

## Preplanned Studies

# Epidemiological Analysis of Tuberculosis Infection and Trend Changes — 152 Belt and Road Partner Countries, 2013–2021

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## Summary

### What is already known about this topic?

The Belt and Road Initiative promotes increased interactions among participating countries, which concurrently elevates the risk of infectious diseases such as tuberculosis (TB). Since TB infection can significantly contribute to the disease burden, it is crucial to delineate the epidemic status and identify the change trends in TB infection among the countries involved in the initiative.

### What is added by this report?

TB infection was prevalent in 152 countries along the Belt and Road initiative. Most of these countries had an infection prevalence between 10% and 30%, among which were 9 countries (5.92%) with a prevalence below 10% and 8 countries (5.26%) with a reported prevalence of 40% and higher. From 2013 to 2021, a notable reduction in TB infection prevalence was observed in 149 countries (98.03%). In contrast, Sri Lanka and the Philippines exhibited an increasing trend, while no significant change was detected in Timor-Leste.

### What are the implications for public health practice?

Addressing TB surveillance, prevention, and management, as well as collaboration among these countries, is a proposed key strategy for achieving the global end TB strategy.

Tuberculosis (TB) infection manifests as a prolonged immune response to *Mycobacterium tuberculosis* (*M. tb*) exposure without presenting clinical symptoms of TB (1). Between 5% and 15% of these infected individuals are at risk of developing TB disease over their lifetime, thus targeting this reservoir could significantly contribute to TB elimination efforts (2). The Belt and Road Initiative, launched in 2013, has notably enhanced interactions and partnerships between China and various countries, regions, and

populations. However, this increased bonding also raises the potential risk of respiratory infections, including TB, largely transmitted via airborne or droplet routes from infected persons (3). This situation highlights the imperative for strengthened TB prevention and control measures within China. Therefore, a comprehensive evaluation of TB infection prevalence and trends in countries along the Belt and Road is essential. Such assessments will help these countries develop robust TB surveillance, prevention, and control strategies, ultimately reducing TB incidence.

As of June 2023, 152 countries had entered into cooperation agreements with China as part of the Belt and Road initiative. Data on the age-standardized prevalence of TB infections from 2013 to 2021, standardized using the global standard population, were obtained from the Global Burden of Disease 2021 (GBD 2021). The trend in TB infection prevalence over this period was analyzed using the estimated annual percentage change (EAPC) and visualized through forest plots. All statistical analyses were conducted using R software (version 4.3.1, R Foundation for Statistical Computing, Vienna, Austria). EAPC was determined by fitting a linear regression model,  $y = \alpha + \beta x + \varepsilon$ , where the year served as the independent variable ( $x$ ) and the natural logarithm of TB infection prevalence as the dependent variable ( $y$ ). The formula for EAPC is given by  $EAPC = 100 \times (e^{\beta} - 1)$ . A negative upper limit of EAPC [95% confidence interval (CI)] signifies a significant declining trend in TB infections, whereas a positive lower limit indicates a significant increasing trend (4).

By June 2023, China had established cooperation agreements through the Belt and Road Initiative with 152 nations across six continents. Table 1 presents the prevalence of TB infection in these countries for 2021, ranked from highest to lowest. The top five countries with the highest TB infection prevalence in 2021 were South Africa, Kiribati, Viet Nam, Solomon Islands,

TABLE 1. The prevalence of TB infection in 152 Belt and Road Partner countries by continent in 2021, ranked from highest to lowest.

