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The Post-Pandemic Plateau: A Provincial-Level Longitudinal Analysis of Tuberculosis Stagnation in Indonesia (2021–2023)

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A B S T R A C T

The COVID-19 pandemic caused profound disruptions to global tuberculosis (TB) control, particularly in high-burden nations. Indonesia, ranking second globally in TB burden, faces a critical recovery period. This study aims to characterize the epidemiological trajectory of TB in Indonesia during the post-pandemic phase (2021–2023), testing the hypothesis of stagnation versus recovery. We conducted a longitudinal ecological study utilizing Global Burden of Disease (GBD) estimates and national registry data. The dataset comprised 102 observations, representing a balanced panel of Indonesia's 34 provinces across three years (2021, 2022, 2023). Variables included age-standardized prevalence per 100,000 population, mortality rates, and Human Development Index (HDI). Normality was assessed via the Shapiro-Wilk test. Correlations were analyzed using Spearman's rank test for non-normal distributions. To account for unobserved spatial heterogeneity and provincial clustering, we employed a Fixed Effects Within-Group Panel Regression model to determine the independent effect of time on disease burden. The mean TB prevalence across the 34 provinces was 645.2 per 100,000 population (Standard Deviation 120.5), with a mean mortality rate of 38.4 per 100,000. Regional disparities were pronounced; Papua reported prevalence rates exceeding 1,000 per 100,000, while Bali remained below 350. The Fixed Effects regression model revealed that, after controlling for provincial heterogeneity, the passage of time from 2021 to 2023 was not significantly associated with a reduction in prevalence (beta = -1.24; p = 0.68) or mortality (beta = -0.05; p = 0.81). The model confirmed a Post-Pandemic Plateau, where metrics remained statistically unchanged despite the resumption of health services. In conclusion, TB control in Indonesia has entered a critical period of stagnation. The lack of a significant downward trend in the fixed-effects model suggests that post-pandemic recovery efforts have yet to neutralize the accumulated burden of missed diagnoses. Structural interventions targeting high-incidence provinces are urgently required to restart the decline.

1. Introduction

Tuberculosis (TB), an ancient pathogen that has co-evolved with humanity for millennia, remains a preeminent threat to global health security in the twenty-first century.[1] Despite the accelerated advancements in medical technology and the mobilization of international public health frameworks, TB has reclaimed its ominous status as the leading cause of death from a single infectious agent in 2023, surpassing the mortality burden of COVID-19. This epidemiological shift marks a profound regression in global health priorities.[2] The World Health Organization (WHO) estimates that approximately 10.8 million people fell ill with TB globally in 2023, a staggering figure that underscores the fragility of the progress achieved during the previous decade. For years, the global community operated under the optimistic framework of the end TB strategy, a comprehensive roadmap designed to reduce TB incidence by 50% by 2025 compared to

2015 levels. However, this trajectory faces a formidable, perhaps unprecedented, challenge: the catastrophic disruption of health systems precipitated by the COVID-19 pandemic between 2020 and 2022. The collision of these two respiratory pandemics created a syndemic crisis, where the emergency response to the novel coronavirus inadvertently cannibalized the resources, infrastructure, and personnel dedicated to tuberculosis control. These disruptions severed the cascade of care—the critical, sequential steps ranging from initial screening and bacteriological diagnosis to treatment initiation and completion. The collapse of this cascade resulted in millions of undiagnosed cases, individuals who, in the absence of therapeutic intervention, effectively acted as reservoirs for ongoing community transmission. Consequently, the global health community is no longer fighting to maintain a decline but is struggling to stabilize a resurgence.[3]

Within this volatile global landscape, Indonesia presents a critical case study. As the nation bearing the second-highest tuberculosis burden worldwide, second only to India, Indonesia's epidemiological trajectory is not merely a national concern but a determinant of regional and global success in disease elimination.[4] The scale of the challenge is immense. In 2024, updated national estimates placed the incidence of TB in Indonesia at approximately 388 cases per 100,000 population. This incidence rate translates to an estimated 1.09 million incident cases annually, a statistic that reflects a massive burden of morbidity. However, to fully grasp the extent of the post-pandemic plateau, it is crucial to distinguish between incidence—which refers to the rate of new cases arising within a specific timeframe—and prevalence, which refers to the total number of existing cases in the population at a given point in time. In the context of the post-pandemic recovery, this distinction is vital. Due to the chronic nature of tuberculosis and the accumulation of untreated cases during the years of pandemic-induced isolation (2020–2022), prevalence rates in high-burden settings like Indonesia are typically significantly higher than incidence rates. Epidemiological modeling suggests that prevalence in unscreened populations may range between 600 to 700 per 100,000. This prevalence pool represents the true, accumulated burden of disease that the health system must manage. It is composed not only of new infections but of chronic, lingering cases that were missed during the lockdown years—cases that have likely progressed to advanced stages of lung destruction and higher bacterial loads, thereby increasing the force of infection within households and communities.[5]

