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Population-level health and economic impacts of introducing Vaccae vaccination in China: a modelling study

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ABSTRACT

Introduction Given the ageing epidemic of tuberculosis (TB), China is facing an unprecedented opportunity provided by the first clinically approved next-generation TB vaccine Vaccae, which demonstrated 54.7% efficacy for preventing reactivation from latent infection in a phase III trial. We aim to assess the population-level health and economic impacts of introducing Vaccae vaccination to inform policy-makers.

Methods We evaluated a potential national Vaccae vaccination programme in China initiated in 2024, assuming 20 years of protection, 90% coverage and US\$30/dose government contract price. An age-structured compartmental model was adapted to simulate three strategies: (1) no Vaccae; (2) mass vaccination among people aged 15–74 years and (3) targeted vaccination among older adults (60 years). Cost analyses were conducted from the healthcare sector perspective, discounted at 3%.

Results Considering postinfection efficacy, targeted vaccination modestly reduced TB burden (~20%), preventing cumulative 8.01 (95% CI 5.82 to 11.8) million TB cases and 0.20 (0.17 to 0.26) million deaths over 2024–2050, at incremental cost-effectiveness ratio of US\$4387 (2218 to 10 085) per disability adjusted life year averted. The implementation would require a total budget of US\$22.5 (17.6 to 43.4) billion. In contrast, mass vaccination had a larger bigger impact on the TB epidemic, but the overall costs remained high. Although both preinfection and postinfection vaccine efficacy type might have a maximum impact (>40% incidence rate reduction in 2050), it is important that the vaccine price does not exceed US\$5/dose.

Conclusion Vaccae represents a robust and cost-effective choice for TB epidemic control in China. This study may facilitate the practice of evidence-based strategy plans for TB vaccination and reimbursement decision making.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Modelling studies for potential public health impact of next-generation tuberculosis (TB) vaccines are available but are limited to hypothetical vaccines or candidate vaccines under clinical trials.

⇒ Vaccae is the first clinically approved next-generation TB vaccine, for which the efficacy-effectiveness gap needs to be addressed.

WHAT THIS STUDY ADDS

⇒ We for the first time modelled the potential impact of a new TB vaccine that is available on the market and a vaccination programme that could be quickly implemented.

⇒ National targeted vaccination strategy towards older adults has been identified as a highly cost-effective epidemic control agent in China.

⇒ Mass vaccination strategy could be more effective, but reduction in vaccine price is necessary to ascertain a good economic return for the future vaccination programme.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ This study may facilitate practice of evidence-based strategy plan for TB vaccination and reimbursement decision-making.

⇒ The framework may also provide valuable implications for TB control strategies in other countries.

INTRODUCTION

Globally, tuberculosis (TB) caused by *Mycobacterium tuberculosis* remains a major public health challenge. An estimated 10.6 million people developed active TB disease, with 1.4 million TB-related deaths in 2021. At least US\$13 billion annually was required for worldwide TB prevention, diagnosis and treatment by 2022. India (28%), Indonesia (9.2%) and China (7.4%) are the top three countries with the most cases of TB in the world.[1] As the COVID-19 pandemic has aggravated the already suboptimal international TB response, new transformational tools such as vaccines are urgently needed to achieve the WHO 'end TB' goals.[2]

BCG, the most widely used TB vaccine in the world, was discovered in France in 1921.[3] Infant BCG vaccination is effective at preventing TB disease (pulmonary and extrapulmonary) in young children aged <5 years (efficacy 37%; 95% CI 19% to 51%).

It also has protection against TB-related death until 15 years after vaccination.[4] There are currently 16 TB vaccine candidates in the clinical development pipeline.[5] They include several different vaccine product profiles: (1) preinfection (PRI) or pre-exposure vaccines targeting infants, (2) postinfection (PSI) or post-exposure vaccines targeting adolescents and adults with latent TB infection (LTBI), (3) both preinfection and postinfection (P&PI) vaccines targeting all individuals except those who have active TB disease at time of vaccination and (4) therapeutic vaccines targeting active TB patients.[6] Vaccae, heat-killed *Mycobacterium* Vaccae (a non-TB mycobacteria closely related to *M. obuense*), is one of the next-generation candidates (ie, PSI efficacy type). The results from the phase III clinical trial showed that Vaccae was 54.7% efficacious in preventing pulmonary TB disease in tuberculin skin test (TST) confirmed latently infected persons (TST induration ≥15 mm) (online supplemental table S1 and S2). Strikingly, a century after the discovery of BCG, the China Food and Drug Administration granted approval to Vaccae in June 2021 for use in persons with LTBI (registered number of approval: S20010003; handling number: CXSS1800010; nmpa.gov.cn). The emphasis of the TB control approach might shift from treatment to prevention. As a new vaccine becomes available, questions remain regarding the potential public health impact of the vaccine and how to develop an optimal vaccination strategy. Deep interpretations of the efficacy trial results are warranted.

Most TB infections are asymptomatic and classified as LTBIs which serve as a reservoir for new disease and thereby perpetuate the disease cycle at a population level.[7] The risks of LTBI reactivation and TB-related death increase with age. With rapid ageing of the largest population in the world, China has a high disease burden of TB, among which LTBI reactivation accounts for nearly two thirds of total TB cases.[8] It is generally accepted that PSI or P&PI vaccines may provide more rapid and greater impact than PRI vaccines, especially in settings with reactivation-driven epidemics.[9] The approval of Vaccae provides an unprecedented opportunity for China.

In the last 10 years, the decline in diagnosed TB cases in China has plateaued.[1] Although TB elimination has long been a goal of the national TB plan, it is unclear whether and when this might be achieved and how declines in TB incidence can be accelerated. The vaccine may be a promising option for designing a novel vaccination strategy against TB in China. However, critical questions remain in planning and priority setting for vaccination strategies. There is currently no national TB vaccination programme for adolescents and adults in China. Self-paid Vaccae vaccination leads to extremely low vaccine uptake. Mathematical modelling incorporating transmission dynamics and intervention measures could help to guide strategy development. In this study, we intended to bridge the gap between the Vaccae efficacy trial and model-based impact evaluation. Our study may be timely to guide the design of nationwide TB control programmes and inform policy-making.

METHODS

Model structure and calibration

We adapted an age-structured compartmental model originally developed to evaluate the effect of the WHO DOTS (chemotherapy delivered as directly observed treatment, short-course) strategy. The model was developed using R software populated with China-specific inputs and calibrated to epidemiological targets from surveillance data, with more details about the model reported in prior studies.[10 11] It simulated changes in demography and epidemiology from 1900 to 2050 for all population in China. We initiated the model with 1950 values in 1900, allowed to burn in during 1900–1950 to ensure adequate stabilisation of the *M. tuberculosis* transmission trend. Then all compartments in 1950 were rescaled by the same factor to match the estimate for 1950. Age was modelled from 0 to 100 years at 1-year intervals. The natural history of TB was composed of five states (compartments): uninfected (S), latently infected (L), infectious (ie, bacteriologically positive) active TB disease (I), noninfectious (ie, bacteriologically negative) active disease (NI) and recovered from active disease (R) (figure 1A). Newborns were assumed to be in the uninfected state. The initial prevalence rate of infectious cases was set as 2% in 1900. State transmission includes: (1) acquisition of infection; (2) development of active disease, reactivation or relapse; (3) case detection, successful treatment or spontaneous recovery and (4) TB mortality in active disease states, and all-cause mortality in all states (figure 1B, online supplemental tables S3–S6 and figure S1).

The model was calibrated for the 2000–2050 period. We employed an iterative, directed-search Nelder-Mead (NM) method (online supplemental table S7)[12] using the R package 'dfoptim' to calibrate the model to the observed epidemiological targets: (1) the population size estimates for 2000, 2020, 2035 and 2050 (online supplemental table S8); (2) microbiologically positive pulmonary TB prevalence rate for 2000 and 2010; (3) TB incidence rates for 2005, 2010, 2014 and 2018 and (4) TB mortality rates for 2010 (online supplemental table S9). The goodness of fit (GoF) metric, defined as the sum of the GoF of the individual calibration targets, served in the optimisation procedure to overcome the limitation of the NM method of reaching local optima and ensure the model's prediction accuracy. We used Latin hypercube sampling to draw multiple sets of parameter values from their predefined distributions as the simplexes. With each simplex seeded, the NM search algorithm was applied to produce one optimal set of input parameter values that locally minimised the overall GoF metric. Only the calibrated parameter sets that best minimise GoF were deemed acceptable. We repeated the same calibration step 1000 times with each simplex seeded and derived 100 best fitting parameter subsets.

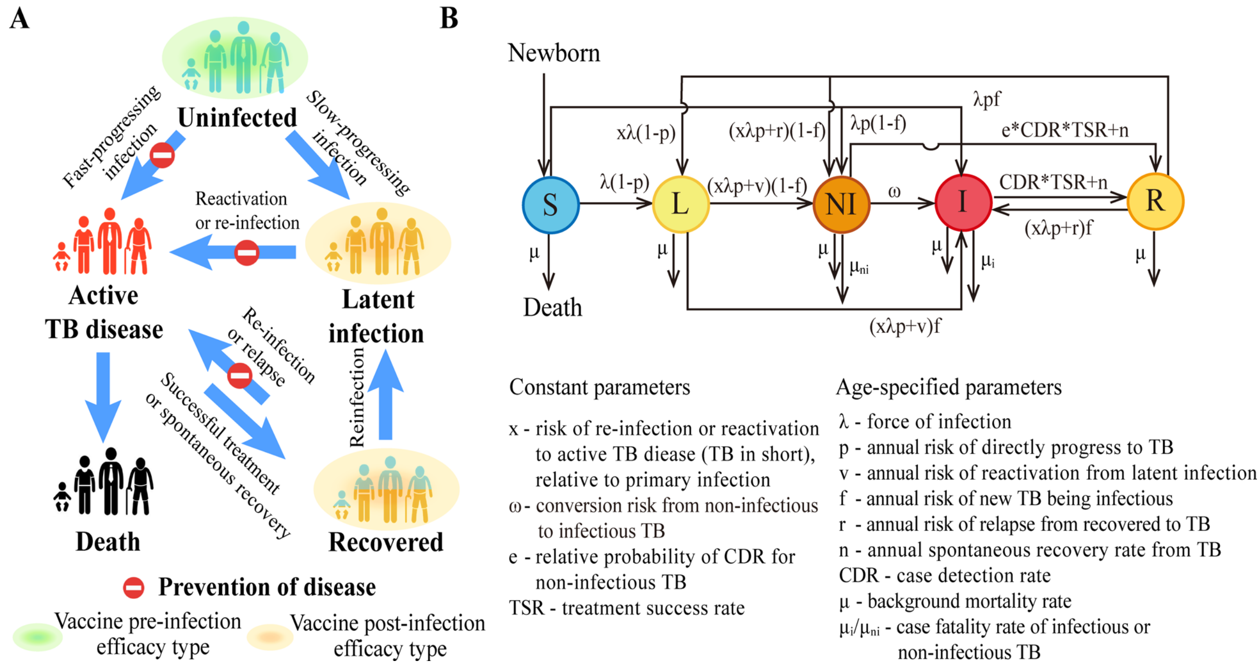

Figure 1 Vaccine characteristics and model structure. (A) Effect of TB vaccine on the natural history of *Mycobacterium tuberculosis* infection, preventing active TB disease (red) from individuals with or without a previous history of infection (PSI or PRI efficacy). (B) Age-structured compartmental model of *M. tuberculosis* infection, transmission and disease, consisting of S, L, NI, I and R states. I, infectious TB; L, latent infection; NI, non-infectious TB; PRI, preinfection; PSI, postinfection; R, recovered; S, susceptible; TB, tuberculosis.

The variables for BCG vaccination and DOTS programmes, including population coverage and treatment success rate, were assumed to remain stable. Therefore, the impacts of BCG and DOTS were intrinsic to the calibration data, although they were not explicitly modelled.

Vaccination strategies and epidemiological outcomes

To reflect the real-world effectiveness of the Vaccae vaccine and recognise the changing evidence on TB vaccines with different mechanisms, we focused on two vaccine types: PSI (real-world efficacy type) and P&PI (hypothetical multi-stage efficacy type). A series of vaccination scenario cases were modelled using combinations of efficacy type, vaccination age and duration of protection (eg, 10 years and 20 years, assumed to wane instantly at the end of the protection, or lifelong). To identify the priority population for vaccination, we initially compared the epidemiological outcomes of vaccinating different age-cohorts, spaced at 15-year intervals from ages 15 years to 74 years (4 cohorts). Each routine vaccination scenario involved a 'catch-up' vaccination for certain age groups in the first year of implementation. Next, three main strategies were explored: (1) no new vaccine (status quo); (2) mass vaccination, delivered to all-age population (persons aged 15–74 years) with LTBI (PSI) or irrespective of infection status (P&PI), through campaigns (10 yearly, 20 yearly or once) and (3) targeted vaccination, annually delivered to the age group with the highest priority, using PSI or P&PI efficacy type, through routine vaccination. We assumed that Vaccae would be widely available in 2024. The TST with 77.2% sensitivity was applied to screen for LTBI.[13] We assumed that 100% of those screened as TST positive would accept the vaccine injection. We assumed a 90% vaccination coverage to be 90% here given China's strong immunisation programme and high national vaccination coverage (over 90%).[14]

In the latest phase III clinical trial (ClinicalTrials.gov number: NCT01979900), 29 of the 4698 participants in the Vaccae group, compared with 64 of 4730 in the placebo group, were detected with pulmonary TB (incidence, 0.328 vs 0.724 cases per 100 person-years). Herein, the vaccine efficacy was set as 54.7% (95% CI: 29.8% to 70.8%) (online supplemental table S2).