Continents	N (%)	Countries
Asia	40 (26.32)	Viet Nam(No.3)*, Philippines(No.7)*, Timor-Leste(No.10)*, Myanmar, Indonesia, Cambodia, Malaysia, Sri Lanka, Maldives, Tajikistan, Nepal, Iran, Thailand, Brunei Darussalam, Mongolia, Turkmenistan, United Arab Emirates, Uzbekistan, Yemen, Azerbaijan, Kyrgyzstan, Afghanistan, Georgia, Kazakhstan, Armenia, Turkey, Lao People's Democratic Republic, Saudi Arabia, Pakistan, Palestine, Iraq, Singapore, Republic of Korea, Syrian Arab Republic, Oman, Bahrain, Lebanon, Qatar, Kuwait, Bangladesh
Africa	52 (34.21)	South Africa(No.1)*, Central African Republic(No.8)*, Uganda, Ethiopia, Democratic Republic of the Congo, Angola, Congo, Seychelles, Egypt, Kenya, Gabon, Lesotho, Equatorial Guinea, Burundi, Eritrea, Mozambique, Madagascar, South Sudan, Guinea-Bissau, Chad, Comoros, Niger, Guinea, Rwanda, Ghana, Burkina Faso, Mali, Zambia, Namibia, Somalia, Sierra Leone, Djibouti, Benin, Cameroon, Togo, Nigeria, Senegal, Cote d'Ivoire, Sudan, Liberia, Morocco, Mauritania, Sao Tome and Principe, Gambia, Libya, Botswana, Tanzania, Cabo Verde, Malawi, Tunisia, Zimbabwe, Algeria
Europe	27 (17.76)	Ukraine, Moldova, Bulgaria, Russian Federation, North Macedonia, Latvia, Lithuania, Albania, Bosnia and Herzegovina, Romania, Poland, Belarus, Serbia, Slovakia, Hungary, Estonia, Montenegro, Czechia, Croatia, Slovenia, Italy, Greece, Portugal, Malta, Cyprus, Luxembourg, Austria
North America	13 (8.55)	Honduras, Nicaragua, Dominica, Dominican Republic, El Salvador, Grenada, Panama, Trinidad and Tobago, Jamaica, Costa Rica, Antigua and Barbuda, Barbados, Cuba
South America	9 (5.92)	Guyana, Suriname, Venezuela, Bolivia, Argentina, Uruguay, Ecuador, Chile, Peru
Oceania	11 (7.24)	Kiribati(No.2)*, Solomon Islands(No.4)*, Papua New Guinea(No.5)*, Vanuatu(No.6)*, Micronesia(No.9)*, Fiji, Samoa, Tonga, Niue, Cook Islands, New Zealand

Note: The asterisks (\*) indicate the ranking of the top 10 countries for the prevalence of TB infection among 152 Belt and Road Partner countries.

Abbreviation: TB=Tuberculosis.

and Papua New Guinea, with prevalence of 44.63%, 43.54%, 43.33%, 41.36%, and 41.31%, respectively. Additionally, Figure 1 shows that most of these countries had a TB infection prevalence between 10% and 30%, with 9 countries (5.92%) having a prevalence below 10% and 8 countries (5.26%) reporting a prevalence of 40% or higher. Regarding the prevalence of TB infection across continents, Oceania exhibited higher infection prevalence, followed by Africa, North America, and Asia, while Europe and South America had comparatively lower prevalence. The top five countries in each continent for TB infection prevalence are shown in Supplementary Table S1 (available at <https://weekly.chinacdc.cn/>).

The analysis of TB infection prevalence from 2013 to 2021 revealed a significant declining trend in 149 countries, accounting for 98.03% of the total. As shown in Figure 2 and Supplementary Table S2 (available at <https://weekly.chinacdc.cn/>), the top 20 countries with the most pronounced declines were all in Africa, with Mauritania showing the largest decrease (EAPC = -4.48, 95% CI = -4.54, -4.42), followed by Sao Tome and Principe (EAPC = -4.32, 95% CI = -4.41, -4.22), Cote d'Ivoire (EAPC = -4.19, 95% CI = -4.44, -3.93), Cameroon (EAPC = -4.17, 95% CI = -4.32, -4.02), and Djibouti (EAPC = -4.13, 95% CI = -4.27, -3.99). In contrast, countries in Oceania exhibited relatively smaller declines, such as Vanuatu (EAPC = -0.13, 95% CI = -0.18, -0.08),