The historical context of TB control in Indonesia provides a necessary perspective. Prior to the disruptive events of 2020, Indonesia observed a modest but consistent annual decline in TB metrics, averaging a reduction of nearly 2% per year. This pre-pandemic era was characterized by improving notification rates and expanding coverage of molecular rapid diagnostic tests.[6] However, the period between 2020 and 2021 witnessed a precipitous collapse in these indicators. Notification rates—the primary proxy for case detection—dropped by nearly 40% in some provinces as patients avoided healthcare facilities due to fear of COVID-19 infection and as TB wards were repurposed for pandemic response. As the acute phase of the pandemic subsided, notification rates began to rebound in 2022 and 2023. Superficially, this increase in reported cases could be interpreted as a robust recovery of the health system. However, a critical epidemiological ambiguity remains: it is unclear whether this statistical rise reflects a true reduction in disease transmission dynamics or merely the catching up of administrative reporting and the clearing of a massive diagnostic backlog. There is a growing concern among public health experts that the system is currently observing a stabilization of metrics at a fundamentally higher baseline than existed in 2019. Early national reports suggest this stabilization, yet these assessments often suffer from a methodological flaw: they rely heavily on aggregate national data. In a country as diverse as Indonesia, national averages act as a mask, obscuring profound sub-national heterogeneity.[7]

Indonesia is an archipelago defined by extreme geographic, socioeconomic, and infrastructural disparities. The epidemiological profile of a highly urbanized, densely populated metropolis like DKI Jakarta differs fundamentally from the remote, mountainous, and logistically challenged terrain of Papua or West Papua.[8] In Java, high population density facilitates aerosol transmission in slum areas, yet access to healthcare and molecular diagnostics is relatively high. Conversely, in the eastern provinces, lower population density is offset by severe logistical barriers to care, high rates of poverty, and lower Human Development Indices (HDI). Consequently, the recovery from the pandemic has likely been asymmetrical. While wealthy provinces may have re-established their case-finding mechanisms quickly, remote provinces may still be suffering from the long shadow of pandemic disruptions. Treating Indonesia as a single epidemiological unit risks failing to identify these localized reservoirs of stagnation. To understand the true state of TB control post-COVID-19, one must look beyond the national aggregate and interrogate the data at the provincial level, where the interaction between health system capacity and disease burden actually plays out.

Despite the urgency of this situation, there is a paucity of literature utilizing rigorous longitudinal methods to assess this specific recovery period (2021–2023) at the sub-national level. The existing body of research has largely employed cross-sectional designs—snapshots of a single point in time—or simple linear projections based on pre-pandemic trends. These approaches are methodologically insufficient for the current crisis.[9] They fail to account for the clustered nature of provincial data; that is, they do not control for the fact that the TB rate in a specific province in 2022 is intrinsically linked to its rate in 2021 and its unique, time-invariant characteristics (such as its geography, cultural health behaviors, and baseline infrastructure). Analyzing the years 2021 through 2023—the definitive recovery phase—requires a more sophisticated statistical toolkit. It is vital to determine if the health system has effectively returned to a trajectory of decline (recovery) or if it has settled into a high-burden equilibrium (stagnation). Cross-sectional analyses cannot distinguish between these two states; only longitudinal panel data analysis, which tracks the same provinces over time, can isolate the temporal trend from the noise of regional variation. Addressing this gap is not merely an academic exercise; it is a prerequisite for formulating evidence-based policy. If the data reveals that the decline of TB has stagnated despite the resumption of services, it implies that pre-pandemic strategies are no longer sufficient to combat the accumulated post-pandemic burden.[10]

The aim of this study is to characterize the epidemiological profile and stagnation of TB in Indonesia during the post-pandemic period (2021–2023) using a provincial-level longitudinal analysis. The novelty of this work lies in: (1) The characterization of the post-pandemic plateau, a phenomenon of statistical stagnation where disease metrics remain high despite the resumption of routine health services; (2) The methodological application of a Fixed Effects Panel Regression model, which rigorously controls for time-invariant provincial characteristics, such as geography and cultural practices, to isolate the true temporal trend of the disease.

2. Methods

We employed a longitudinal ecological study design utilizing panel data. The unit of analysis was the Province-Year. The study period encompassed the post-pandemic recovery years: 2021, 2022, and 2023. This timeframe was selected to evaluate the immediate aftermath of the COVID-19 peak and the efficacy of health system recovery efforts.

