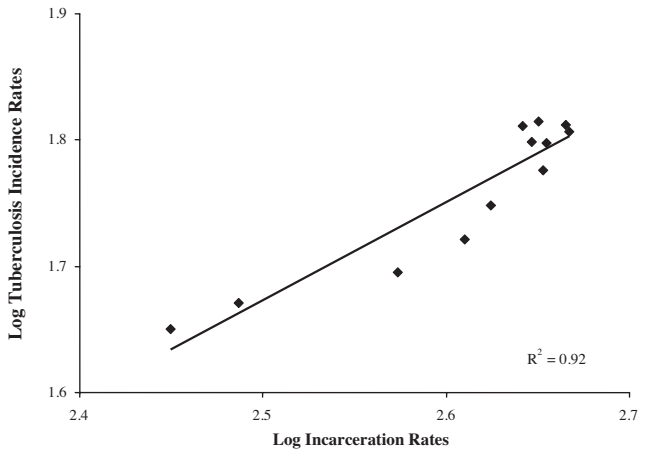

Fig. 2. Relationship between average TB incidence and incarceration rates, 1991–2002. Incarceration rates are assessed by using sentencing data from UNICEF TransMonee Database, 2005 edition (21) [TB incidence data are from the WHO Global Tuberculosis Database 2007 (5).]

Table 2. Effect of incarceration on log TB incidence rates in eastern European and central Asian countries, 1991–2002

Covariates	Model 1	Model 2
Log incarceration rate	0.34**	0.27*
	(0.12)	(0.10)
Log GDP per capita	−0.38**	−0.28**
	(0.11)	(0.09)
Heritage Foundation Democracy Index	0.00	0.00
	(0.03)	(0.01)
Military conflict	−0.22*	−0.05
	(0.08)	(0.08)
Percentage of population urban	−0.10*	−0.09**
	(0.04)	(0.02)
Population dependency ratio	−0.04**	0.00
	(0.01)	(0.01)
Percentage of population with tertiary education	−0.00	−0.00
	(0.00)	(0.00)
Log HIV cases	—	0.09**
		(0.01)
Number of country years	211	193
Number of countries	19	18
R^2	0.88	0.91

Constant estimated but not reported; robust standard errors clustered by country to reflect nonindependence of sampling and robustness to heteroskedasticity and serial correlation in parentheses. Models include dummy variables for each country. TB data are from the WHO Global Tuberculosis Database 2007 (5). Incarceration data are from the UNICEF TransMonee Database, 2005 edition (21). Data are further described in *SI Appendix 1*. Estimation sample includes: Armenia, Azerbaijan, Belarus, Bulgaria, Croatia, Czech Republic, Estonia, Georgia, Hungary Latvia, Lithuania, Macedonia, Moldova, Poland, Romania, Russia, Slovakia, Slovenia, and Uzbekistan. When including HIV prevalence in Model 2, Uzbekistan drops out of the model, because UNAIDS/WHO data are not available. *SI Appendix 2 a* and *b* present TB and sentencing rate data. *SI Appendix 4* presents miniplot pairs for each country. *SI Appendices 5–12* present a series of sample, specification, and functional form robustness checks.
* = $P < 0.05$; ** = $P < 0.01$ (two-tailed tests).

capita is −0.38, which means that a 1% increase in GDP levels corresponds to a 0.38% reduction in TB incidence. This sizable protective effect reinforces the notion that economic development is a powerful determinant of health, complementing growing evidence that better health contributes to economic development in this region (25). Thus, the precipitous decline in GDP per capita in several countries of this region after the market liberalization (26) seems likely to have exacerbated the TB crisis.