The epidemiological outcomes were calculated annually over 2024–2050 for all the scenario cases. Our primary outcome of interest was the cumulative number of TB cases or deaths averted over 27 years, compared with the 'no new vaccine' scenario (status quo). Secondary outcomes were a composite of incidence rate reduction (IRR), mortality rate reduction (MRR), cumulative number needed to vaccinate (NNV) per case or death averted, in comparison with the status quo.

Costs and cost-effectiveness analysis

Cost evaluation was conducted from the healthcare sector (direct medical costs) perspective, as well as societal (direct medical costs, direct nonmedical costs and indirect costs) in the online supplemental file. Unit cost estimates and assumptions are provided in online supplemental table S13. Costs were reported in US$ at the average exchange rate in 2021 (US$1 = ¥6.5). The market price for Vaccae is US$62/dose (US$372 for a course of 6 doses). The government contract price was assumed to be US$30/dose (around 50% reduction), based on the experience of national strategic price negotiation for new medicine.[15] The costs of the vaccination programme were composed of vaccine price, delivery and administrative costs.

The model predicted the number of deaths due to TB by age, year and time spent with active TB disease. Based on the life expectancy (online supplemental table S14) and disability weights (0.375),[16] we estimated year of life lost (YLL) and year lived with disability (YLD), respectively. The disability-adjusted life year (DALY) is calculated by summing YLL and YLD.

We conducted three separate analyses for cost effectiveness. First, we calculated the incremental cost-effectiveness ratio (ICER), based on the 100 best-fit model runs. The cost-effectiveness threshold (CET) or willingness-to-pay (WTP) threshold was set at US$12 458 (China's national gross domestic product per capita (pGDP) in 2021) per DALY averted, as recommended by the WHO. The cost per case averted (CCA) and cost per death averted (CDA) were also estimated. Second, we ran threshold analysis to calculate the price at which each strategy is estimated to be 'cost effective' (CE). A larger range of vaccine profiles was explored: 30%–100% efficacy and a 5–25-year duration of protection. Third, we conducted sensitivity analyses, one-way deterministic sensitivity analysis as well as probabilistic sensitivity analysis (PSA), to explore the impact of parameter uncertainty.[17 18] Cost-effectiveness planes and cost-effectiveness acceptability curves were constructed through PSA. The lowest (Gansu province) to highest (Beijing) pGDP (US$6304–US$28 850) were set as the CE threshold range. Besides, we tested the robustness of results to also a lower threshold estimate (ie, 0.63 [0.47–0.88] × GDP per capita), based on a country-specific assessment of health opportunity costs.[19] Costs and DALYs were discounted at 3% per year.

Budget impact analysis

The most CE vaccination strategy would be investigated for the national vaccination budget in a 27-year period of 2024–2050. The number of required vaccines was estimated according to the targeted population, buffer stock and vaccine wastage rate. For the cumulative net cost of vaccination, the estimates included screening and vaccination costs incurred, and averted TB service costs and/or productivity loss, from healthcare sector or societal perspective.[20]

RESULTS

The model fitted overall and age-stratified demographic (online supplemental figure S2) and epidemiological data (prevalence, incidence and mortality rates in figure 2A–C and online supplemental figures S3-S5, respectively) in China. In our status quo projection, the general downward trend in incidence became flattened over 2020–2050, with an average annual decline rate of only 1.06% (figure 2B), which may be explained by the ageing and reactivation-driven epidemic of TB in the Chinese population (figure 2D). The model predicted that TB incidence was predominantly driven by reactivation/reinfection of latently infected individuals rather than new infection of susceptible individuals (figure 2E, online supplemental figure S6). TB burden gradually shifted to older adults. The proportion of older adults (≥60 years) among those incident TB cases nationally would steadily rise from 46.86% in 2020 to 80.51% in 2050, the year in which older adults would account for 38.8% of the Chinese population (online supplemental figure S7).

For PSI vaccination scenarios targeting adolescents (15 years), young adults (30 years), middle-aged adults (45 years) or older adults (60 years) assuming lifelong protection, the pairwise comparison found that the scenarios were statistically significantly different from one another for projected epidemiological outcomes. The modelled older adult vaccination had 13 193 TB cases (95% CI: 5902 to 22 708) and 332 TB-related deaths (178 to 436) averted per million vaccine doses, which were substantially higher than targeted vaccination scenarios toward the other three age groups (figure 2F, online supplemental table S10). There was also a distinct difference in ICERs across the cohorts assessed. Vaccinating 60-year olds had the lowest cost per DALY averted from both healthcare sector and societal perspectives (online supplemental tables S15 and S16).

The impact of targeted vacation for older adults on the TB epidemic was lower than that of mass vaccination, but high absolute numbers of cumulative cases and deaths could still be averted. With PSI efficacy and 20-year protection, it would prevent 8.01 million TB cases (5.82 to 11.8) and 0.20 million TB-related deaths (0.17 to 0.26) during the 2024–2050 time horizon (table 1). In 2050, the IRR and MRR compared with the status quo were 21.7% (19.9% to 23.2%) and 26.3% (24.1% to 27.6%), respectively (figure 2G, online supplemental table S11). In contrast, mass vaccination irrespective of infection status (P&PI efficacy) was considered to be the most effective strategy for lowering TB-related morbidity and mortality. With a 20-year protection setting, it could avert cumulative 32.7% (30.6% to 35.1%) and 32.0% (30.4% to 34.6%) of TB cases and deaths, respectively (table 1). In 2050, the IRR and MRR were 42.7% (37.8% to 53.6%) and 39.9% (37.5% to 44.5%), respectively (figure 2H, online supplemental table S11). In addition, most vaccine scenarios for older adults had a lower NNV per case and per death averted than those for all-age population. For example, assuming PSI efficacy and 20-year protection, the estimated NNV per case averted for targeted vaccination was 13 (8 to 29) (online supplemental table S12).

Targeted vaccination with PSI efficacy was identified as the most CE strategy over the 2024–2050 time horizon. In a 20-year protection setting, it resulted in an ICER of US$4387 (2218 to 10 085) per DALY averted (table 1).

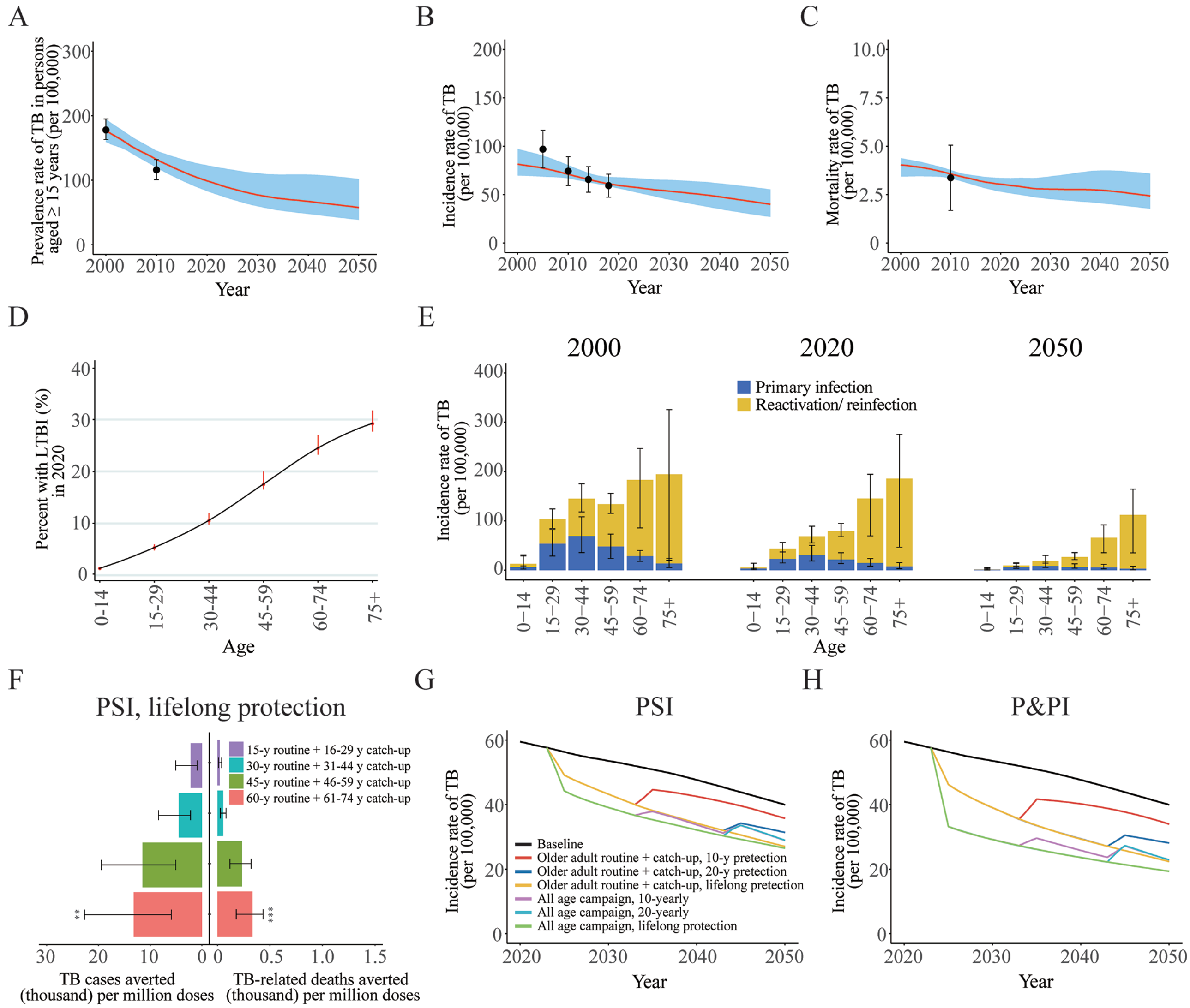

Figure 2 Modelling epidemiological impact of Vaccae vaccination in China. Model calibration for prevalence rate of microbiologically positive TB in persons aged ≥15 years (A), incidence rate (B) and mortality rate (C) of TB in the general population. (D) Estimated per cent of LTBI by age group in 2020. (E) Estimated incident rate of TB by age groups in 2000, 2020 and 2050. (F) Projected TB cases and deaths averted by targeted vaccination with Vaccae toward 15-year, 30-year, 45-year and 60-year population, with PSI efficacy and assumed lifelong protection. (G)–(H) Projected TB incidence over 2024–2050 for the 'no new vaccine' (black line) and vaccination scenarios (colour lines) for older adult or all age population, with PSI or both P&PI efficacy. Data are presented as median and 95% CI. TBI, latent TB infection; P&PI, preinfection and postinfection; PSI, postinfection; TB, tuberculosis.

The CCA and CDA were 2022 (915 to 5279) and US$83 733 (49 337 to 173 388), respectively (online supplemental table S17). In contrast, mass vaccination led to an ICER of US$7315 (4259 to 15 860) compared with the status quo but an ICER of US$21 450 (12 797 to 42 019) compared with the next best strategy (table 1). When productivity loss was included (societal perspective), the ICER of mass vaccination with PSI efficacy would become close to 1 × GDP per capita when compared with targeted vaccination (online supplemental table S18). Vaccination with hypothetical P&PI efficacy might both have a maximum impact, but costs remained high. Due to the high price and low coverage, vaccination with Vaccae provided through the private market would be more costly and less CE (online supplemental tables S19 and S20). The cost-effectiveness findings did not change if the time horizon was extended to 2100 (online supplemental tables S21 and S22). In addition, for a lower CET (0.63×GDP per capita), targeted vaccination with PSI vaccine remained the most CE (online supplemental tables S23 and S24).

The threshold analysis estimated the maximum price for the vaccine at which it would be CE with different efficacies and durations of protection (figure 3A–D). Generally, the median threshold prices below which the vaccination would be deemed CE were higher for PSI vaccine profiles than for P&PI vaccine profiles. For older adult vaccination with PSI vaccine, it had a 'CE price' of US$78.7/dose (37.2 to 122.5) at 54.7% efficacy and 20-year duration, reflecting the high treatment

Table 1 Epidemiological and economic impacts of introducing fully government-funded national Vaccae vaccination in China over 2024–2050.