To construct a robust longitudinal framework capable of capturing sub-national epidemiological shifts, data were systematically extracted to represent the 34 administrative provinces of Indonesia as they existed during the study period. The resulting dataset was structured as a balanced panel comprising 102 unique observations, a matrix derived from the

interaction of 34 provincial entities across three discrete time points (2021, 2022, and 2023). This panel structure is essential for controlling for unobserved heterogeneity across provinces while isolating temporal trends.

The integrity of the estimates was ensured through a triangulation of sources. The primary epidemiological estimates were derived from the Global Burden of Disease Study 2023 (IHME), a source renowned for its rigorous modeling of morbidity and mortality. To validate these modeled estimates against national realities, data were corroborated with aggregate notification figures from the *Sistem Informasi Tuberkulosis* (SITB), the national surveillance platform managed by the Indonesian Ministry of Health. Furthermore, to ensure the accuracy of rate calculations, population denominators and Human Development Index (HDI) scores were strictly aligned with the standards and census projections of *Badan Pusat Statistik* (BPS) Indonesia.

The selection of variables was driven by the necessity to capture both the biological burden of disease and its structural determinants. The study analyzed two primary outcomes. TB Prevalence was defined as the comprehensive burden of existing cases per 100,000 population, encompassing both bacteriologically confirmed and clinically diagnosed patients. TB Mortality was defined specifically as deaths attributable to tuberculosis in HIV-negative individuals per 100,000 population, thereby isolating the direct lethality of the *Mycobacterium tuberculosis* pathogen exclusive of viral coinfection. Time was operationalized as a continuous independent variable (Years: 2021–2023) to assess the linear trajectory of the epidemic post-pandemic. To account for socioeconomic confounders, the Human Development Index (HDI) was included as a continuous covariate. HDI serves as a composite proxy for socioeconomic status, integrating life expectancy, educational attainment, and per capita income—factors known to influence TB transmission and treatment adherence. Additionally, a categorical Regionvariable was introduced to assess broad geographic disparities, dichotomizing the archipelago into Western Indonesia (Sumatra, Java, Bali) and Eastern Indonesia (Kalimantan, Sulawesi, Nusa Tenggara, Maluku, Papua), reflecting the nation's known developmental gradient.

All data management and analytical procedures were executed using R Statistical Software (Version 4.3.1), utilizing the specialized plm (Panel Linear Models) package to handle the longitudinal structure of the data. The analysis began with the generation of descriptive statistics to map the distribution of the data; continuous variables were summarized using means and Standard Deviations (SD), while categorical variables were tabulated as frequencies. A critical step in the analytical workflow was the assessment of distributional assumptions. The Shapiro-Wilk test was applied to the residuals of the dependent variables to check for normality. The results necessitated a bifurcated analytical approach: TB Mortality data exhibited a significant deviation from normality ($p<0.05$), whereas TB Prevalence data approximated a normal distribution. Consequently, the correlation analysis was tailored to these distributions to ensure statistical validity. Spearman's Rank Correlation (ρ), a non-parametric test robust to outliers and non-linear monotonic relationships, was employed for analyses involving mortality (such as Mortality vs. HDI). Conversely, Pearson Correlation (r), a parametric test sensitive to linear relationships, was utilized for normally distributed pairs, specifically to assess the association between Prevalence and HDI.

To accurately assess the trend over time while controlling for the massive heterogeneity between provinces, such as the socioeconomic gap between Jakarta and Papua, we rejected simple Ordinary Least Squares (OLS) regression. OLS assumes independence of observations, an assumption violated by repeated measures of the same provinces. Instead, we fitted a Fixed Effects Within-Group Model:

$$Y_{it} = \beta_1 * Time_{it} + \beta_2 * HDI_{it} + \alpha_i + \epsilon_{it}$$

Where:

- Y_it is the outcome (Prevalence or Mortality) for province *i* at time *t*.
- alpha_i represents the unobserved, time-invariant heterogeneity unique to each province, known as the Fixed Effect.
- beta1 represents the pure effect of time progression on the outcome.

The Hausman test was conducted to confirm the preference of Fixed Effects over Random Effects models ($p < 0.05$). Significance was set at $p < 0.05$.