The Freedom House democratization index had no effect on TB rates in the countries studied. Military conflict had the effect of decreasing TB incidence by 22% in Model 1; however, because war has been noted to compromise health surveillance systems (27), a decline might have been expected as an artifact of reduced reporting and other empirical studies have found similar results in this context (28). Urbanization, conversely, had a protective effect: each percentage increase in the proportion of the population living in urban settings corresponded to a 10.4% reduction in TB incidence. Surprisingly, urbanization is unrelated to DOTS population coverage (Pearson $R = 0.05$) and negatively correlated with DOTS treatment success (Pearson $R = -0.34$). Thus, the positive effect of urbanization is most likely because of its positive correlation with aspects of general social and economic development missed by GDP.

Modeling using country fixed effects is effectively the same as evaluating the effect of changes in incarceration rates, and not their overall levels, in each country over time. An alternative way to examine the data is to model only the variation between countries' average levels. Using this approach, the coefficient on log incarceration rates becomes 0.73 and is again significant at $P < 0.01$. The interpretation is a little more challenging than the fixed effects models; each 10% that a country deviates from the average incarceration rate among the sampled countries (407 per 100,000 population) accounts for a 7.30% difference in TB incidence rates in the same direction. Returning to the comparison of the "best- and worst-performing" TB countries (Table 1) and taking the average incarceration rate values for these two groups over the sample period (worst five performers: 498 per 100,000 per year; best five performers: 450 per 100,000 per year) gives rise to a 11.8% difference in terms of a 10% deviation from the sample mean. Thus, differences in incarceration levels are able to explain only 8.61% of the difference in TB incidence rates between best and worst countries. This is less than one-fifth of the magnitude of the differential TB incidence explained by relative increases in incarceration between the two groups. The epidemiological implication is that rapid growth in prison populations is a more critical driver of TB incidence than their overall size. This finding probably reflects the TB risks associated with overcrowding caused by rapid prison growth.

A potential criticism of the basic finding is that, given the effect of HIV on the epidemiology of TB and the high prevalence of HIV among prisoners (15) and, in particular, among injecting drug users, our results are not due to incarceration *per se* but rather confounded by rising HIV-injection drug user (IDU) levels. In Model 2, we add the log of the number of HIV cases reported. HIV enters as a significant predictor of TB incidence; for every one percentage-point increase in reported HIV cases, TB increases by 0.09%. The results for sentencing rates' effect on TB incidence are attenuated ($\beta = 0.27$) but remain robust. This suggests that HIV-IDU may account for an important part of the adverse effects of incarceration on TB but not all of it.

One further possibility is that poverty rates may relate to both incarceration and TB and, as a result, have confounded the observed relationship between incarceration and TB. We explored this possibility using a set of variables that capture poverty levels from the World Bank's World Development Indicators. In fact, we found that incarceration rates were negatively associated with all of the variables examined. For example, the percentage of the population living under U.S. $1 ($R = -0.09$, $P = 0.41$) and U.S. $2 ($R = -0.21$, $P = 0.06$). To the extent that these poverty measures were significantly correlated with log TB incidence, prevalence or mortality rates (U.S. $1 per day, $R = 0.39$, $P < 0.01$; U.S. $2 per day, $R = 0.47$, $P < 0.01$), not adjusting for poverty would render our results conservative. When we included these variables in our models, the coefficient on sentencing rates adjusted for poverty rates was slightly increased (fixed effects: $\beta = 0.30$, $P < 0.05$; pooled cross-sectional: 0.52, $P < 0.001$) as compared with using the same sample without poverty rates, although because of missing poverty data, the C.I.s widened. The poverty measures were not significantly associated with TB outcomes once the other controls were taken into account.