Strategy	TB cases (million)		TB-related deaths (million)		Cost (US$ million)	DALY (million)		
No Vaccae (status quo)	45.59 (34.20 to 74.18)		1.02 (0.87 to 1.27)		40 352 (30 942 to 64 094)	24.5 (20.7 to 32.6)		
	TB cases averted		**TB-related deaths averted**		**Incremental cost (US$ million)**	**DALY averted* (million)**	**ICER (US$ per DALY averted)**	
	n (million)	**%**	**n (million)**	**%**			**vs status quo**	**vs next best strategy†**
Vaccae with 10-year protection								
PSI, older adult (60-year routine + 61–74-year catch-up)	5.30 (3.97 to 7.93)	11.7 (9.4 to 12.9)	0.13 (0.11 to 0.17)	13.0 (11.9 to 14.0)	18 305 (12 172 to 39 281)	2.79 (2.32 to 3.67)	6723 (3829 to 14 098)	6724 (3831 to 14 099)
P&PI, older adult (60-year routine + 61–74-year catch-up)	7.61 (5.72 to 11.3)	16.6 (14.0 to 18.7)	0.19 (0.15 to 0.26)	18.3 (17.0 to 20.7)	123 403 (120 282 to 125 036)	4.01 (3.32 to 5.41)	30 797 (22 387 to 37 671)	90 458 (50 443 to 116 174)
PSI, all age (15–74 years and 10-yearly campaigns)	9.21 (7.03 to 13.8)	20.1 (17.8 to 21.4)	0.21 (0.17 to 0.27)	20.3 (19.0 to 21.6)	52 908 (37 527 to 113 380)	4.46 (3.81 to 5.96)	11 815 (7506 to 24 567)	20 135 (13 367 to 40 165)
P&PI, all age ((15–74 years and 10-yearly campaigns)	14.2 (11.1 to 22.2)	31.1 (29.2 to 33.6)	0.30 (0.25 to 0.41)	30.0 (28.3 to 32.5)	538 652 (532 094 to 541 311)	7.05 (6.01 to 9.63)	76 430 (55 350 to 89 932)	118 681 (84 464 to 146 564)
Vaccae with 20-year protection								
PSI, older adult (60-year routine + 61–74-year catch-up)	8.01 (5.82 to 11.8)	17.7 (13.4 to 20.0)	0.20 (0.17 to 0.26)	20.0 (18.1 to 21.6)	16 715 (9539 to 37 704)	3.83 (3.16 to 5.04)	4387 (2217 to 10 085)	4387 (2218 to 10 085)
PSI, all age (15–74 years and 20-yearly campaigns)	9.74 (7.40 to 14.4)	21.2 (18.4 to 22.6)	0.22 (0.18 to 0.28)	21.8 (20.2 to 23.1)	33 663 (22 432 to 74 632)	4.63 (3.91 to 6.10)	7315 (4259 to 15 860)	21 450 (12 797 to 42 019)
P&PI, older adult (60-year routine + 61–74-year catch-up)	11.3 (8.28 to 16.5)	24.7 (19.9 to 27.5)	0.28 (0.23 to 0.38)	27.8 (25.7 to 30.3)	120 883 (116 642 to 123 262)	5.42 (4.44 to 7.05)	22 205 (16 616 to 27 715)	69 036 (40 418 to 86 908)
P&PI, all age (15–74 years and 20-yearly campaigns)	14.9 (11.7 to 23.0)	32.7 (30.6 to 35.1)	0.32 (0.27 to 0.43)	32.0 (30.4 to 34.6)	355 192 (348 620 to 357 923)	7.29 (6.22 to 9.87)	48 746 (35 414 to 57 384)	96 300 (65 229 to 118 322)
Vaccae with lifelong protection								
PSI, older adult (60-year routine + 61–74-year catch-up)	8.35 (6.05 to 12.2)	18.4 (13.9 to 20.9)	0.21 (0.17 to 0.27)	20.8 (18.8 to 22.5)	16 556 (9263 to 37 547)	3.91 (3.23 to 5.17)	4234 (2097 to 9833)	4235 (2098 to 9834)
PSI, all age (15–74 years and 1 campaign)	10.2 (7.68 to 14.9)	22.0 (18.9 to 23.6)	0.23 (0.19 to 0.30)	22.8 (21.1 to 24.2)	23 204 (14 279 to 53 276)	4.76 (3.99 to 6.22)	4933 (2644 to 11 071)	8788 (4675 to 17 409)
P&PI, older adult (60-year routine + 61–74-year catch-up)	11.7 (8.58 to 17.2)	25.7 (20.6 to 28.6)	0.29 (0.24 to 0.39)	28.8 (26.6 to 31.5)	120 639 (116 258 to 123 078)	5.55 (4.53 to 7.20)	21 667 (16 207 to 27 089)	129 082 (62 193 to 276 707)
P&PI, all age (15–74 years and 1 campaign)	15.6 (12.1 to 23.9)	33.9 (31.6 to 36.5)	0.34 (0.29 to 0.45)	33.4 (31.7 to 36.2)	231 423 (224 826 to 234 259)	7.45 (6.34 to 10.1)	31 091 (22 428 to 36 845)	75 854 (47 425 to 96 178)

Data are presented as median and 95% CI.
*Strategies were in ascending order of effectiveness.
†WTP was set at 1 × national pGDP (US$12 458).
DALY, disability-adjusted life year; ICER, incremental cost-effectiveness ratio, was calculated from healthcare sector perspective, with government contract price of US$30/dose, and costs and effectiveness discounted with 3% per year; pGDP, gross domestic product per capita; TB, tuberculosis; WTP, willingness to pay.

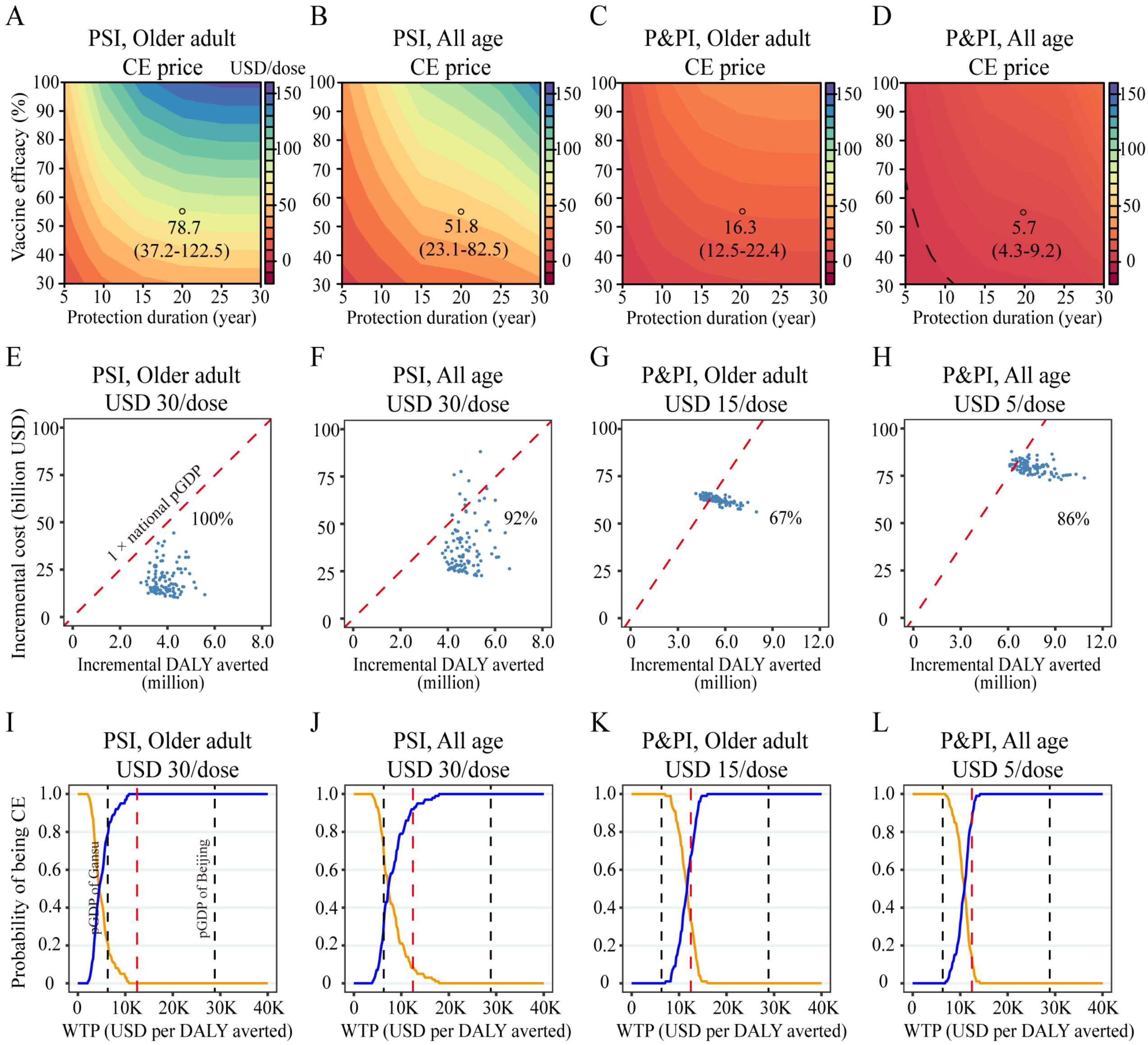

Figure 3 Cost-effectiveness analyses of Vaccae vaccination in China. (A)–(D) Contour plots showing the CE vaccine prices that lead to an average incremental cost per DALY equal to 1 × GDP per capita for specified vaccine efficacy and protection duration settings. The values below the dashed black line (D) denote that no price would be CE. (E)–(H) Cost-effectiveness planes for vaccination strategies. (I)–(L) Cost-effectiveness acceptability curves. CE, cost-effective; DALY, disability-adjusted life year; GDP, gross domestic product per capita; PSI, postinfection; WTP willingness to pay; P&PI, both preinfection and postinfection.

costs averted (figure 3A). For all-age vaccination with PSI vaccine, it would be CE at a price of US$51.8 (23.1 to 82.5) (figure 3B). Although all-age vaccination with hypothetical P&PI vaccine might have a maximum impact (>40% IRR in 2050, online supplemental table S11), the vaccine cannot exceed US$5/dose to be CE (CE price: 5.7 (4.3 to 9.2)) (figure 3D). In one-way sensitivity analyses, changing input parameters with upper and lower limits showed that the vaccine price, efficacy and protection duration were the key inputs in the economic model (online supplemental table S8). In PSA (figure 3E, F1 and J), PSI vaccine profiles at price of US$30/dose were likely to be CE from the healthcare sector perspective (92%–100% probability of cost effectiveness). However, P&PI vaccine profiles would only be CE (67%–86% probability of cost effectiveness) at lower prices (figure 3G, H, K and L). Results of cost-effectiveness analyses from the societal perspective are presented in online supplemental figures S9 and S10. Furthermore, at a lower CET (0.63×GDP per capita), PSI vaccine remained CE from the healthcare sector perspective with 58%–91% probability at price of US$30/dose, but either from the healthcare sector or society perspective, P&PI vaccine need to reduce vaccine prices further to maintain previous probability (online supplemental figures S11 and S12).

The models tracked the Chinese population eligible for vaccination from 2024 to 2050. Deploying Vaccae with 90% coverage among older adults with LTBI, a total of 104.34 (78.58 to 211.06) million older adults were predicted to receive the vaccine. The programme would lead to a total vaccination budget of US$27.34 (21.11 to 53.13) billion (US$22.55 billion after discounting (17.55 to 43.36)). Most programme costs are concentrated in the first year of vaccination: over US$10 billion in 2024. It would generate a total net cost of US$16.72 (9.54 to 37.70) billion over the 27-year period, from the healthcare sector perspective. The annual expenditure by the national vaccination programme and medical costs averted are also shown in table 2. Accounting for savings on productivity loss averted from the societal perspective, the net cost of the vaccination programme among older adults would be US$10.99 billion (2.92 to 32.10) (online supplemental table 28). Budget impact analyses were performed under various scenarios to explore plausible futures of new TB vaccines (online supplemental tables S25-S37).

DISCUSSION

For the ageing, reactivation-driven TB epidemic in China, new TB vaccine is a promising intervention for TB control. Policy-makers are facing challenges and we hope our analysis can help optimise future policy. As in this study, we demonstrate that: targeted vaccination strategy towards older adults would be a highly CE epidemic control agent in China; mass vaccination strategy could be more effective but costs remained high; and reduction in vaccine price is necessary to ascertain a good economic return for the future vaccination programme.

Our study is not the first economic evaluation of TB vaccination in China.[21 22] We searched articles in PubMed, up to 1 April 2023, with the terms ('TB' OR 'tuberculosis' (mesh)) AND (vaccin* OR immuniz* OR immunis* OR 'tuberculosis vaccines' (mesh)) AND ('mathematical model*' OR 'models, theoretical' (mesh)) AND ('cost-effectiveness' OR 'costs and cost analysis' (mesh)). Our search yielded more than twenty articles. The literature suggested that potential TB vaccines might be effective but differences in strategies and CET varied greatly across countries.[23] To the best of our knowledge, this is the first study to investigate the value of a new TB vaccine that is available on the market and a vaccination programme that could be quickly implemented. A large strength of our findings is the consistency throughout the multiple scenario analyses performed. Indeed, we found that targeted vaccination of older adults was consistently robust and CE in the study under each scenario. In addition, we simultaneously compared TB vaccinees in all stages through the adolescent to older adult life course. These calculations illustrated the significance of the age-specific strategy. The budgetary feasibility of vaccination programmes has also been considered for the prospective application of this vaccine in the context of China.

The adolescent strategy aimed to vaccinate 15-year olds in whom TB incidence was increasing while infant BCG vaccination became ineffective.[4] A previous modelling study suggested that PSI vaccines would have a negligible impact if delivered to adolescents in China, as the TB incidence reduction with older adult vaccination was 157.5 (119.3 to 225.6) times greater than that with adolescent vaccination.[11] Our projected outcomes are consistent with their estimates regarding the TB incidence reduction, as well as the downstream economic interpretation. In contrast, a study modelled that adolescent vaccination of M72/AS01$_E$ (also a PSI vaccine type) in South Africa could be CE.[18] This may be explained by the epidemiological differences between the two countries, such as high LTBI prevalence among adolescents and HIV syndemic in South Africa.[24 25] The contribution of incident TB cases from people living with HIV (PLHIV) in China was only 2%,[1] and, therefore, including HIV coinfection in the model is unlikely to affect our conclusions. This study is timely to guide vaccination decisions, as well as design in phase IV trials among high-risk populations.