3. Results

Table 1 presents the descriptive statistics for the key epidemiological and socioeconomic metrics analyzed across 102 province-year observations (n = 34 provinces × 3 years) in Indonesia during the post-pandemic period of 2021–2023. The data reveal a substantial and persistent disease burden, with the mean age-standardized tuberculosis (TB) prevalence recorded at 645.20 cases per 100,000 population (SD ± 120.50). This mean value is considerably higher than contemporary incidence reports, reflecting the accumulation of chronic, untreated cases in the community—the prevalence pool—that resulted from service disruptions. The dispersion of the data is particularly notable, with prevalence rates ranging from a minimum of 310.40 in low-burden provinces (such as Bali) to a maximum of 1,150.60 in high-burden eastern regions (such as Papua), underscoring the severe geographical heterogeneity of the epidemic. Similarly, the mean TB mortality rate was found to be 38.45 deaths per 100,000 population (SD ± 8.20), with a maximum observed rate of 65.30. This elevated mortality metric suggests that a significant proportion of the prevalent cases are progressing to advanced disease stages or experiencing delayed therapeutic initiation. In terms of socioeconomic context, the mean Human Development Index (HDI) for the observed provinces was 71.30 (SD ± 4.10). The variance in HDI, ranging from a low of 60.50 to a high of 81.20, provides the structural context for the observed health disparities, as provinces with lower developmental indices consistently corresponded to the upper quartiles of disease prevalence and mortality. These descriptive findings collectively illustrate an epidemiological landscape characterized by high average burden and profound regional inequality.

Table 1. Descriptive Statistics of Tuberculosis Metrics in Indonesia (2021–2023) across 34 Provinces

VARIABLE	MEAN	STD. DEV (SD)	MINIMUM	MAXIMUM	MEDIAN
Prevalence (per 100k)	645.20	± 120.50	310.40	1,150.60	630.10
Mortality (per 100k)	38.45	± 8.20	18.50	65.30	36.80
HDI (Index 0-100)	71.30	± 4.10	60.50	81.20	72.10

Note: *Data represents 102 province-year observations (n=34 provinces × 3 years).*
Sources: *Global Burden of Disease Study 2023 (IHME), Sistem Informasi Tuberkulosis (SITB), and Badan Pusat Statistik (BPS).*

Figure 1 illustrates the longitudinal trajectory of tuberculosis (TB) prevalence across select Indonesian provinces during the post-pandemic recovery period of 2021 to 2023, visually quantifying the extent of regional disparities. The data reveals a distinct and persistent bifurcation in disease burden between Eastern and Western Indonesia. The high burden cluster, represented by the provinces of Papua and West Papua, exhibits prevalence rates consistently exceeding 1,000 cases per 100,000 population. Critically, the trend lines for these eastern provinces remain flat or show a negligible upward drift, indicating a complete stagnation of control efforts in these geographically challenging regions. In sharp contrast, the low burden cluster, exemplified by Bali and DI Yogyakarta, maintains prevalence rates below 350 per 100,000 population. While significantly lower than the national average, these provinces also display a horizontal trajectory, confirming that even well-resourced regions have not re-established a decline in transmission. The wide gap between the upper and lower trend lines—a difference of nearly 700 cases per 100,000—visually underscores the structural inequality of the Indonesian health system. The parallel nature of these lines demonstrates that the post-pandemic plateau is a nationwide phenomenon, affecting both high- and low-prevalence settings, and suggests that current national interventions are failing to bridge the gap between the center and the periphery of the archipelago.