Papua New Guinea (EAPC = -0.12, 95% CI = -0.17, -0.08), and Micronesia (EAPC = -0.11, 95% CI = -0.15, -0.08). Only two countries in Asia exhibited an increasing trend: Sri Lanka (EAPC = 1.19, 95% CI = 1.06, 1.32) and the Philippines (EAPC = 0.04, 95% CI = 0.03, 0.06). However, Timor-Leste (EAPC = -0.02, 95% CI = -0.05, 0.02) in Asia showed no significant change in infection prevalence.

## DISCUSSION

Achieving the End-TB Strategy by 2035 relies on implementing interventions designed to reduce the incidence of TB. Critical to this effort is the enhancement of surveillance strategies to effectively prevent and control TB infections, as these infections substantially contribute to the development of TB disease.

This study indicates that countries with high TB infection prevalence are predominantly concentrated in Asia, Oceania, and Africa. In particular, the incidence of tuberculosis in certain Oceanian countries, such as Kiribati, continues to exhibit an upward trend (5). This substantial burden may be attributed to low coverage of tuberculosis preventive treatment (TPT). A key factor contributing to this poor TPT coverage, and consequently to the high TB incidence, is the inadequate knowledge among Asian healthcare

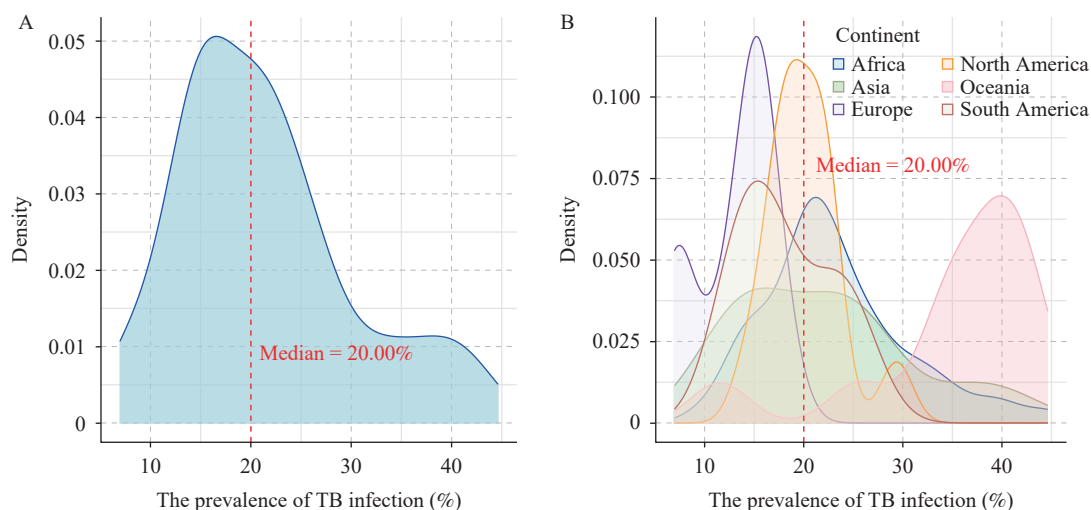


FIGURE 1. The prevalence of TB infection in 152 Belt and Road Partner countries in 2021. (A) TB infection prevalence across all countries; (B) TB infection prevalence by continent. Abbreviation: TB = Tuberculosis.