We also analyzed the role of expanding DOTS coverage and improving DOTS success rates, although there are high levels of missing data in these as provided by the WHO. The effect of both factors was not significant in regressions explaining TB incidence, although DOTS coverage was associated with lower log TB incidence. Pearson correlation coefficients were $R = -0.15$, $P = 0.07$ for treatment success and $R = -0.31$, $P < 0.01$ for population coverage. However, the sample size for the analysis falls to $n = 123$ and $n = 89$, respectively, when including these two factors, suggesting that further data could be collected to analyze the role of these variables. Supporting Information (SI) Tables S1–S11 in *SI Appendix* present a broad set of robustness checks used in the course of our analysis, including a variety of model diagnostics and outlier tests, incremental inclusion of our controls, and corrections for additional socioeconomic, health

Table 3. Effect of country income per head and incarceration rates on drug-resistant TB in eastern European and central Asian countries

Covariates	Cases never treated		Cases previously treated	
	Odds ratio	*P* value (two-tailed)	Odds ratio	*P* value (two-tailed)
Log GDP per capita	0.04 (0.01–0.21)	<0.01	0.13 (0.03–0.57)	<0.01
Log incarceration rates	6.93 (1.96–24.44)	<0.01	2.91 (0.92–9.19)	0.16
Number of countries	24		24	
R^2	0.53		0.25	

Logistic regression models also control for whether the MDR data are representative of the entire country and the year of MDR data survey. The R^2 value presented is based on a linear regression model using only the two main covariates; 95% C.I. in parentheses. Models are also robust to the effect of urbanization, population education levels, population dependency ratios, and membership in the Former Soviet Union. MDR TB data are the most recently available data taken from Euro TB 2007 (6) report. Incarceration rates are from the UNICEF TransMonee 2005 (21) database using registered crime rates, although results are consistent when using log sentencing rates. Countries included in the sample are: Armenia, Azerbaijan, Belarus, Bulgaria, Croatia, Czech Republic, Estonia, Georgia, Hungary, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Macedonia, Moldova, Poland, Romania, Russia, Slovakia, Slovenia, Tajikistan, Turkmenistan, Ukraine, and Uzbekistan. *SI Appendix* 14–16 describe all data, present linear regression models, and provide additional robustness tests.

system, and demographic variables, and estimation using alternative functional forms. All results were consistent with our basic finding.

Cross-Sectional MDR TB Results. Comparative longitudinal data are unavailable for MDR TB. Thus, the MDR TB analysis is cross-sectional, using the most recent data for each country.

Because the sample size for the MDR TB analysis is inherently smaller than that for TB incidence analysis, natural logarithms of registered crime rates were used as an indicator of imprisonment to maximize the effective sample size. Although committing a crime does not imply sentencing, in our data a little over one-third of reported crimes were associated with a criminal sentence, and the correlation between crime rates and sentencing was strong (Pearson $R = 0.70$). Our results were replicated using sentencing rates, only the C.I.s, as expected, were wider, albeit still significant (see Tables S14 and S15 in *SI Appendix*). Controls were used to adjust for how the MDR TB data were collected, the year of data collection, and whether the data are representative of the entire country; results from these analyses did not qualitatively change.

Table 3 shows the results of logistic regression models of MDR TB prevalence for untreated and treated cases of incident TB in 24 eastern European and central Asian countries. Log-registered crime rates have a significant effect on MDR prevalence among untreated TB cases (odds ratio = 6.93, 95% C.I.: 1.96–24.44) but not for the treated TB cases. The large C.I.s reflect high levels of uncertainty associated with the small sample size. The results are consistent with the possibility that imprisonment plays an important role in incubating MDR TB, which subsequently spreads into the community, but that secondary resistance is primarily due to individual treatment failure.

GDP per capita had a strongly protective effect for untreated cases (odds ratio = 0.04, 95% C.I.: 0.01–0.21) and a strong but smaller effect on treated cases (OR = 0.13, 95% C.I.: 0.03–0.57). Again, these findings indicate that the economic depression in transition countries played a role in perpetuating drug-resistant strains of TB, although the exact mechanisms are unclear. Together, the two variables, crime rates and GDP per capita, explain 53% of the between-country variation in MDR TB levels for untreated cases.

Discussion

Our results show that differences in incarceration rates among countries are strongly associated with key differences in the incidence of TB and the prevalence of its MDR phenotype. By using within- and between-country variation, we identify that the rate of growth of the prison population, more than the overall size of the prison population, critically relates to variations in TB incidence. We also find that higher HIV prevalence exacerbates the effect of incarceration on TB incidence, strengthening the argument for a coordinated approach to these two diseases (29).