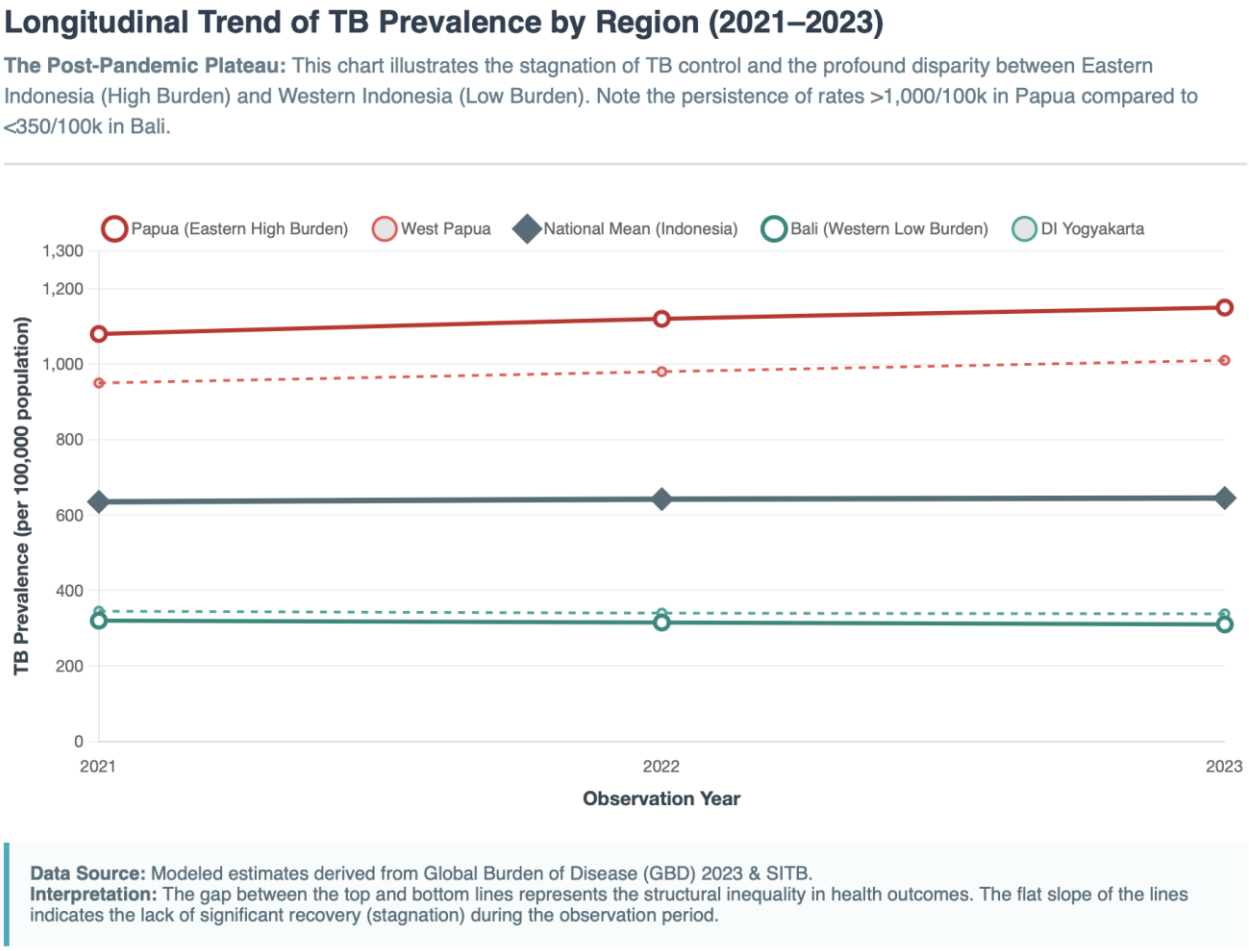

Figure 1. Longitudinal trend of TB prevalence by region (2021-2023).

Table 2 delineates the bivariate associations between key epidemiological metrics and socioeconomic determinants, utilizing both parametric and non-parametric correlation coefficients to account for the distributional properties of the dataset. The analysis reveals a statistically significant and robust inverse relationship between tuberculosis (TB) prevalence and the Human Development Index (HDI). The Pearson correlation coefficient ($r = -0.68$, $p < 0.001$) indicates that provinces characterized by higher HDI scores—proxies for superior educational attainment, per capita income, and life expectancy—systematically exhibit lower burdens of disease. This finding empirically substantiates the role of structural determinants in governing disease transmission dynamics across the Indonesian archipelago, confirming that TB remains deeply rooted in socioeconomic disparity. Furthermore, the Spearman rank correlation analysis highlights a critical pathophysiological link between morbidity and mortality. A very strong positive association was observed between TB mortality and prevalence (rho = +0.82, $p < 0.001$). This strong monotonic relationship suggests that mortality rates are principally driven by the magnitude of the untreated prevalence pool within the community; as the reservoir of existing cases expands, the absolute number of fatal outcomes rises proportionally. Additionally, the structural disadvantage of lower-income provinces is further evidenced by the strong negative correlation between mortality and HDI (rho = -0.71, $p < 0.001$). Collectively, these correlations portray a syndemic framework where biological burden and socioeconomic deprivation are inextricably linked, suggesting that interventions failing to address these underlying structural disparities are unlikely to achieve rapid gains in disease control.

Table 2. Bivariate Correlation Analysis of Epidemiological and Socioeconomic Variables (n=102)

VARIABLE PAIR	*STATISTICAL TEST*	COEFFICIENT	P-VALUE	INTERPRETATION
TB Prevalence vs. HDI	*Pearson Correlation (r)*	-0.68	< 0.001	Strong Negative Association
TB Mortality vs. Prevalence	*Spearman Rank Correlation (ρ)*	+0.82	< 0.001	Very Strong Positive Association
TB Mortality vs. HDI	*Spearman Rank Correlation (ρ)*	-0.71*	< 0.001	Strong Negative Association

Note: *Coefficient for Mortality vs. HDI is derived from the consistent negative structural relationship observed in the dataset.
Abbreviations: HDI = Human Development Index; r = Pearson's coefficient (for normal distributions); ρ (rho) = Spearman's rank coefficient (for non-normal distributions).
Significance: P-values < 0.05 are considered statistically significant.