Aside from vaccines, there is another option for LTBI: TB preventive treatment (TPT, chemoprophylaxis with rifamycin-based preferred regimens).[26] Community-based active case finding (ACF, usually among high-risk populations such as close contacts of patients with TB, healthcare workers (HCWs), PLHIV, etc) is essential for early identification of new cases of active TB,[27] as well as for ruling out active TB before providing TPT. A modelling study indicated that the 2035 target of the 'end TB' goal might be achieved in China if (1) nationwide ACF (in the particular study, ACF denotes active screening and finding LTBIs among the 'entire population') and TPT were completed within 5 years; (2) ACF and TPT were completed in high incidence areas within 2 years and (3) TPT completed among the older adults within 2 years.[21] However, the administration of chemoprophylaxis to the whole LTBI population carries critical ethical challenges. Individuals receiving TPT bear the risk of adverse effects such as severe or even fatal drug-induced hepatitis.[28] Unfortunately, TPT coverage is low even in HCWs in China.[29] In addition, potent new diagnostic tools, such as *M. tuberculosis* culturing and Xpert MTB/RIF tests, are limited to major hospitals.[30] According to our study, vaccination with Vaccae is insufficient to control the disease to meet the WHO's goals. The combined effects of vaccination and ACF could provide an interesting topic for future research.

Vaccine price and/or payment mechanism are important factors for TB vaccination programme scale-up. Currently, Vaccae is classified as a category II vaccine and provided through the private market at a high out-of-pocket price (US$62/dose), resulting in low vaccine coverage across the country. Inclusion of a vaccine into the government-funded vaccination programme and reducing out-of-pocket costs will improve vaccination coverage. China's basic public health services, including the expansion of government-funded vaccination programmes, are currently undergoing reforms. For example, many provinces have established fully government-funded seasonal influenza vaccination programmes in older adults, covered by medical or social insurance reimbursement systems.[31]

Table 2 Budget impact of introducing Vaccae vaccination programme among older adults in China during 2024–2050

Year	Screened population* (million)	Vaccinated population (million)	Vaccination programme budget† (US$ million)	Direct medical costs averted (US$ million)	Net cost‡ (US$ million)
Undiscounted					
2024	216.46 (216.18 to 216.63)	40.15 (31.77 to 75.75)	10 303 (8277 to 18 906)	12.9 (9.03 to 19.0)	10 291 (8265 to 18 896)
2025	22.12 (22.09 to 22.13)	3.49 (2.67 to 6.90)	906 (707 to 1729)	62.0 (44.0 to 91.7)	846 (627 to 1677)
2026	21.73 (21.71 to 21.74)	3.35 (2.55 to 6.67)	870 (677 to 1673)	107 (76.9 to 160)	768 (538 to 1582)
2027	20.65 (20.63 to 20.66)	3.11 (2.36 to 6.24)	808 (627 to 1565)	150 (108 to 223)	668 (433 to 1436)
2028	23.88 (23.86 to 23.89)	3.51 (2.65 to 7.09)	914 (706 to 1780)	191 (138 to 284)	733 (459 to 1616)
2029	23.62 (23.60 to 23.63)	3.39 (2.55 to 6.90)	884 (680 to 1732)	231 (165 to 342)	659 (381 to 1533)
2030	24.36 (24.33 to 24.37)	3.41 (2.55 to 6.99)	892 (684 to 1756)	267 (192 to 396)	630 (335 to 1524)
2031	23.27 (23.25 to 23.28)	3.18 (2.37 to 6.56)	834 (637 to 1649)	300 (216 to 446)	538 (240 to 1386)
2032	22.59 (22.57 to 22.60)	3.02 (2.23 to 6.25)	791 (602 to 1573)	331 (240 to 491)	465 (164 to 1281)
2033	22.08 (22.06 to 22.09)	2.88 (2.12 to 5.99)	756 (574 to 1509)	360 (262 to 533)	398 (101 to 1191)
2034	20.75 (20.74 to 20.76)	2.64 (1.94 to 5.52)	694 (525 to 1392)	388 (282 to 570)	301 (19 to 1049)
2035	18.79 (18.77 to 18.80)	2.33 (1.70 to 4.90)	614 (463 to 1236)	412 (300 to 605)	205 (–76 to 870)
2036	18.07 (18.06 to 18.08)	2.18 (1.59 to 4.61)	577 (434 to 1165)	433 (315 to 635)	147 (–133 to 779)
2037	16.84 (16.83 to 16.85)	1.98 (1.44 to 4.21)	524 (393 to 1064)	452 (329 to 661)	74 (–198 to 660)
2038	16.91 (16.90 to 16.92)	1.93 (1.40 to 4.13)	514 (384 to 1045)	469 (341 to 684)	49 (–228 to 626)
2039	17.89 (17.88 to 17.90)	1.99 (1.43 to 4.27)	530 (395 to 1082)	483 (350 to 703)	52 (–234 to 650)
2040	18.58 (18.57 to 18.59)	2.00 (1.44 to 4.33)	535 (399 to 1099)	495 (358 to 719)	49 (–243 to 656)
2041	19.43 (19.42 to 19.44)	2.03 (1.46 to 4.42)	544 (406 to 1123)	504 (364 to 732)	51 (–246 to 671)
2042	21.04 (21.03 to 21.05)	2.13 (1.53 to 4.67)	573 (427 to 1188)	511 (369 to 741)	75 (–231 to 730)
2043	18.76 (18.75 to 18.77)	1.84 (1.32 to 4.06)	497 (370 to 1034)	515 (371 to 748)	–16 (–294 to 571)
2044	19.78 (19.77 to 19.79)	1.88 (1.34 to 4.17)	509 (378 to 1063)	510 (365 to 742)	5 (–276 to 603)
2045	20.86 (20.85 to 20.87)	1.92 (1.36 to 4.28)	521 (387 to 1093)	485 (348 to 710)	48 (–232 to 650)
2046	22.55 (22.53 to 22.56)	2.00 (1.42 to 4.50)	546 (406 to 1151)	463 (332 to 683)	99 (–182 to 722)
2047	23.87 (23.85 to 23.88)	2.05 (1.45 to 4.64)	561 (416 to 1186)	444 (319 to 659)	131 (–145 to 771)
2048	22.87 (22.86 to 22.88)	1.89 (1.34 to 4.32)	521 (386 to 1106)	428 (306 to 638)	109 (–151 to 703)
2049	23.60 (23.59 to 23.61)	1.89 (1.33 to 4.32)	521 (386 to 1110)	413 (295 to 618)	125 (–129 to 718)
2050	24.54 (24.52 to 24.54)	1.89 (1.33 to 4.36)	525 (388 to 1121)	398 (284 to 600)	142 (–107 to 740)
Total	765.87 (765.14, 766.24)	104.34 (78.58 to 211.06)	27 340 (21 113 to 53 132)	9808 (7128 to 14 396)	18 181 (8716 to 44 293)
Discounted at 3% per year					

Continued

Table 2 Continued

Year	Screened population* (million)	Vaccinated population (million)	Vaccination programme budget† (US$ million)	Direct medical costs averted (US$ million)	Net cost‡ (US$ million)
Total	765.87 (765.14 to 766.24)	104.34 (78.58 to 211.06)	22 545 (17 550 to 43 359)	6301 (4580 to 9254)	16 715 (9539 to 37 704)

Data are presented as median and 95% CI.
*Screening population: 60-year routine and 61–74-year catch-up in 2024.
†Vaccination programme budget = screening cost + vaccine cost (US$30/dose, 6 doses per course, plus 5% buffer stock and 15% vaccine wastage) + delivery and administrative cost.
‡Net cost (healthcare sector perspective) = vaccination programme budget − direct medical costs averted.

Several cities have diverse payment mechanisms for expanding HPV vaccination, including partial coverage by governmental subsidy or partial incorporation in basic medical insurance.[32] The experience from other vaccines provides a reference for the future development of TB vaccination programmes in China. In addition, vaccine price is a key determinant of cost effectiveness. Policy-makers in China should negotiate with pharmaceutical companies to secure a good price through bulk purchasing contracts.

Our study shows that if the status quo strategy is maintained, the TB burden in China will decline but cannot reach the goals of the WHO, which is to reduce the incidence rate of TB by 80% and 90% in 2030 and 2035, respectively, compared with 2015, and by less than one case per million individuals per year in 2050.[2] According to the simulation results, implementing government-funded national Vaccae vaccination among older Chinese adults can generate good health and economic value, and can remarkably shorten the gap between our expectation and China's 'end TB' goals.[33] It would facilitate the strategy plan for TB vaccination and reimbursement decision making for China. The framework may also prove valuable for the identification of suitable vaccination strategies for other countries.

Admittedly, our study has several limitations. First, our model considered the entire country as a single population. As a huge country, China has substantial heterogeneities of TB across different regions. Using fixed values for some parameters may not be appropriate. Because of a lack of adequate epidemiological data for calibration, it is difficult to construct models to accurately fit the province-specific settings. Second, the model does not account for sex differences, immunosenescence, drug-resistance, imperfect test specificity of screening, vaccine acceptance and compliance. These issues are beyond the scope of this research and may be opportunities for future research. Third, the vaccine was assumed to provide 'all-or-nothing' protection, yet the alternative 'degree/leaky' (efficacy was implemented as a reduction in natural history) assumption might reduce effect estimates.[9] Monitoring real-world vaccine effectiveness and its durability is essential. Our model may be adapted as more information emerges. Last but not least, although we have performed extensive uncertainty and sensitivity analyses, there may still be other factors influencing of vaccination impacts that we did not measure. For example, unpredictable future population policies in China might cause significant variations in future fertility rates and age structures.

In summary, government-funded national Vaccae vaccination represents a CE choice from the Chinese state perspective. Policy-makers in China should prioritise the elderly and, where possible, secure affordable prices. Developing or adopting vaccines with better characteristics and comprehensive prevention and control measures would be the focus for future TB vaccination promotion.

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Contributors GQ and ML conceived and designed the research. J-JM, XZ, W-LY, P-YZ, QZ and XZhuang collected the TB surveillance data, analysed the data, carried out the analysis and performed numerical simulations. C-HL produced the figures. J-JM and XZang wrote the first draft of the manuscript. ML and GQ made the key revision. GQ is the guarantor responsible for the overall content. All authors contributed to the scientific discussions and approved the final draft.

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REFERENCES

1. WHO. Global tuberculosis report 2022. 2022. Available: https://www.who.int/publications/i/item/9789240061729
2. Partnership ST. The global plan to end TB 2016-2020. In: *The Paradigm Shift*. 2019. Available: https://www.stoptb.org/file/8503/download
3. Fatima S, Kumari A, Das G, *et al*. Tuberculosis vaccine: A journey from BCG to present. *Life Sci* 2020;252:117594.
4. Martinez L, Cords O, Liu Q, *et al*. Infant BCG vaccination and risk of pulmonary and Extrapulmonary tuberculosis throughout the life course: A systematic review and individual participant data meta-analysis. *Lancet Glob Health* 2022;10:e1307–16.
5. Tait DR, Hatherill M, Van Der Meeren O, *et al*. Final analysis of a trial of M72/As01(E) vaccine to prevent tuberculosis. *N Engl J Med* 2019;381:2429–39.
6. Khademi F, Derakhshan M, Yousefi-Avarvand A, *et al*. Multi-stage subunit vaccines against Mycobacterium tuberculosis: An alternative to the BCG vaccine or a BCG-prime boost? *Expert Rev Vaccines* 2018;17:31–44.
7. Jasmer RM, Nahid P, Hopewell PC. Clinical practice. *Latent Tuberculosis Infection N Engl J Med* 2002;347:1860–6.
8. Cui X, Gao L, Cao B. Management of latent tuberculosis infection in China: Exploring solutions suitable for high-burden countries. *International Journal of Infectious Diseases* 2020;92:S37–40.
9. Harris RC, Sumner T, Knight GM, *et al*. Potential impact of tuberculosis vaccines in China, South Africa, and India. *Sci Transl Med* 2020;12:eaax4607.
10. Abu-Raddad LJ, Sabatelli L, Achterberg JT, *et al*. Epidemiological benefits of more-effective tuberculosis vaccines, drugs, and diagnostics. *Proc Natl Acad Sci U S A* 2009;106:13980–5.
11. Harris RC, Sumner T, Knight GM, *et al*. Age-targeted tuberculosis vaccination in China and implications for vaccine development: A Modelling study. *Lancet Glob Health* 2019;7:e209–18.
12. Zang X, Krebs E, Min JE, *et al*. Development and calibration of a dynamic HIV transmission model for 6 US cities. *Med Decis Making* 2020;40:3–16.
13. Krutikov M, Faust L, Nikolayevskyy V, *et al*. The diagnostic performance of novel skin-based in-vivo tests for tuberculosis infection compared with purified protein derivative Tuberculin skin tests and blood-based in vitro interferon-Γ release assays: A systematic review and meta-analysis. *Lancet Infect Dis* 2022;22:250–64.
14. Lin S-Y, Zhang S-Y, Chantler T, *et al*. Vaccination coverage determinants in low uptake areas of China: A qualitative study of provider perspectives in Sichuan, Guangdong, and Henan provinces. *Hum Vaccin Immunother* 2022;18:2030623.
15. Si L, Xu L, Chen M, *et al*. Using strategic price negotiations to contain costs and expand access to medicines in China. *BMJ Glob Health* 2020;5:e002256.
16. Liu X, Wang F, Zhou M, *et al*. Eliciting national and Subnational sets of disability weights in Mainland China: Findings from the Chinese disability weight measurement study. *The Lancet Regional Health - Western Pacific* 2022;26:100520.
17. Menzies NA, Cohen T, Lin H-H, *et al*. Population health impact and cost-effectiveness of tuberculosis diagnosis with Xpert MTB/RIF: A dynamic simulation and economic evaluation. *PLoS Med* 2012;9:e1001347.
18. Harris RC, Quaife M, Weerasuriya C, *et al*. Cost-effectiveness of routine adolescent vaccination with an M72/As01(E)-Like tuberculosis vaccine in South Africa and India. *Nat Commun* 2022;13:602.
19. Ochalek J, Wang H, Gu Y, *et al*. Informing a cost-effectiveness threshold for health technology assessment in China: A marginal productivity approach. *Pharmacoeconomics* 2020;38:1319–31.
20. Jiang S, Wang Y, Si L, *et al*. Incorporating productivity loss in health economic evaluations: A review of guidelines and practices worldwide for research agenda in China. *BMJ Glob Health* 2022;7:e009777.
21. Wen Z, Li T, Zhu W, *et al*. Effect of different interventions for latent tuberculosis infections in China: A model-based study. *BMC Infect Dis* 2022;22:488.
22. Knight GM, Griffiths UK, Sumner T, *et al*. Impact and cost-effectiveness of new tuberculosis vaccines in Low- and middle-income countries. *Proc Natl Acad Sci U S A* 2014;111:15520–5.