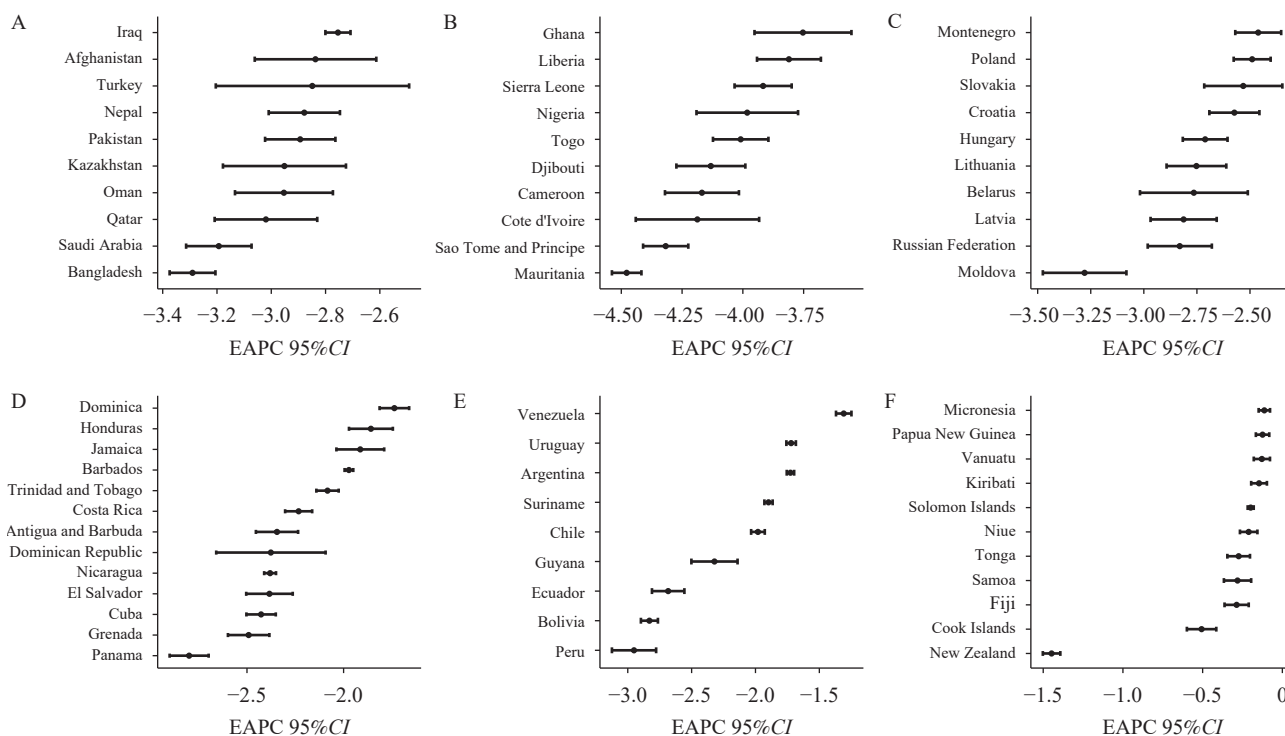


FIGURE 2. Epidemic trends of TB infection in 63 Belt and Road Partner countries, 2013-2021. (A) Asia; (B) Africa; (C) Europe; (D) North America; (E) South America; (F) Oceania. Note: Asia, Africa, and Europe show the distribution of the top 10 countries by descending EAPC absolute values. Abbreviation: TB=Tuberculosis; EAPC= Estimated annual percentage change.

professionals about the World Health Organization (WHO) and national TB management guidelines and the critical need for monitoring and treating TB in at-risk populations. Additionally, healthcare providers are often hesitant to prescribe TPT to individuals infected

with TB due to fears of potential side effects and the emergence of drug resistance (6). Moreover, some regions continue to face shortages in the supply of TB medications. Issues such as drug availability and the lengthy duration of TPT may cause some infected

individuals to discontinue their treatment, thereby facilitating ongoing TB transmission (7). In Africa, 34 countries (65.38%) reported a TB infection prevalence of 20% or higher. The continent grapples with challenging economic conditions, widespread poverty, malnutrition, and suboptimal living environments. These socioeconomic factors contribute to the increased vulnerability to TB infection among disadvantaged populations, exacerbated by overcrowded living conditions, limited access to education, and greater social susceptibility. South Africa experiences a significant burden of HIV-associated TB, with the majority of new cases in 2019 being HIV-infected drug-susceptible TB (HIV-DS-TB) (8). Furthermore, in regions heavily burdened by TB, national policies often focus more on managing TB disease rather than controlling TB infection.