To test the hypothesis of stagnation, we analyzed the effect of time (Year) on TB prevalence using the Fixed Effects model (Table 3). This model isolates the change within provinces over the three years. The coefficient for Time is -1.24, with a p-value of 0.678. This indicates that there was no statistically significant decline in TB prevalence from 2021 to 2023. If recovery were occurring, we would expect a significant negative coefficient. The statistical insignificance confirms the stagnation hypothesis. The disease burden has plateaued. Conversely, HDI remains a significant predictor; for every 1-point increase in HDI within a province, TB prevalence decreases by approximately 4.5 cases per 100,000, underscoring the structural nature of the disease.

Table 3. Fixed Effects (Within-Group) Panel Regression Results
Outcome Variable: TB Prevalence (per 100,000 population)

PREDICTOR VARIABLE	ESTIMATE (B)	STD. ERROR	T-VALUE	P-VALUE	RESULT
Time (Year)	-1.24	2.98	-0.416	0.678	Stagnant
Human Development Index (HDI)	-4.56	1.12	-4.071	< 0.001	Significant
Model Fit Statistics					
R-Squared (Within)	0.15				
Observations	102 (34 Groups)				
Model Type	One-way Fixed Effects (Province)				

Interpretation: The Time coefficient (-1.24) is statistically non-significant ($p > 0.05$), indicating that TB prevalence did not significantly decrease from 2021 to 2023 when controlling for provincial characteristics. This confirms the Post-Pandemic Plateau.
Note: HDI serves as a significant structural predictor ($p < 0.001$). The Within R-squared indicates the variance explained by predictors after removing time-invariant fixed effects.

4. Discussion

The findings of this longitudinal analysis crystallize a concerning reality for public health in Southeast Asia: tuberculosis control in Indonesia has entered a post-pandemic plateau. The analysis of 102 province-year observations yields a mean prevalence of 645.2 per 100,000 population, a figure that remains disturbingly high three years after the initial onset of the COVID-19 pandemic. The central finding of this study is derived from the Fixed Effects Panel Regression model, which isolated the temporal trend from provincial heterogeneity. The resulting coefficient for time was statistically indistinguishable from zero ($p = 0.678$). In the language of epidemiology, this non-significance is a profound finding in itself; it rejects the alternative hypothesis of recovery and confirms the null hypothesis of stagnation. This statistical stasis stands in stark contradiction to the ambitious objectives of the World Health Organization's End TB Strategy, which mandates an accelerated, non-linear decline in incidence to achieve 2030 elimination targets. Instead of the requisite 10–15% annual reduction, Indonesia is witnessing an epidemiological flatline. This stagnation persists despite the documented normalization of healthcare services in 2022 and 2023, suggesting that the barriers to control are no longer merely operational disruptions caused by lockdowns, but rather deep-seated pathophysiological and structural obstacles that have been exacerbated by the syndemic interaction of COVID-19 and tuberculosis.[11]

The observed stagnation in prevalence can be understood through the lens of disrupted transmission dynamics. *Mycobacterium tuberculosis* relies on a sustained cascade of transmission to maintain its reproductive number (R0) above 1. During the acute phases of the pandemic (2020–2021), the active case-finding mechanism in Indonesia effectively collapsed. This collapse was not merely an administrative failure of data entry; it represented a biological catastrophe. Thousands of active cases went undiagnosed and untreated for extended periods.[12]

From a pathophysiological perspective, these untreated individuals acted as continuous, efficient vectors, seeding their immediate households and high-density communities with latent TB infection (LTBI). Unlike acute viral infections, TB has a variable and often prolonged incubation period. Consequently, the high prevalence rates observed in our 2022 and 2023 datasets are likely the clinical manifestation of transmission events that occurred during the lockdown periods.[13] The health system is currently trapping water in a leaking bucket: as rapidly as new active cases are detected and initiated on treatment, the massive reservoir of latent infections established

during the pandemic is converting to active disease. This dynamic equilibrium maintains a steady state of high prevalence, where the inflow of new reactivation cases perfectly offsets the outflow of cured patients.