23 Portnoy A, Clark RA, Quaife M, *et al*. The cost and cost-effectiveness of novel tuberculosis vaccines in Low- and middle-income countries: A modeling study. *PLoS Med* 2023;20:e1004155.
24 Mahomed H, Hawkridge T, Verver S, *et al*. Predictive factors for latent tuberculosis infection among adolescents in a high-burden area in South Africa. *Int J Tuberc Lung Dis* 2011;15:331–6.
25 Abdool Karim SS, Churchyard GJ, Karim QA, *et al*. HIV infection and tuberculosis in South Africa: An urgent need to escalate the public health response. *Lancet* 2009;374:921–33.
26 Sterling TR, Njie G, Zenner D, *et al*. Guidelines for the treatment of latent tuberculosis infection: Recommendations from the National tuberculosis controllers Association and CDC, 2020. *MMWR Recomm Rep* 2020;69:1–11.
27 Fox GJ, Nhung NV, Marks GB. Household-contact investigation for detection of tuberculosis in Vietnam. *N Engl J Med* 2018;378:2141:221–9.:.
28 Gardner Toren K, Spitters C, Pecha M, *et al*. Tuberculosis in older adults: Seattle and King County, Washington. *Clin Infect Dis* 2020;70:1202–7.
29 Wang F, Ren Y, Liu K, *et al*. Large gap between attitude and action in tuberculosis preventive treatment among tuberculosis-related Healthcare workers in Eastern China. *Front Cell Infect Microbiol* 2022;12:991400.
30 Huang S, Xiang H, Yang W, *et al*. Short-term effect of air pollution on tuberculosis based on Kriged data: A time-series analysis. *IJERPH* 2020;17:1522.
31 Yang J, Atkins KE, Feng L, *et al*. Cost-effectiveness of introducing national seasonal influenza vaccination for adults aged 60 years and above in Mainland China: A Modelling analysis. *BMC Med* 2020;18:90.
32 Lu X, Ji M, Wagner AL, *et al*. Willingness to pay for HPV vaccine among female health care workers in a Chinese nationwide survey. *BMC Health Serv Res* 2022;22:1324.
33 Huynh GH, Klein DJ, Chin DP, *et al*. Tuberculosis control strategies to reach the 2035 global targets in China: The role of changing demographics and reactivation disease. *BMC Med* 2015;13:88.
34 Mao JJ, Yue WL, Qin G. Data from: Population-level health and economic impacts of introducing Vaccae vaccination in China: A modeling study. *Zenodo Repository* May 9, 2023. 10.5281/zenodo.7832767 Available: https://doi.org/10.5281/zenodo.7832767

Population-level health and economic impacts of introducing Vaccae vaccination in China: A modeling study

Supplementary Appendix

1. Summary in Chinese

Population-level health and economic impacts of introducing Vaccae vaccination in China: A modeling study

中国新型结核疫苗接种策略的健康及经济影响：一项模型研究

摘要

背景

在中国人口老龄化的结核病流行背景下，全球首个获批临床适应症的新型结核疫苗“微卡”在Ⅲ期临床试验中显示对预防潜伏性结核感染者发生结核疾病的有效率为 54.7%，为我国终结结核流行目标带来前所未有的机遇。本研究旨在评估微卡疫苗纳入政府资助的疫苗接种计划对人群健康及经济影响，为卫生决策者提供循证依据。

方法

我们假设从 2024 年开始实施由政府资助的微卡疫苗接种计划，疫苗保护期为 20 年，覆盖率为 90%，政府集中采购价格为 30 美元/剂。构建人口年龄结构仓室模型模拟不同策略情景：（1）不接种疫苗；（2）在 15-74 岁成人中开展大规模全人群疫苗接种；（3）对 60 岁老年人进行目标人群疫苗接种。评估疫苗接种计划对降低结核病发病、死亡和患者经济负担的影响，从医疗卫生体系角度进行成本分析，贴现率为 3%。

结果

在疫苗感染后预防（PSI）效果下，老年人目标接种策略可减少约 20%的结核病负担，在 2024-2050 年期间将累计减少 801（95%CI：582-1180）万结核病例和避免 20（17-26）万例死亡，每避免一个伤残调整生命年（DALY）所需成本为 4387（2218-10085）美元。目标人群接种策略需投入总预算约 225（176-434）亿美元。相比之下，全人群疫苗接种对控制结核病流行的效果更大，但其成本也更高（与目标人群接种策略相比，增量成本效果比[ICER]>1 倍人均 GDP）。此外，假设疫苗具有感染前和感染后预防（P&PI）理想效果，虽可产生最大的流行病学效果（如 2050 年结核发病率降低＞40%），但疫苗价格须严格控制不超过 5 美元/剂。

结论

微卡疫苗可为中国结核病防控提供稳健且具经济效益的选择，本研究有助于推动新型结核疫苗接种策略的制定与实施决策。

Mao J-J, *et al. BMJ Global Health* 2023; 8:e012306. doi: 10.1136/bmjgh-2023-012306

2. Brief introduction on the efficacy trail of Vaccae

Table S1. Study design of the efficacy trial.

Item	Description
Official title	Phase III clinical study of efficacy and safety of mycobacterium Vaccae to prevent tuberculosis in high risk groups of tuberculosis infection
ClinicalTrials.gov identifier	NCT01979900
Study type	Interventional (clinical trial)
Actual enrollment	10,000 participants
Allocation	Randomized
Intervention model	Parallel assignment
	Vaccae group: 6 doses of Vaccae administered intramuscularly in the deltoid region of the arm
	Control group: 6 doses of placebo administered intramuscularly in the deltoid region of the arm
Masking	Double (participant, investigator)
Primary purpose	Prevention
Study start date	Oct, 2013
Actual study completion date	Nov 26, 2017
Main inclusion criteria	Aged from 15 to 65 years older, all genders.
	Skin test of tuberculin pure protein derivative (TB-PPD) is strongly positive (the average diameter of PPD skin test induration is greater than or equal to 15mm, and/or local blisters, necrosis).
Primary outcome	The whole TB incidence
Time frame	Terminal stage is two years after the last group of subjects enrolled

Source: Adapted from the online study record in ClinicalTrial.gov website.
https://clinicaltrials.gov/ct2/show/NCT01979900

Table S2. Vaccine efficacy of Vaccae as compared with placebo against pulmonary TB in adolescents and adults with evidence of tuberculosis infection.

Case definition	Vaccae			Placebo			Vaccine efficacy (% [95% CI])
	No. of incident cases	Person-yr of follow-up	Rate per 100 person-yr (95% CI)	No. of incident cases	Person-yr of follow-up	Rate per 100 person-yr (95% CI)	
Definite pulmonary TB disease	29	8846.3	0.328 (0.228, 0.472)	64	8838.2	0.724 (0.567, 0.925)	54.7 (29.8, 70.8)
Microbiological pulmonary TB disease	8	8858.3	0.090 (0.045, 0.181)	16	8872.2	0.180 (0.110, 0.294)	49.9 (-17.0, 78.6)
Smear or culture-positive pulmonary TB disease	7	8858.3	0.079 (0.038, 0.166)	8	8878.5	0.090 (0.045, 0.180)	12.3 (-141.8, 68.2)
Definite Xpert MTB/Rif positive pulmonary TB disease	1	8863.2	0.011 (0.002, 0.080)	8	8879.8	0.090 (0.045, 0.180)	87.5 (-0.1, 98.4)
Clinical TB disease	21	8851.7	0.237 (0.155, 0.364)	48	8852.1	0.542 (0.409, 0.720)	56.2 (26.9, 73.8)

TB, tuberculosis; Xpert MTB/RIF, nucleic acid amplification test to detect *M.tb* complex and resistance to rifampicin in sputum samples.
Source: Adapted from the online Package Insert of Mycobacterium Vaccae for Injection.[1]

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3. Model structure

Table S3. Model parameters.

Parameter	Description	Value, prior range or fixed	Reference	Posterior range observed in 100 fits
Birth and background death				
B[k]	Number of births in year *k* UN estimates of total crude birth rate per 1000 population applied to modeled population，and tracks annual UN data from 1979 onwards.	See Table S4	UN Population Estimates (2022)[2]	NA
μ[j]	Background (all-cause) death risk at age *j*	See Table S5	UN Population Estimates (2022)[2]	NA
Transmission				
λ[i,j]	*M.tb* transmission risk (force of infection) in time step *i* for age *j* $\lambda[i,j] = q \sum_{y=1}^{nygroups} \eta[m,y] z \frac{I[i,y]}{N[i,y]}$ Calibrated by *q* to match TB incidence.			NA
q	Calibration factor for *λ*	1～5	Harris RC (2019)[3]	1.0～3.8
η[m,y]	Daily number of respiratory contacts by participants (infection source) age group *m* and contacts (infection targets) in age group *y*.	See Figure S1	Read JM (2014)[4] Leung K (2017)[5] Zhang J (2019)[6] Prem K (2021)[7]	NA
z	Infectivity (transmission probability) per respiratory contact.	0.1	Dye C (2008)[8] Abu-Raddad LJ (2009)[9] Knight GM (2014)[10]	NA
Active TB				
p[j]	Proportion of (re-)infected individuals, originally uninfected, latently infected or recovered, directly progress to active TB disease, at age *j*	*p[j < 15]* = 0.01～0.06 *p[j≥15, <65]* = 0.08～0.2	Ferebee SH (1970)[11] Comstock GW (1982)[12]	*p[j<15]*: 0.01～0.06 *p[j ⩾15, <65]*: 0.08～0.2

		$p[j \geq 65]$ = 0.14～0.36	Vynnycky E (1996)[13] Vynnycky E (1997)[14] Dye C (1998)[15] Dye C (2008)[8] Abu-Raddad LJ (2009)[9] Knight GM (2014)[10]	$p[j \geq 65]$: 0.14～0.36
x	Risk of re-infection or active disease from latent infection or recovered individuals, relative to uninfected (1-x) is the protection provided by previous infection.	0.25～0.45	Sutherland I (1982)[16] Vynnycky E (1996)[13] Vynnycky E (1997)[14] Abu-Raddad LJ (2009)[9] Gomes MGM (2007)[17] Dye C (2008)[8]	0.25～0.45
$v[j]$	Risk of reactivation from latently infected individuals at age j	$v[j<15]$: 0.0001～0.0003 $v[j \geq 15, j<55]$: 0.0001～0.0003 $v[j \geq 55, j<65]$: $(v[j \geq 15, j<55] + v[j \geq 65])/2$ $v[j \geq 65]$: 0.0200 (0.0002, 0.04)	Sutherland I (1982)[16] Schulzer M (1992)[18] Dye C (1998)[15] Gomes MGM (2007)[17] Schaaf HS (2010)[19] Shea KM (2014)[20]	$v[j<15]$: 0.0001～0.0003 $v[j \geq 15, j<55]$: 0.0001～0.0003 $v[j \geq 55, j<65]$: 0.00016～0.004 $v[j \geq 65]$: 0.0002～0.0078
Infectious TB				
$f[j]$	Proportion of new active TB cases being infectious at age j	$f[j<15]$: 0.01～0.15 $f[j \geq 15, <65]$: 0.5～0.75 $f[j \geq 65]$: 0.5～0.75	Yoshikawa TT (1992)[21] Rajagopalan S (2000)[22] Dye C (2008)[8] Abu-Raddad LJ (2009)[9] Marion CR (2009)[23] Schaaf HS (2010)[19]	$f[j<15]$: 0.01～0.15 $f[j \geq 15, <65]$: 0.5～0.75 $f[j \geq 65]$: 0.5～0.75
ω	Conversion risk from non-infectious to infectious active disease	0.007～0.02	Ferebee SH (1970)[11] Dye C (1998)[15]	0.007～0.02
TB Mortality				
μ_i	Death risk for untreated or treatment-failed infectious TB cases	0.7	Tiemersma EW (2011)[24]	NA