This study demonstrated a decline in TB infection prevalence from 2013 to 2021 in the majority of countries (149 out of 152), primarily attributed to enhanced policies and the implementation of coordinated measures. Adherence to WHO guidelines and public health strategies was integral to the effective management of TB infections. However, focusing solely on isolated factors and interventions may be insufficient to improve the current situation of TB infections. Strategic adjustments and the implementation of a multifaceted intervention approach are crucial to reduce the impact of TB infections. Several countries in Southern Africa including Botswana, South Africa, and Zambia, have adopted stringent legal and regulatory measures to curb infections, inclusive TB. Moreover, expanding TB infection screening and promoting TPT is vital for achieving the objectives of the End-TB Strategy.

The prevalence of TB infection in the Philippines and Sri Lanka is on the rise, although the increase is not markedly sharp. The Philippines, ranked fourth worldwide in terms of TB burden, faces considerable challenges. With almost 10 million people residing in urban slums, limited access to education and healthcare heightens the vulnerability to TB infection. A particularly high prevalence of TB is observed among individuals aged 0–24 years, especially within the 10–24 year-old age group, who are often in densely populated school environments that facilitate TB transmission. Additionally, youth in this age group are more prone to discontinuing TB treatment (9). The increasing incidence of HIV among young people

could further aggravate the situation. Given these factors, the Philippine government urgently needs to implement proactive social protections for vulnerable and young populations, utilizing a comprehensive whole-of-society and whole-of-government strategy to address the TB challenges (10).

This study is subject to some limitations. First, the TB infection data were sourced from the GBD website. The accuracy and reliability of our findings depend on the quality and scope of the data used in the modeling process, potentially leading to an overestimation or underestimation of the actual TB infection burden. Moreover, the detailed information and reasons behind the increasing trends observed in certain countries could not be fully explained by the available data. Additionally, the ongoing coronavirus disease 2019 (COVID-19) pandemic has adversely affected access to TB diagnosis and treatment, causing a resurgence in TB infection and disease prevalence in some countries post-2020.

In conclusion, TB infection remains prevalent across all 152 countries participating in the Belt and Road initiative, with the highest rates in Oceania, Africa, and Asia. Fortunately, the majority of these countries are experiencing a declining trend in TB infections. As a staunch supporter and advocate of the Belt and Road initiative, China is committed to collaborating closely with participating nations to maintain high public health standards. Historically, China has been actively involved in cross-border prevention of infectious diseases and in responding to health emergencies. Looking ahead, China is dedicated to reducing TB infections and enhancing TPT efforts. Furthermore, China plans to strengthen existing health policies in collaboration with other countries that have a high burden of TB, and will facilitate the exchange of technologies related to the diagnosis, treatment, prevention, and control of TB. Additionally, it will promote collaborative scientific research and the development of health resources to further the achievement of the End-TB Strategy.

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## SUPPLEMENTARY MATERIAL

SUPPLEMENTARY TABLE S1. Top 5 countries in each continent for TB infection prevalence in Belt and Road Initiative in 2021.