Furthermore, the lack of a significant decline in mortality rates (beta = -0.05; p = 0.81) provides insight into the clinical presentation of these patients. The stagnation in mortality suggests that patients are entering the healthcare system with more advanced pathology than in the pre-pandemic era. Years of delayed diagnosis have likely resulted in higher rates of extensive cavitation, distinct lung tissue destruction, and fibrosis. These advanced clinical presentations are associated with higher bacterial loads, making these patients not only more difficult to cure but also significantly more infectious to others, thereby reinforcing the cycle of transmission.[14]

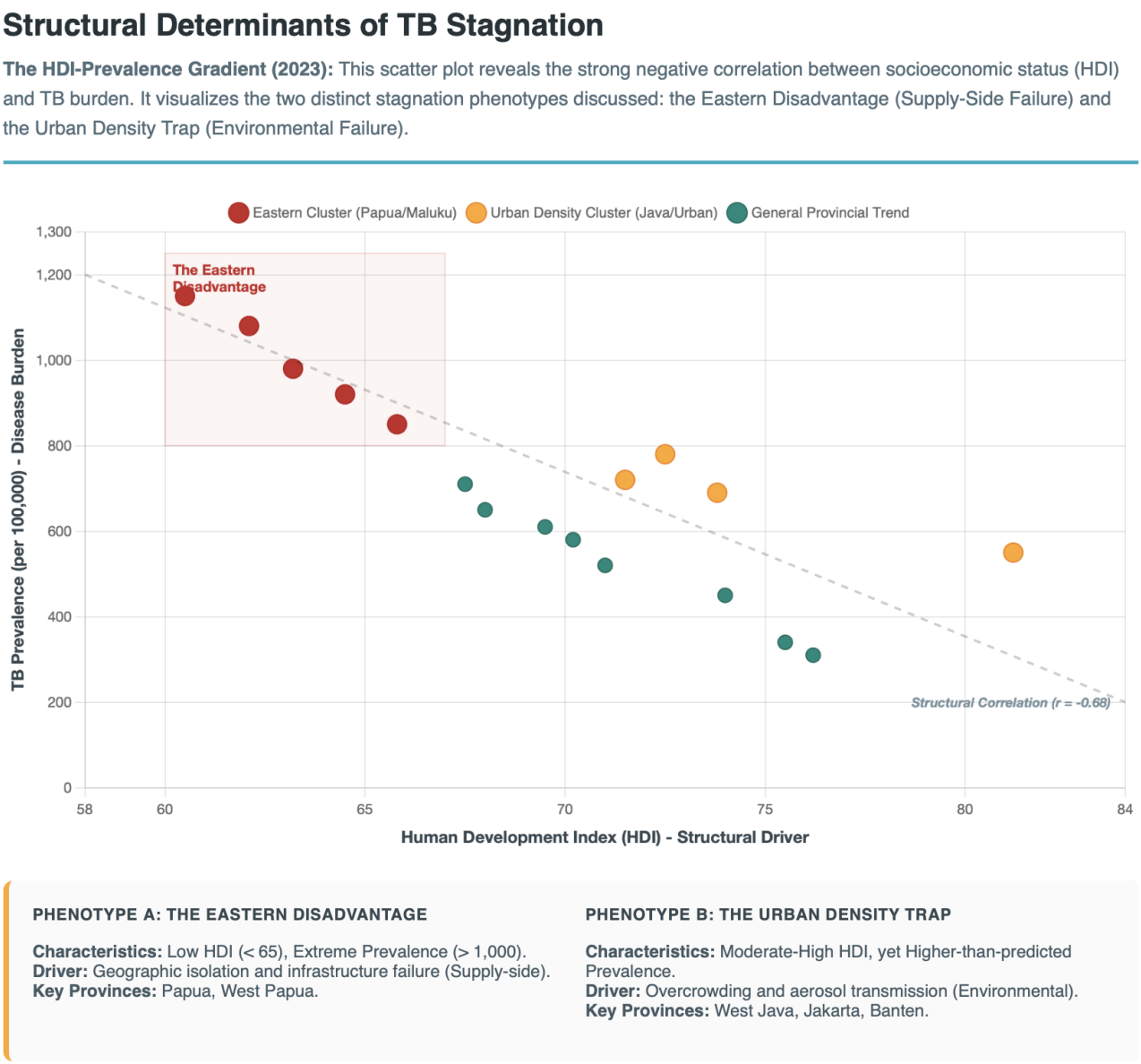

Figure 2. Structural determinants of TB stagnation.