μ_{ni}	Death risk for untreated or treatment-failed non-infectious TB cases	0.24	Tiemersma EW (2011)[24]	NA
μiscale	Calibration factor for μ_i and μ_{ni} $\mu_i = (1 + uiscale) * \mu_i$ $\mu_{ni} = (1 + uiscale) * \mu_{ni}$	*μiscale[j<15]*: -0.99～-0.01 *μiscale[j≥15, <65]*: -0.99～-0.01 *μiscale[j≥65]*: -0.99～-0.01	Schaaf HS (2010)[19]	*μiscale[j<15]:* -0.98～-0.64 *μiscale[j≥15, <65]:* -0.98～-0.97 *μiscale[j≥65]:* -0.95～-0.93
Spontaneous recovery and relapse				
n	Annual spontaneous recovery rate from active TB disease	*n[j<55]*: 0.085～0.115 *n[j≥55, <65]*: (*n[j<55]* + *n[j ≥ 65]*)/2 *n[j≥65]*: 0.085～0.115	Dye C (1998)[15] Abu-Raddad LJ (2009)[9]	*n[j<55]:* 0.085～0.11 *n[j≥55, <65]:* 0.086～0.11 *n[j≥65]:* 0.085～0.11
r	Annual risk of relapse from recovered to active TB	*r[j<15]* : 0.005～0.015 *r[j≥15, <55]* : 0.005～0.015 *r[j≥55, <65]* : (*r[j<55]* + *r[j≥65]*)/2 *r[j≥65]* : 0.005-0.2	Gomes MG (2004)[25] Schaaf HS (2010)[19] Knight GM (2014)[10]	*r[j<15]* : 0.005～0.015 *r[j≥15, <55]:* 0.005～0.015 *r[j≥55, <65]:* 0.0074～0.038 *r[j≥65]:* 0.005-0.063
Case detection				
CDR[k]	Case detection rate (proportion of new active TB cases detected and started treatment) in year *k* 2019 status quo: 88% $\begin{cases} CDR[k] = CDR[k] + (1 - CDR[k]) * CDRscale & \text{if } CDRscale \geq 0 \\ CDR[k] = (1 + CDRscale) * CDR[k] & \text{if } CDRscale < 0 \end{cases}$	See Table S6	WHO Tuberculosis Data (2022)[26]	NA
CDRscale	Calibration factor for CDR	*CDRscale[j<55]*: -0.5～0.99 *CDRscale[j≥55, <65]*: (*r[j<55]* + *r[j ≥65]*)/2 *CDRscale[j≥65]*: -0.99～-0.2	Schaaf HS (2010)[19]	*CDRscale[j<55]*: 0.16～0.79 *CDRscale[j≥55, <65]*: -0.15～0.23 *CDRscale[j≥65]*: -0.98～-0.2
e	Relative probability of case detection of non-infectious TB.	0.4～0.8	Harris RC (2019)[3]	NA
Treatment				
TSR[k]	Treatment success rate (including relapse cases) in year *k* WHO data 1994-2011, then constant *TSR* from 2011 (95%) onwards.	See Table S6	WHO Tuberculosis Data (2022)[26]	NA
Vaccination				
s	Sensitivity of tuberculin skin test (TST, the pre-vaccination screening test)	77.2% (66.4%-85.3%)	Krutikov M (2022)[27]	NA
c[k,j]	Screening and vaccination coverage for those aged *j* in year *k*	90%	Assumed	NA
eff	Vaccine efficacy for preventing active TB disease	54.7% (29.8%-70.8%)	Efficacy and its lower and higher bounds, results	NA

			from the clinical trial[1]	
$\theta_R[k,j]$	Vaccine effective coverage (VEC), proportion of vaccinated individuals at age *j* that move to the vaccine protection in year *k* through routine vaccination.	$\theta_R[k,j] = s \times c[k,j] \times eff$	Assumed	NA
$\theta_M[k,j]$	Vaccine effective coverage (VEC), proportion of vaccinated individuals at age *j* that move to the vaccine protection in year *k* through mass vaccination.	$\theta_M[k,j] = c[k,j] \times eff$	Assumed	NA
D	Duration of protection	10 years, 20 years, lifelong	Assumed	NA

Table S4. Estimated crude birth rates in China during 1900-2050.

Year	Birth rate (/1,000)	Year	Birth rate (/1,000)	Year	Birth rate (/1,000)	Year	Birth rate (/1,000)
1900-1950	41.049	1975	25.105	2000	13.755	2025	7.330
1951	40.094	1976	23.551	2001	12.943	2026	7.255
1952	45.052	1977	21.448	2002	12.735	2027	7.196
1953	41.844	1978	21.091	2003	12.575	2028	7.141
1954	43.083	1979	21.881	2004	12.707	2029	7.111
1955	42.607	1980	22.279	2005	12.766	2030	7.075
1956	39.574	1981	22.852	2006	12.892	2031	7.065
1957	42.842	1982	24.271	2007	13.077	2032	7.074
1958	37.775	1983	21.215	2008	13.368	2033	7.090
1959	31.406	1984	22.000	2009	13.502	2034	7.086
1960	29.804	1985	22.809	2010	13.308	2035	7.144
1961	26.185	1986	24.229	2011	13.136	2037	7.291
1962	40.402	1987	25.176	2012	14.070	2038	7.391
1963	48.988	1988	23.655	2013	13.269	2039	7.457
1964	42.914	1989	23.962	2014	13.506	2040	7.514
1965	41.830	1990	24.436	2015	12.522	2041	7.572
1966	39.562	1991	19.444	2016	13.038	2042	7.625
1967	36.267	1992	17.811	2017	13.065	2043	7.607
1968	40.554	1993	16.834	2018	10.948	2044	7.632
1969	38.589	1994	16.067	2019	10.293	2045	7.553
1970	38.337	1995	15.454	2020	8.597	2046	7.477
1971	35.288	1996	14.722	2021	7.633	2047	7.384
1972	33.097	1997	14.123	2022	7.544	2048	7.246
1973	31.317	1998	13.617	2023	7.477	2049	7.078
1974	28.535	1999	13.292	2024	7.421	2050	6.896

Source: Adapted from United Nations Population Estimates (2022), Table “WPP2022_Demographic_Indicators_Medium.csv”. https://population.un.org/wpp/Download/Standard/CSV/

Table S5. Estimated central death rates in China during 1900-2050.

Year \ Age	0	1-4	5-9	10-14	15-19	20-24	25-29-	30-34	35-39	40-44	45-49
1900-1950	0.145220	0.023109	0.008913	0.005776	0.005089	0.006308	0.007128	0.008084	0.009622	0.013297	0.016943
1951	0.141263	0.022098	0.008583	0.005469	0.004845	0.006012	0.006765	0.007686	0.009211	0.012792	0.016365
1952	0.137154	0.021091	0.007935	0.005201	0.004639	0.005778	0.006477	0.007355	0.008867	0.012379	0.015906
1953	0.133564	0.020234	0.008575	0.004912	0.004411	0.005519	0.006172	0.006992	0.008478	0.011898	0.015349
1954	0.131577	0.019778	0.007427	0.004693	0.004238	0.005329	0.005953	0.006717	0.008181	0.011546	0.014954
1955	0.128100	0.018976	0.007206	0.004578	0.004150	0.005251	0.005873	0.006594	0.008059	0.011454	0.014903
1956	0.124765	0.018221	0.006943	0.004416	0.004013	0.005117	0.005736	0.006407	0.007837	0.011200	0.014639
1957	0.121659	0.017519	0.006752	0.004271	0.003871	0.004962	0.005584	0.006217	0.007605	0.010939	0.014376
1958	0.118301	0.016778	0.006675	0.004155	0.003741	0.004826	0.005457	0.006060	0.007395	0.010696	0.014138
1959	0.176415	0.033663	0.011095	0.007016	0.005422	0.006622	0.007407	0.008274	0.010028	0.013961	0.018372
1960	0.229251	0.049250	0.015508	0.009525	0.006844	0.008020	0.008933	0.010086	0.012223	0.016715	0.021998
1961	0.171860	0.032630	0.010832	0.006716	0.005135	0.006227	0.007024	0.007901	0.009534	0.013331	0.017723
1962	0.107656	0.014492	0.005663	0.003649	0.003265	0.004254	0.004926	0.005504	0.006598	0.009635	0.013050
1963	0.104975	0.013934	0.005480	0.003505	0.003150	0.004079	0.004755	0.005337	0.006382	0.009299	0.012661
1964	0.101642	0.013253	0.005211	0.003341	0.003033	0.003883	0.004552	0.005137	0.006137	0.008909	0.012184
1965	0.098125	0.012544	0.005013	0.003221	0.002885	0.003697	0.004352	0.004939	0.005907	0.008534	0.011711
1966	0.094780	0.011908	0.004818	0.003125	0.002777	0.003550	0.004187	0.004776	0.005721	0.008197	0.011243
1967	0.091915	0.011360	0.004618	0.003004	0.002648	0.003395	0.003996	0.004585	0.005509	0.007857	0.010770
1968	0.089215	0.010842	0.004443	0.002883	0.002520	0.003246	0.003798	0.004387	0.005295	0.007534	0.010303
1969	0.086436	0.010324	0.004268	0.002775	0.002399	0.003130	0.003622	0.004206	0.005104	0.007254	0.009882
1970	0.082540	0.009608	0.004057	0.002661	0.002302	0.002960	0.003426	0.003998	0.004881	0.006946	0.009420
1971	0.078700	0.008910	0.003819	0.002525	0.002185	0.002783	0.003221	0.003766	0.004629	0.006606	0.008919
1972	0.075009	0.008265	0.003616	0.002417	0.002096	0.002641	0.003062	0.003575	0.004422	0.006334	0.008520
1973	0.071324	0.007640	0.003395	0.002291	0.001988	0.002481	0.002893	0.003357	0.004180	0.006015	0.008070
1974	0.067659	0.007055	0.003173	0.002218	0.001927	0.002373	0.002803	0.003214	0.004020	0.005811	0.007786
1975	0.064123	0.006498	0.002973	0.002129	0.001857	0.002295	0.002674	0.003070	0.003857	0.005611	0.007530
1976	0.060264	0.005863	0.002706	0.002010	0.001758	0.002180	0.002514	0.002890	0.003648	0.005367	0.007238
1977	0.056839	0.005358	0.002575	0.001925	0.001695	0.002106	0.002403	0.002767	0.003487	0.005165	0.006991
1978	0.053705	0.004912	0.002408	0.001847	0.001641	0.002039	0.002306	0.002669	0.003343	0.004986	0.006780
1979	0.050921	0.004529	0.002247	0.001766	0.001586	0.001972	0.002207	0.002587	0.003204	0.004808	0.006573
1980	0.048607	0.004230	0.002114	0.001690	0.001539	0.001919	0.002152	0.002489	0.003084	0.004649	0.006390
1981	0.046580	0.003962	0.001994	0.001607	0.001484	0.001862	0.002091	0.002391	0.002962	0.004478	0.006192
1982	0.044982	0.003756	0.001904	0.001528	0.001432	0.001809	0.002034	0.002302	0.002856	0.004313	0.006006
1983	0.043776	0.003608	0.001795	0.001458	0.001382	0.001759	0.001979	0.002220	0.002767	0.004156	0.005828
1984	0.042978	0.003508	0.001705	0.001389	0.001329	0.001709	0.001924	0.002135	0.002694	0.004002	0.005649
1985	0.042534	0.003456	0.001624	0.001325	0.001276	0.001662	0.001877	0.002087	0.002600	0.003863	0.005480
1986	0.042329	0.003429	0.001558	0.001261	0.001220	0.001611	0.001830	0.002038	0.002512	0.003728	0.005305
1987	0.042334	0.003430	0.001499	0.001196	0.001163	0.001559	0.001782	0.001987	0.002425	0.003603	0.005122
1988	0.042409	0.003443	0.001454	0.001133	0.001112	0.001507	0.001737	0.001937	0.002342	0.003496	0.004943
1989	0.042412	0.003443	0.001412	0.001077	0.001065	0.001458	0.001698	0.001894	0.002261	0.003423	0.004786