Continent	Country	Prevalence of TB infection (%)	Order*
Africa	South Africa	44.63	1
Africa	Central African Republic	40.40	8
Africa	Uganda	38.66	11
Africa	Ethiopia	35.72	15
Africa	Democratic Republic of the Congo	33.95	18
Asia	Viet Nam	43.33	3
Asia	Philippines	40.53	7
Asia	Timor-Leste	38.71	10
Asia	Myanmar	37.41	13
Asia	Indonesia	36.10	14
Europe	Ukraine	18.95	85
Europe	Moldova	17.89	90
Europe	Bulgaria	16.95	96
Europe	Russian Federation	16.67	101
Europe	North Macedonia	16.04	103
North America	Honduras	29.37	26
North America	Nicaragua	22.83	54
North America	Dominica	22.25	59
North America	Dominican Republic	21.98	61
North America	El Salvador	21.94	62
Oceania	Kiribati	43.54	2
Oceania	Solomon Islands	41.36	4
Oceania	Papua New Guinea	41.31	5
Oceania	Vanuatu	41.10	6
Oceania	Micronesia	39.17	9
South America	Guyana	26.01	38
South America	Suriname	23.50	48
South America	Venezuela	22.62	57
South America	Bolivia	18.40	87
South America	Argentina	17.30	93

Abbreviation: TB=Tuberculosis.

\* Refers to the ranking of TB infection prevalence from highest to lowest among 152 Belt and Road Initiative countries.



SUPPLEMENTARY TABLE S2. Epidemic trends of TB infection in 89 Belt and Road Partner countries, 2013–2021.

Continent	Country	EAPC (95%CI)	Order <sup>a</sup>
Africa	Benin	-3.71 (-3.88, -3.53)	11
Africa	Guinea	-3.69 (-3.93, -3.45)	12
Africa	Zimbabwe	-3.66 (-3.77, -3.56)	13
Africa	Senegal	-3.64 (-3.82, -3.47)	14
Africa	Guinea-Bissau	-3.60 (-3.73, -3.47)	15
Africa	Cabo Verde	-3.45 (-3.60, -3.31)	16
Africa	Mali	-3.42 (-3.55, -3.29)	17
Africa	Gambia	-3.41 (-3.54, -3.27)	18
Africa	Tanzania	-3.39 (-3.52, -3.26)	19
Africa	Chad	-3.35 (-3.44, -3.25)	20
Africa	Zambia	-3.09 (-3.12, -3.06)	24
Africa	Niger	-3.07 (-3.20, -2.94)	25
Africa	Botswana	-3.05 (-3.17, -2.94)	26
Africa	Burkina Faso	-3.04 (-3.24, -2.84)	27
Africa	Malawi	-3.01 (-3.11, -2.91)	29
Africa	Namibia	-2.98 (-3.04, -2.91)	30
Africa	Somalia	-2.75 (-3.06, -2.44)	45
Africa	Algeria	-2.74 (-2.83, -2.66)	46
Africa	Sudan	-2.66 (-2.71, -2.60)	52
Africa	Morocco	-2.63 (-2.69, -2.57)	54
Africa	Rwanda	-2.55 (-2.64, -2.45)	57
Africa	Tunisia	-2.50 (-2.56, -2.45)	60
Africa	Mozambique	-2.44 (-2.59, -2.28)	70
Africa	Eritrea	-2.36 (-2.44, -2.29)	80
Africa	Lesotho	-2.36 (-2.42, -2.30)	82
Africa	Comoros	-2.29 (-2.55, -2.03)	87
Africa	Madagascar	-2.20 (-2.31, -2.09)	91
Africa	South Sudan	-2.15 (-2.21, -2.09)	92
Africa	Burundi	-2.03 (-2.12, -1.94)	98
Africa	Gabon	-1.88 (-2.10, -1.65)	106
Africa	Egypt	-1.81 (-1.98, -1.65)	108
Africa	Equatorial Guinea	-1.78 (-2.04, -1.52)	109
Africa	Angola	-1.74 (-1.96, -1.52)	110
Africa	Uganda	-1.62 (-1.76, -1.47)	114
Africa	Congo	-1.56 (-1.77, -1.35)	117
Africa	Democratic Republic of the Congo	-1.55 (-1.80, -1.30)	118
Africa	Libya	-1.33 (-1.66, -1.01)	123
Africa	Kenya	-0.68 (-0.75, -0.62)	129
Africa	Central African Republic	-0.47 (-0.64, -0.29)	132
Africa	Ethiopia	-0.45 (-0.49, -0.41)	133
Africa	South Africa	-0.24 (-0.26, -0.21)	142
Africa	Seychelles	-0.15 (-0.23, -0.06)	146
Asia	Kyrgyzstan	-2.72 (-2.82, -2.62)	47
Asia	Mongolia	-2.69 (-2.80, -2.57)	49
Asia	Singapore	-2.66 (-2.78, -2.55)	51