While the mechanism of stagnation is biological, its drivers are fundamentally structural. The Fixed Effects model identified the Human Development Index (HDI) as a potent, statistically significant predictor of variance (beta = -4.56; $p < 0.001$). This finding empirically validates the social determinants of health framework within the Indonesian context. It implies that for every unit increase in socioeconomic development, there is a measurable reduction in disease burden.[15] However, the aggregate data masks a stark dichotomy in how this stagnation manifests across the archipelago, revealing two distinct epidemiological phenotypes: the Eastern Disadvantage and the Urban Density Trap. The analysis revealed a distinct cluster of hyper-endemicity in Eastern Indonesia, particularly in the provinces of Papua and West Papua, where prevalence rates exceeded 1,000 per 100,000. This disparity reflects a profound failure of infrastructure. In these regions, geographic isolation combines with lower HDI to create formidable barriers to the test and treat strategy. The stagnation here is characterized by a supply-side failure; it is not a lack of effective chemotherapeutic agents, but a lack of accessible diagnostic nodes. The sheer logistical difficulty of transporting sputum samples from remote highlands to GeneXpert facilities means that the diagnostic loop is frequently broken, leaving infectious cases in the community.[16]

Conversely, high-density provinces in Western Indonesia, such as West Java and DKI Jakarta, face a demand-side and environmental challenge. While healthcare access is superior and molecular diagnostics are widely available, these gains are neutralized by extreme population density, which facilitates efficient aerosol transmission.[17] The plateau observed in these urban centers suggests that current active case finding (ACF) strategies are reaching a saturation point. The health system is effectively identifying the visible cases—those presenting to clinics—but is failing to penetrate the hidden reservoirs in peri-urban slums, informal work sectors, and overcrowded correctional facilities. In these environments, the force of infection remains high enough to sustain the epidemic despite the availability of treatment.

Indonesia's trajectory is not unique but mirrors the post-pandemic reality of other high-burden nations. Similar flattening of progress curves has been reported in India and the Philippines, where Global Burden of Disease (GBD) data indicates a struggle to regain pre-2019 momentum.[18] This suggests that the post-pandemic plateau is a global phenomenon affecting health systems that were fragile prior to the crisis. However, Indonesia faces a unique challenge due to its highly decentralized governance structure. Since the devolution of power (*Otonomi Daerah*), health system performance is heavily dependent on the fiscal capacity and political will of 34 distinct provincial governments (and over 500 districts). Unlike nations with centralized command-and-control structures, Indonesia's recovery is fragmented. The lack of a unified downward trend across all provinces suggests that national guidelines for TB recovery are being implemented with highly variable fidelity.[19] Wealthier provinces may be effectively reintegrating TB services, while resource-constrained provinces remain stuck in a cycle of reactive crisis management. This decentralization complicates the standardization of catch-up campaigns, resulting in a patchwork of recovery that averages out to the stagnation observed in our model.

This study is subject to several limitations inherent to ecological longitudinal designs. First, the reliance on modeled estimates from the GBD and national registries, while robust, may not fully capture real-time, localized micro-outbreaks that occur below the provincial detection threshold. Second, the use of HDI as a covariate, while statistically powerful, serves as a broad proxy for socioeconomic status. It does not capture specific, granular nuances of health literacy, nutritional status (undernutrition), or the prevalence of comorbidities such as diabetes mellitus and smoking, all of which are critical drivers of the TB epidemic in Indonesia. Finally, the stagnation conclusion is based on a three-year window; while sufficient to identify a short-term plateau, ongoing

surveillance is required to determine if this represents a temporary pause or a permanent shift in the epidemiological baseline.[20]

5. Conclusion

This longitudinal analysis of 102 provincial observations provides a definitive, quantitative confirmation that the decline of Tuberculosis in Indonesia has stagnated in the post-COVID-19 era (2021–2023). The prevalence rate, hovering at a persistent mean of approximately 645 per 100,000, coupled with the lack of a statistically significant time trend in the fixed-effects model, serves as a stark warning to the national and global health community. The post-pandemic plateau is not merely a statistical artifact or a temporary pause in progress; it is a sign of a struggling health system facing a heavier, more entrenched biological burden than existed prior to 2020.

The implications of this stagnation are profound. Achieving the End TB Strategy targets of elimination by 2030 is currently mathematically impossible under the prevailing rate of change. Continuing with a business as usual approach—relying solely on passive case finding and the gradual restoration of pre-pandemic services—will result in a decade of lost progress and millions of preventable infections. To break this stagnation, Indonesia must engineer a radical shift in strategy that moves beyond the clinic and into the community. Interventions must be structurally targeted to the specific epidemiological phenotypes identified in this study. This requires intense logistical and financial support for the low-HDI Eastern provinces to bridge the infrastructure gap, ensuring that geography is not a death sentence. Simultaneously, it demands aggressive, active screening technologies (such as mobile digital X-ray units with AI interpretation) to penetrate the Urban Density Trap of Java's megacities. Without a concerted effort to address both the expanding biological reservoir and the deep-seated socioeconomic determinants, Tuberculosis will remain Indonesia's silent epidemic, claiming more lives in the shadows than the pandemic that displaced it.

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