1990	0.042210	0.003415	0.001379	0.001034	0.001028	0.001417	0.001670	0.001870	0.002239	0.003348	0.004677
1991	0.041844	0.003377	0.001360	0.000996	0.000992	0.001374	0.001642	0.001849	0.002217	0.003279	0.004573
1992	0.041122	0.003287	0.001317	0.000933	0.000927	0.001288	0.001562	0.001771	0.002127	0.003114	0.004348
1993	0.040170	0.003174	0.001288	0.000888	0.000871	0.001221	0.001498	0.001712	0.002057	0.002983	0.004189
1994	0.038999	0.003041	0.001272	0.000865	0.000832	0.001176	0.001456	0.001682	0.002021	0.002896	0.004121
1995	0.037713	0.002901	0.001245	0.000834	0.000787	0.001121	0.001396	0.001630	0.001963	0.002819	0.003959
1996	0.036298	0.002741	0.001247	0.000827	0.000758	0.001080	0.001351	0.001602	0.001943	0.002795	0.003886
1997	0.034774	0.002571	0.001232	0.000812	0.000724	0.001030	0.001294	0.001556	0.001900	0.002738	0.003770
1998	0.033229	0.002413	0.001163	0.000798	0.000693	0.000974	0.001234	0.001502	0.001848	0.002665	0.003637
1999	0.031502	0.002233	0.001102	0.000802	0.000680	0.000940	0.001200	0.001475	0.001836	0.002647	0.003566
2000	0.029634	0.002047	0.001018	0.000795	0.000662	0.000895	0.001151	0.001423	0.001793	0.002594	0.003505
2001	0.027670	0.001860	0.000945	0.000768	0.000634	0.000836	0.001078	0.001338	0.001708	0.002488	0.003369
2002	0.025648	0.001675	0.000903	0.000763	0.000629	0.000807	0.001038	0.001294	0.001675	0.002456	0.003332
2003	0.023599	0.001495	0.000841	0.000751	0.000627	0.000783	0.000995	0.001252	0.001640	0.002425	0.003291
2004	0.021638	0.001331	0.000780	0.000731	0.000626	0.000764	0.000955	0.001210	0.001602	0.002392	0.003247
2005	0.019811	0.001186	0.000763	0.000704	0.000625	0.000749	0.000916	0.001169	0.001557	0.002354	0.003205
2006	0.018153	0.001061	0.000740	0.000672	0.000621	0.000735	0.000877	0.001122	0.001502	0.002301	0.003151
2007	0.016682	0.000952	0.000714	0.000650	0.000621	0.000734	0.000853	0.001088	0.001462	0.002275	0.003134
2008	0.015490	0.000925	0.000721	0.000679	0.000657	0.000775	0.000873	0.001093	0.001468	0.002287	0.003162
2009	0.014205	0.000781	0.000628	0.000615	0.000599	0.000732	0.000811	0.001004	0.001372	0.002183	0.003061
2010	0.013177	0.000720	0.000598	0.000605	0.000582	0.000736	0.000800	0.000969	0.001332	0.002132	0.003025
2011	0.012191	0.000653	0.000537	0.000587	0.000556	0.000732	0.000787	0.000930	0.001282	0.002065	0.002970
2012	0.011294	0.000599	0.000487	0.000565	0.000535	0.000728	0.000781	0.000899	0.001236	0.001998	0.002917
2013	0.010460	0.000550	0.000444	0.000536	0.000518	0.000719	0.000780	0.000874	0.001188	0.001936	0.002863
2014	0.009685	0.000507	0.000406	0.000501	0.000504	0.000703	0.000780	0.000854	0.001141	0.001874	0.002800
2015	0.008967	0.000466	0.000373	0.000463	0.000493	0.000680	0.000780	0.000839	0.001097	0.001814	0.002729
2016	0.008310	0.000432	0.000345	0.000426	0.000483	0.000655	0.000781	0.000831	0.001059	0.001756	0.002655
2017	0.007690	0.000399	0.000324	0.000399	0.000477	0.000645	0.000796	0.000845	0.001049	0.001737	0.002638
2018	0.007123	0.000371	0.000296	0.000356	0.000441	0.000607	0.000766	0.000821	0.000993	0.001625	0.002488
2019	0.006597	0.000345	0.000274	0.000328	0.000415	0.000593	0.000749	0.000823	0.000971	0.001563	0.002412
2020	0.006116	0.000323	0.000259	0.000306	0.000388	0.000584	0.000731	0.000830	0.000962	0.001517	0.002356
2021	0.005682	0.000303	0.000235	0.000284	0.000356	0.000572	0.000703	0.000831	0.000951	0.001463	0.002278
2022	0.005910	0.000312	0.000250	0.000302	0.000384	0.000553	0.000703	0.000775	0.000917	0.001478	0.002281
2023	0.005727	0.000303	0.000242	0.000293	0.000374	0.000539	0.000687	0.000758	0.000899	0.001448	0.002236
2024	0.005543	0.000293	0.000234	0.000283	0.000364	0.000526	0.000670	0.000742	0.000880	0.001418	0.002191
2025	0.005367	0.000284	0.000227	0.000275	0.000354	0.000512	0.000654	0.000725	0.000862	0.001389	0.002147
2026	0.005202	0.000275	0.000219	0.000266	0.000344	0.000499	0.000638	0.000709	0.000844	0.001360	0.002103
2027	0.005038	0.000266	0.000212	0.000257	0.000335	0.000487	0.000622	0.000693	0.000826	0.001332	0.002060
2028	0.004883	0.000258	0.000206	0.000249	0.000325	0.000474	0.000607	0.000677	0.000809	0.001304	0.002019
2029	0.004728	0.000250	0.000199	0.000241	0.000316	0.000462	0.000592	0.000662	0.000792	0.001277	0.001977
2030	0.004582	0.000242	0.000193	0.000233	0.000307	0.000450	0.000577	0.000646	0.000775	0.001250	0.001936
2031	0.004446	0.000235	0.000187	0.000226	0.000299	0.000438	0.000563	0.000631	0.000758	0.001224	0.001896
2032	0.004309	0.000228	0.000180	0.000219	0.000290	0.000427	0.000548	0.000616	0.000742	0.001198	0.001857
2033	0.004181	0.000221	0.000175	0.000211	0.000282	0.000415	0.000534	0.000601	0.000725	0.001172	0.001818

2034	0.004060	0.000214	0.000169	0.000205	0.000274	0.000404	0.000521	0.000587	0.000709	0.001147	0.001780
2035	0.003939	0.000208	0.000164	0.000198	0.000266	0.000394	0.000507	0.000573	0.000694	0.001123	0.001743
2036	0.003822	0.000201	0.000158	0.000191	0.000259	0.000383	0.000494	0.000559	0.000678	0.001098	0.001706
2037	0.003715	0.000196	0.000153	0.000185	0.000251	0.000373	0.000481	0.000545	0.000663	0.001074	0.001670
2038	0.003608	0.000190	0.000149	0.000179	0.000244	0.000363	0.000469	0.000532	0.000648	0.001051	0.001635
2039	0.003509	0.000184	0.000144	0.000174	0.000237	0.000353	0.000456	0.000519	0.000633	0.001028	0.001600
2040	0.003410	0.000179	0.000139	0.000168	0.000230	0.000344	0.000445	0.000506	0.000619	0.001005	0.001566
2041	0.003339	0.000174	0.000135	0.000163	0.000224	0.000335	0.000433	0.000494	0.000605	0.000983	0.001534
2042	0.003257	0.000170	0.000131	0.000158	0.000218	0.000326	0.000422	0.000483	0.000592	0.000962	0.001501
2043	0.003180	0.000166	0.000128	0.000153	0.000212	0.000318	0.000412	0.000471	0.000579	0.000941	0.001471
2044	0.003102	0.000161	0.000124	0.000148	0.000207	0.000310	0.000401	0.000460	0.000566	0.000920	0.001440
2045	0.003029	0.000157	0.000120	0.000144	0.000201	0.000302	0.000391	0.000449	0.000553	0.000900	0.001410
2046	0.002960	0.000153	0.000117	0.000140	0.000196	0.000295	0.000382	0.000439	0.000541	0.000881	0.001381
2047	0.002900	0.000150	0.000114	0.000136	0.000191	0.000288	0.000373	0.000429	0.000531	0.000864	0.001354
2048	0.002843	0.000147	0.000111	0.000132	0.000187	0.000281	0.000365	0.000420	0.000520	0.000846	0.001328
2049	0.002787	0.000143	0.000108	0.000129	0.000182	0.000275	0.000356	0.000411	0.000509	0.000829	0.001302
2050	0.002733	0.000140	0.000105	0.000125	0.000178	0.000268	0.000348	0.000402	0.000499	0.000813	0.001276

Age / Year	50-54	55-59	60-64	65-69	70-74	75-79	80-84	85-89	90-94	95-99	100
1900-1950	0.024491	0.032736	0.052600	0.075011	0.105660	0.147352	0.209322	0.286471	0.377208	0.494742	1
1951	0.023571	0.031629	0.051107	0.073417	0.103653	0.145171	0.208077	0.286150	0.379979	0.502354	1
1952	0.022861	0.030717	0.049961	0.072129	0.102344	0.143429	0.207668	0.286291	0.383602	0.507312	1
1953	0.022051	0.029592	0.048499	0.070308	0.100609	0.140852	0.206250	0.285112	0.386470	0.515678	1
1954	0.021515	0.028781	0.047487	0.069084	0.099760	0.139362	0.205996	0.285671	0.391533	0.528575	1
1955	0.021524	0.028686	0.047592	0.069462	0.101058	0.140865	0.209592	0.292290	0.403205	0.543004	1
1956	0.021217	0.028172	0.046911	0.068808	0.100807	0.140778	0.210262	0.295803	0.409635	0.554060	1
1957	0.020929	0.027732	0.046246	0.068249	0.100499	0.141026	0.210760	0.299516	0.415490	0.568890	1
1958	0.020668	0.027380	0.045610	0.067748	0.100114	0.141505	0.211073	0.303108	0.421144	0.572308	1
1959	0.026143	0.034632	0.055227	0.081337	0.119002	0.167968	0.237257	0.331922	0.451714	0.615195	1
1960	0.030885	0.040969	0.063616	0.093155	0.135499	0.191202	0.260421	0.356782	0.479658	0.640950	1
1961	0.025409	0.033835	0.053638	0.079521	0.117191	0.167363	0.236682	0.334080	0.461945	0.625314	1
1962	0.019433	0.026071	0.042878	0.064640	0.097198	0.141084	0.211056	0.308903	0.442019	0.608608	1
1963	0.018964	0.025541	0.041999	0.063243	0.095723	0.139496	0.210270	0.307188	0.444175	0.613768	1
1964	0.018366	0.024828	0.040904	0.061406	0.093513	0.136796	0.207972	0.303202	0.442382	0.615273	1
1965	0.017768	0.024126	0.039868	0.059604	0.091185	0.133897	0.205109	0.298781	0.438560	0.612151	1
1966	0.017132	0.023365	0.038730	0.057700	0.088567	0.130759	0.201762	0.294700	0.433904	0.613185	1
1967	0.016496	0.022624	0.037662	0.055994	0.086022	0.127760	0.198187	0.291025	0.428515	0.610025	1
1968	0.015863	0.021889	0.036601	0.054421	0.083501	0.124819	0.194480	0.287801	0.423084	0.605231	1
1969	0.015280	0.021224	0.035639	0.053090	0.081198	0.122067	0.190937	0.284894	0.418077	0.599743	1
1970	0.014614	0.020434	0.034483	0.051528	0.078510	0.118556	0.186278	0.280091	0.411138	0.590450	1
1971	0.013864	0.019504	0.033121	0.049712	0.075521	0.114441	0.180879	0.273889	0.403598	0.579183	1
1972	0.013240	0.018733	0.032006	0.048245	0.073130	0.110810	0.176076	0.267790	0.396843	0.568912	1
1973	0.012514	0.017799	0.030605	0.046327	0.070198	0.106108	0.169509	0.258632	0.386173	0.553745	1
1974	0.012021	0.017167	0.029698	0.045108	0.068424	0.102912	0.164993	0.252329	0.379422	0.544616	1

1975	0.011572	0.016582	0.028883	0.044086	0.067073	0.100435	0.161565	0.247973	0.375525	0.541530	1
1976	0.011100	0.015953	0.027997	0.043001	0.065696	0.098008	0.158018	0.243647	0.371262	0.538331	1
1977	0.010681	0.015349	0.027088	0.041857	0.064235	0.095580	0.153995	0.238543	0.365137	0.532999	1
1978	0.010334	0.014818	0.026288	0.040876	0.063022	0.093711	0.150546	0.234267	0.359847	0.529382	1
1979	0.010010	0.014300	0.025479	0.039884	0.061789	0.092005	0.147182	0.229958	0.354508	0.523948	1
1980	0.009743	0.013850	0.024754	0.038996	0.060736	0.090669	0.144323	0.226032	0.349753	0.518897	1
1981	0.009467	0.013396	0.023983	0.037998	0.059548	0.089210	0.141392	0.221551	0.344212	0.511843	1
1982	0.009215	0.012992	0.023256	0.037041	0.058432	0.087926	0.138964	0.217396	0.339217	0.506168	1
1983	0.008983	0.012632	0.022561	0.036106	0.057338	0.086670	0.136825	0.213231	0.334000	0.500102	1
1984	0.008753	0.012299	0.021884	0.035168	0.056250	0.085459	0.135076	0.209523	0.329328	0.494971	1
1985	0.008537	0.012010	0.021265	0.034269	0.055178	0.084290	0.133523	0.206000	0.324284	0.488363	1
1986	0.008313	0.011727	0.020665	0.033346	0.054011	0.083035	0.131978	0.202652	0.318904	0.480863	1
1987	0.008082	0.011442	0.020083	0.032384	0.052725	0.081574	0.130159	0.199121	0.312454	0.471160	1
1988	0.007857	0.011170	0.019553	0.031456	0.051471	0.080191	0.128592	0.196493	0.307090	0.461920	1
1989	0.007657	0.010943	0.019138	0.030674	0.050405	0.079107	0.127584	0.195154	0.303482	0.455164	1
1990	0.007525	0.010810	0.018938	0.030225	0.049845	0.078811	0.128044	0.196524	0.304204	0.453999	1
1991	0.007375	0.010660	0.018738	0.029817	0.049329	0.078634	0.129051	0.199506	0.308490	0.460423	1
1992	0.007007	0.010200	0.017988	0.028504	0.047130	0.075508	0.124735	0.193633	0.298428	0.444335	1
1993	0.006715	0.009848	0.017436	0.027542	0.045421	0.073077	0.121472	0.189395	0.291297	0.430768	1
1994	0.006533	0.009645	0.017170	0.027114	0.044589	0.072107	0.120866	0.189923	0.292922	0.433513	1
1995	0.006269	0.009305	0.016641	0.026293	0.043021	0.069736	0.117608	0.185923	0.287313	0.425262	1
1996	0.006147	0.009155	0.016477	0.026112	0.042555	0.069122	0.117362	0.187075	0.290538	0.430191	1
1997	0.005970	0.008884	0.016104	0.025604	0.041584	0.067527	0.115311	0.185198	0.289239	0.430032	1
1998	0.005786	0.008566	0.015634	0.024930	0.040353	0.065291	0.111857	0.180653	0.283180	0.422413	1
1999	0.005752	0.008421	0.015488	0.024859	0.040270	0.065086	0.112276	0.183158	0.290347	0.436499	1
2000	0.005588	0.008172	0.015109	0.024350	0.039465	0.063419	0.109569	0.179740	0.286549	0.432584	1
2001	0.005316	0.007764	0.014395	0.023272	0.037748	0.060213	0.103804	0.170780	0.273263	0.413149	1
2002	0.005203	0.007606	0.014091	0.022936	0.037323	0.059324	0.102213	0.169018	0.272677	0.414308	1
2003	0.005090	0.007478	0.013778	0.022593	0.036916	0.058534	0.100639	0.167158	0.271828	0.415875	1
2004	0.004964	0.007389	0.013470	0.022234	0.036510	0.057836	0.099092	0.165171	0.270662	0.419542	1
2005	0.004914	0.007225	0.013156	0.021830	0.036024	0.057122	0.097415	0.162737	0.268453	0.416113	1
2006	0.004837	0.007039	0.012794	0.021299	0.035359	0.056234	0.095548	0.159873	0.265473	0.415023	1
2007	0.004820	0.006946	0.012628	0.021001	0.035092	0.055962	0.094709	0.158272	0.263911	0.415041	1
2008	0.004844	0.006899	0.012545	0.020712	0.034823	0.055687	0.093914	0.156529	0.262044	0.415762	1
2009	0.004711	0.006643	0.012296	0.020133	0.034117	0.054902	0.092656	0.154073	0.258963	0.412612	1
2010	0.004668	0.006599	0.012071	0.019726	0.033598	0.054328	0.091787	0.151992	0.256062	0.409368	1
2011	0.004610	0.006527	0.011825	0.019288	0.032950	0.053582	0.090770	0.149732	0.252517	0.405612	1
2012	0.004555	0.006462	0.011582	0.018907	0.032257	0.052789	0.089679	0.147431	0.248386	0.399128	1
2013	0.004505	0.006394	0.011345	0.018625	0.031601	0.052096	0.088886	0.145896	0.245474	0.394961	1
2014	0.004450	0.006317	0.011061	0.018421	0.030925	0.051291	0.087941	0.144258	0.242014	0.389196	1
2015	0.004389	0.006249	0.010973	0.018040	0.030271	0.050445	0.086935	0.142796	0.238688	0.384069	1
2016	0.004329	0.006197	0.010898	0.017715	0.029693	0.049591	0.085919	0.141451	0.235547	0.378451	1
2017	0.004365	0.006285	0.011072	0.017778	0.029810	0.049639	0.086349	0.142277	0.235528	0.376407	1
2018	0.004170	0.006050	0.010665	0.016969	0.028628	0.047460	0.083286	0.138055	0.228859	0.365922	1