Continued

Continent	Country	EAPC (95%CI)	Order*
Asia	Palestine	-2.64 (-2.70, -2.58)	53
Asia	United Arab Emirates	-2.63 (-2.72, -2.54)	55
Asia	Azerbaijan	-2.51 (-2.59, -2.44)	59
Asia	Syrian Arab Republic	-2.46 (-2.62, -2.30)	64
Asia	Armenia	-2.45 (-2.50, -2.40)	65
Asia	Republic of Korea	-2.45 (-2.55, -2.36)	66
Asia	Bahrain	-2.45 (-2.58, -2.32)	67
Asia	Uzbekistan	-2.44 (-2.48, -2.40)	69
Asia	Turkmenistan	-2.38 (-2.40, -2.36)	75
Asia	Georgia	-2.31 (-2.38, -2.25)	86
Asia	Kuwait	-2.26 (-2.41, -2.11)	88
Asia	Lebanon	-2.15 (-2.24, -2.05)	93
Asia	Brunei Darussalam	-2.12 (-2.22, -2.02)	94
Asia	Tajikistan	-2.05 (-2.12, -1.99)	97
Asia	Lao People's Democratic Republic	-1.59 (-1.62, -1.55)	116
Asia	Yemen	-1.29 (-1.40, -1.18)	125
Asia	Cambodia	-1.24 (-1.28, -1.21)	126
Asia	Iran	-0.71 (-0.76, -0.66)	128
Asia	Myanmar	-0.64 (-0.68, -0.60)	130
Asia	Thailand	-0.41 (-0.46, -0.35)	134
Asia	Indonesia	-0.37 (-0.40, -0.33)	135
Asia	Viet Nam	-0.32 (-0.35, -0.29)	136
Asia	Maldives	-0.28 (-0.36, -0.20)	139
Asia	Malaysia	-0.27 (-0.32, -0.23)	141
Asia	Timor-Leste	-0.02 (-0.05, 0.02)	150
Asia	Philippines	0.04 (0.03, 0.06)	151
Asia	Sri Lanka	1.19 (1.06, 1.32)	152
Europe	Romania	-2.45 (-2.58, -2.32)	68
Europe	Serbia	-2.41 (-2.54, -2.29)	72
Europe	Bosnia and Herzegovina	-2.40 (-2.48, -2.32)	73
Europe	Bulgaria	-2.38 (-2.47, -2.28)	77
Europe	Albania	-2.37 (-2.40, -2.33)	79
Europe	Slovenia	-2.36 (-2.52, -2.20)	81
Europe	Estonia	-2.33 (-2.43, -2.23)	84
Europe	Czechia	-2.21 (-2.32, -2.10)	90
Europe	North Macedonia	-2.08 (-2.11, -2.06)	95
Europe	Ukraine	-2.02 (-2.12, -1.91)	99
Europe	Portugal	-1.90 (-1.97, -1.83)	104
Europe	Malta	-1.90 (-1.95, -1.85)	105
Europe	Austria	-1.62 (-1.63, -1.60)	115
Europe	Luxembourg	-1.52 (-1.55, -1.49)	119
Europe	Cyprus	-1.51 (-1.57, -1.45)	120
Europe	Italy	-1.36 (-1.51, -1.21)	122
Europe	Greece	-1.18 (-1.30, -1.06)	127

Abbreviation: TB= Tuberculosis; EAPC= Estimated annual percentage change.

\*Refers to the ranking of the EAPC from the highest to the lowest among 152 Belt and Road Partner countries.