Despite the robustness of our findings to a broad set of social and healthcare system variables, there are several important limitations to our analysis. First, as with all cross-country analyses, the potential exists for ecological fallacies. However, as we note above, the observed associations are biologically plausible, given the numerous mechanisms by which incarceration may increase TB incidence (3, 17, 24). In future research, it would be desirable to complement our ecological analyses with individual data, ideally following cohorts over time. Unfortunately, such data do not exist in any of the countries we have studied. In particular, this would allow us to examine the impact of duration of incarceration and of repeated incarceration. However, on the basis of evidence from other settings, these may have limited additional explanatory power as most people who will be infected are infected during the brief initial period of occupancy in enclosed spaces (30–33).

Second, our measure of incarceration relies on the ability of crime-sentencing rates to capture imprisonment. Because the probability of custodial sentencing varies between countries, we use a set of dummies to control for national legislation and policies which shape how closely our proxy maps onto incarceration. Any remaining differences would register as nondifferential measurement error and have the effect of diluting our results. Third, although we control for differences in surveillance between countries, there is potential for bias arising from time-varying surveillance changes within countries. It is, however, unlikely that the temporal variation in surveillance can account for the relationship between incarceration and TB net of our control variables, and the direction of the potential bias is unclear. Finally, because of high levels of TB underreporting in prisons, our findings may not adequately reflect the prominence of transmission of TB within prisons, which would understate the population-level relationship between incarceration and TB incidence and thus renders our estimates conservative.

Of the four major population TB pathways: intrapopulation transmission, population-to-prison transmission, intraprison transmission, and prison-to-population transmission, our study finds that the latter three mechanisms, as measured by incarceration rates, have played a prominent role in driving overall population-level differences in TB incidence, prevalence, and mortality rates. In our models, prevailing population explanations, such as GDP per capita and DOTS coverage and success rates, were not found to account for the observed population trends as substantially as was mass incarceration. These results echo findings by the WHO in 2008 that GDP per capita and

DOTS are important, but incomplete, population explanations of TB rises (7).

Given multiple circulating strains may exist in this environment (34), and strain heterogeneity can lead to increased incidence as a result of limited cross-strain immunity further amplified by the increasingly observed clonal spread of virulent *Mycobacterium tuberculosis* subtypes (35, 36), our model produces conservative predictions about the potential amplification of TB that can occur as a result of imprisonment. MDR TB is also underdiagnosed in this region, and higher actual MDR TB rates would act on population TB dynamics to (*i*) increase TB mortality rates by reducing the effectiveness of treatment and (*ii*) increase TB spread, because effective risk will be higher as a result of prolonged infectiousness and less effective treatment. This would produce a positive interaction with incarceration for increasing population-level TB rates. Characterizing the relationships between MDR TB and TB spread remains an important step for future research.

A reduction in incarceration rates is desirable for many reasons, especially in settings where prison conditions are often extremely harsh (37). This study provides a further rationale for reform, indicating that a reduction in custodial sentencing would impact favorably on the risk to the general population from TB and MDR TB.

Periods of excessive growth of prison populations necessitate particular emphasis on controlling TB transmission. The positive news for former Soviet countries is that the growth in prison populations has slowed, and prisons are now beginning to shrink in size (Table 1). Our results offer a partial explanation of the turnaround in TB witnessed in high-prevalence regions around the turn of the century that cannot be explained by DOTS, health infrastructure, poverty rates, or GDP per capita alone. Nonetheless, the results also highlight the need to integrate better TB control efforts with institutions that manage prisons. Several microlevel studies have examined the effect of specific programs on the incidence of TB and MDR TB in prisons (14), but the macrolevel effects of such practices, and of alternatives to incarceration, should be a subject of public health research and action.

Data and Methods

We use four sets of health data, all of which are from the WHO. TB incidence, prevalence, mortality, and DOTS population coverage and treatment success data are from the WHO Global Tuberculosis Database (5), MDR TB data are from the Euro Tuberculosis Report 2007 (6), and HIV case data are from the WHO/UNAIDS Global HIV database (38). Crime and sentencing rate measures are from the UNICEF TransMonee database (21), and control variables are from the WHO European Health For All Database, 2007 edition, and World Bank World Development Indicators, 2005 edition (39).

To our knowledge, there are no direct and comparable measures of the incidence of imprisonment over time and across countries. Thus, we use the rate of sentencing per 100,000 total population as an indicator of incarceration, recognizing that not all sentences will result in imprisonment. This, however, can be justified as community penalties, which do not involve custodial sentencing, such as probation or parole, have been slow to develop throughout this region (40). We cope with data monitoring and quality issues in two ways. First, we use a set of dummy variables for each country, which holds time-varying effects, such as the strength of national surveillance systems or differences in national sentencing legislation, constant within nations. These variables also correct for factors that differ across countries but remain relatively fixed over time, such as past membership of the Soviet Union or proximity to Western Europe, the probability of custodial sentencing, and historical levels of TB (41). By using country-specific slopes, our conservative modeling approach isolates how changes within individual countries impact their own TB incidence profiles, which renders the data suitable to answer our research question.

We also considered the impacts of possible changes in detection and reporting biases over time. Such biases could skew our results only if they related to both the TB incidence data and the sentencing data in a consistent way. For example, if higher incarceration rates were associated with improved TB surveillance, then we might artifactually observe a relationship between incarceration and TB. However, the evidence from central and eastern European and former Soviet countries has established the opposite: TB is known to be highly underreported in prison settings (42, 43), which means that any TB detection bias that may be associated with incarceration runs counter to our hypothesis. Similarly, if prison policies altered the reporting of sentencing over time, or diagnostic systems improved TB surveillance, our results could potentially be biased, although the direction of such bias is unclear. If this were the case, we would observe a structural break in the sentencing data; yet, in our dataset, we find no evidence of such breaks. Taken together, the data appear sufficiently internally valid and reliable to permit our modeling approach.

We also control for GDP per capita as a measure of overall economic development; democratization, which has been theorized to exert positive effects on health (44) and captures political change; the occurrence of military or ethnic conflict, which has been shown to adversely impact disease surveillance (27) and infectious disease control (45); urbanization, which may facilitate the transmission of TB but also may provide access to better healthcare services and proxy for overall social development; population dependency ratios, which reflect the stage of demographic transition and population age-structure; and population education levels, which capture the stock of human capital.

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

$$\begin{aligned} Log\ Tuberculosis_{it} = \alpha + B_1 PRI_{it} + \beta_2 GDP_{it} + \beta_3 DEM_{it} \\ + \beta_4 WAR_{it} + \beta_5 URBAN_{it} + \beta_6 DEP_{it} \\ + \beta_7 EDUC_{it} + \mu_i + \epsilon_{it} \end{aligned}$$

Here, *i* is country, and *t* is year. PRI is the measure of mass incarceration, logged to adjust for positive skew; GDP is logged per capita GDP in current U.S. $; DEM is a widely used index of democratization from the Freedom House political indicators, which combines measures of civil liberties and political freedoms (26); WAR is a dummy variable for whether a country experienced military or ethnic conflict; URBAN is the percentage of population living in urban settings; EDUC is the percentage of the population with tertiary education; and μ is a set of dummy variables that control for country-specific effects. Tables S1 and S2 in *SI Appendix* further describes all of the variables and presents summary statistics.

ACKNOWLEDGMENTS. S.B. is supported by a grant from the U.S. Centers for Disease Control (R36) and National Institutes of Health Medical Scientist Training Program (T32). M.M. is supported by the European Observatory on Health Systems and Policies and the Wellcome Trust.

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