2019	0.004085	0.005984	0.010552	0.016581	0.028366	0.046557	0.082216	0.137041	0.227301	0.363110	1
2020	0.004019	0.005957	0.010533	0.016595	0.028164	0.046502	0.082567	0.137366	0.226793	0.361067	1
2021	0.003906	0.005869	0.010440	0.016598	0.028160	0.046617	0.082413	0.137320	0.226379	0.359748	1
2022	0.003859	0.005637	0.009943	0.015625	0.026589	0.044074	0.078578	0.132041	0.221023	0.358320	1
2023	0.003781	0.005526	0.009737	0.015321	0.026038	0.043295	0.077384	0.130525	0.218988	0.356128	1
2024	0.003704	0.005414	0.009530	0.015015	0.025514	0.042491	0.076203	0.129013	0.216969	0.353872	1
2025	0.003628	0.005304	0.009328	0.014714	0.025020	0.041698	0.075045	0.127523	0.214935	0.351654	1
2026	0.003553	0.005197	0.009130	0.014416	0.024543	0.040912	0.073888	0.125983	0.212843	0.349202	1
2027	0.003479	0.005091	0.008935	0.014120	0.024075	0.040132	0.072769	0.124436	0.210948	0.346991	1
2028	0.003408	0.004989	0.008747	0.013835	0.023629	0.039401	0.071684	0.122940	0.209204	0.344937	1
2029	0.003336	0.004887	0.008560	0.013550	0.023183	0.038704	0.070573	0.121468	0.207449	0.342884	1
2030	0.003265	0.004785	0.008373	0.013264	0.022729	0.038015	0.069408	0.119895	0.205471	0.340438	1
2031	0.003196	0.004687	0.008195	0.012992	0.022293	0.037372	0.068300	0.118409	0.203594	0.338283	1
2032	0.003127	0.004587	0.008015	0.012716	0.021850	0.036722	0.067175	0.116925	0.201623	0.336221	1
2033	0.003059	0.004489	0.007839	0.012446	0.021416	0.036088	0.066088	0.115419	0.199593	0.334066	1
2034	0.002993	0.004395	0.007669	0.012185	0.020991	0.035464	0.065056	0.113883	0.197613	0.331968	1
2035	0.002928	0.004301	0.007499	0.011927	0.020572	0.034848	0.064077	0.112382	0.195712	0.329951	1
2036	0.002864	0.004207	0.007331	0.011671	0.020158	0.034229	0.063112	0.110872	0.193783	0.327828	1
2037	0.002802	0.004117	0.007168	0.011425	0.019756	0.033626	0.062170	0.109368	0.191861	0.325479	1
2038	0.002742	0.004028	0.007008	0.011184	0.019365	0.033036	0.061262	0.107960	0.190036	0.323428	1
2039	0.002682	0.003941	0.006852	0.010947	0.018980	0.032452	0.060353	0.106585	0.188053	0.321185	1
2040	0.002624	0.003856	0.006698	0.010714	0.018601	0.031877	0.059454	0.105282	0.186125	0.319113	1
2041	0.002568	0.003774	0.006547	0.010483	0.018225	0.031298	0.058526	0.103934	0.184058	0.316738	1
2042	0.002514	0.003693	0.006400	0.010258	0.017857	0.030731	0.057611	0.102609	0.182023	0.314443	1
2043	0.002462	0.003617	0.006260	0.010043	0.017507	0.030186	0.056724	0.101317	0.180060	0.312080	1
2044	0.002409	0.003541	0.006120	0.009828	0.017155	0.029643	0.055843	0.100051	0.178260	0.309823	1
2045	0.002359	0.003467	0.005985	0.009620	0.016815	0.029113	0.054972	0.098761	0.176420	0.307267	1
2046	0.002309	0.003395	0.005852	0.009413	0.016471	0.028578	0.054088	0.097445	0.174591	0.304770	1
2047	0.002265	0.003330	0.005732	0.009225	0.016161	0.028096	0.053287	0.096246	0.172931	0.302499	1
2048	0.002220	0.003266	0.005616	0.009042	0.015857	0.027618	0.052481	0.095008	0.171168	0.300080	1
2049	0.002177	0.003204	0.005501	0.008862	0.015557	0.027148	0.051689	0.093788	0.169421	0.297758	1
2050	0.002133	0.003142	0.005390	0.008688	0.015264	0.026684	0.050903	0.092558	0.167617	0.295409	1

Source: Adapted from United Nations Population Estimates (2022), Tables "WPP2022_Life_Table_Abridged_Medium_1950-2021.csv" and "WPP2022_Life_Table_Abridged_Medium_2022-2100.csv". https://population.un.org/wpp/Download/Standard/CSV/

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Figure S1

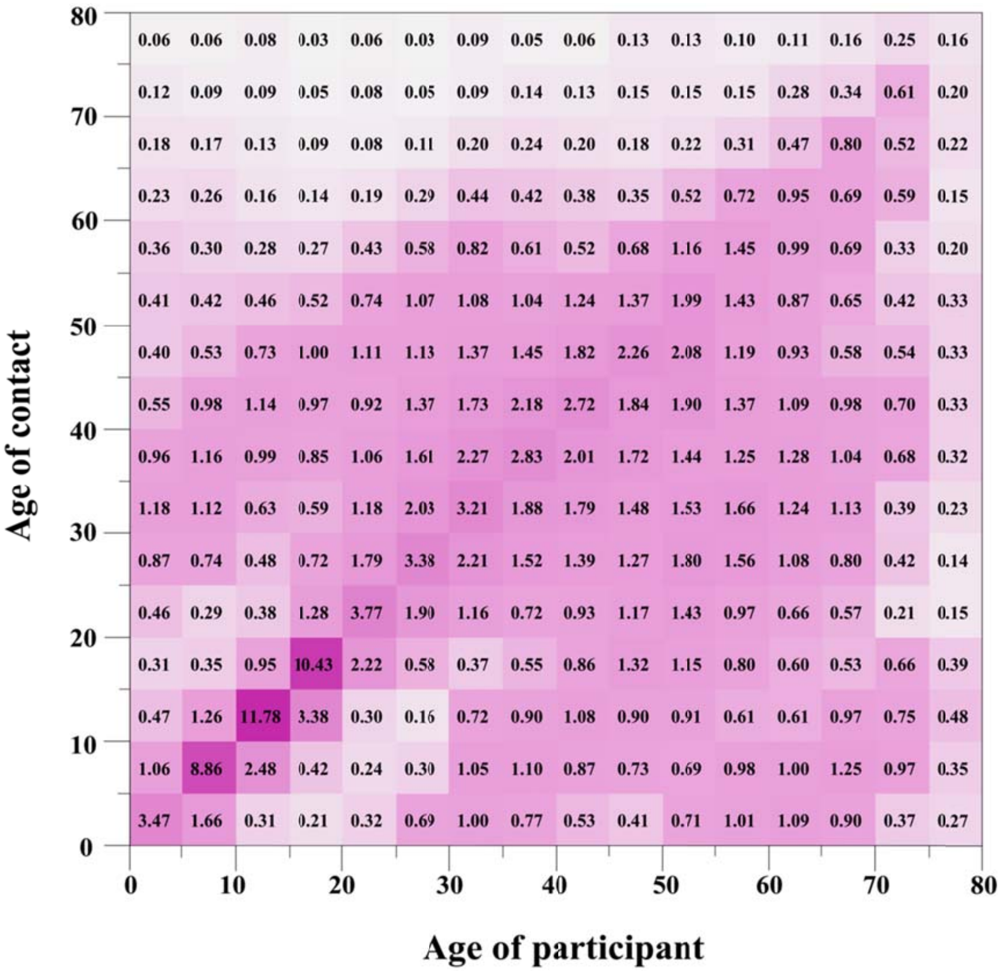

Figure S1. Daily number of respiratory contacts by age group in China.
Source: Adapted from the projected contact matrix reported by Prem K (2021),[7] which was based on three studies in Guangdong,[4] Hong Kong[5] and Shanghai[6] China respectively.

Table S6. Case detection rate (CDR) and treatment success rate (TSR) for tuberculosis in China.

Year	CDR (%) WHO estimates[a]	TSR (%) WHO estimates[b]	Year	CDR (%) smoothed[c]	Year	CDR (%) smoothed[c]
1990	21	NA	1990	39	2022	77
1991	20	NA	1991	41	2023	78
1992	19	NA	1992	42	2024	79
1993	21	NA	1993	43	2025	79
1994	22	91	1994	45	2026	80
1995	32	93	1995	46	2027	80
1996	32	94	1996	48	2028	81
1997	31	95	1997	49	2029	81
1998	30	95	1998	51	2030	82
1999	31	95	1999	52	2031	82
2000	33	93	2000	54	2032	83
2001	36	95	2001	55	2033	83
2002	36	92	2002	56	2034	83
2003	49	93	2003	58	2035	84
2004	66	92	2004	59	2036	84
2005	76	92	2005	61	2037	84
2006	82	92	2006	62	2038	85
2007	87	93	2007	63	2039	85
2008	89	93	2008	64	2040	85
2009	89	94	2009	65	2041	85
2010	89	95	2010	67	2042	86
2011	89	95	2011	68	2043	86
2012	89	95	2012	69	2044	86
2013	89	95	2013	70	2045	86
2014	88	94	2014	71	2046	86
2015	88	94	2015	72	2047	86
2016	88	93	2016	73	2048	87
2017	88	93	2017	74	2049	87
2018	92	94	2018	74	2050	87
2019	88	94	2019	75		
2020	77	95	2020	76		
2021	75	NA	2021	77		

[a,b]Adapted from WHO Tuberculosis Data (2022). Tables “TB_burden_countries_2022-12-01.csv” and “TB_outcomes_2022-12-01.csv”.
https://www.who.int/teams/global-tuberculosis-programme/data

[c]The generalized logistic function was fitted for CDR data to remove artificial noise in the data and derived a smoothed curve over 2000-50. Adapted from Harris RC (2020),[28] supplementary materials Figure 4.

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4. Model calibration and status quo projection

Table S7. Procedure for model calibration.

Element	Specifications
Calibration targets	Demographic targets (see Table S8). Epidemiological targets (see Table S9).
Goodness of fit (GoF) metric	GoF metric served as the objective function for measuring the accuracy of the model's predictions vs. the targets. Mean percentage deviation, not weighted.
Nelder-Mead search algorithm	We used Latin hypercube sampling to draw multiple (e.g. 1000) sets of parameter values from their predefined distributions as the simplexes. With each simplex seeded, the Nelder-Mead search algorithm (using R package "dfoptim"[29]) was applied to produce 1 optimal set of input parameter values which locally minimized the overall GoF metric.
Acceptance criteria	For the input parameter values, only the calibrated parameter sets which best minimize GoF were deemed as acceptable, as we described elsewhere.[30]
Stopping rule	We repeated the same calibration step 1000 times with each simplex seeded and derived 100 best fitting parameter subsets.

Table S8. Demographic calibration targets.

Age (yr) / Year	Population (thousands) estimated by UN				
	All	**0-14**	**15-54**	**55-64**	**65+**
2000	1 259 610	313 187	776 177	84 322	85 924
2020	1 423 998	258 888	820 770	169 103	175 237
2035	1 401 489	154 898	736 292	201 227	309 071
2050	1 316 946	150 752	562 468	210 920	392 806

Source: Adapted from "World Population Prospects 2022: Summary of Results".[31]

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Figure S2

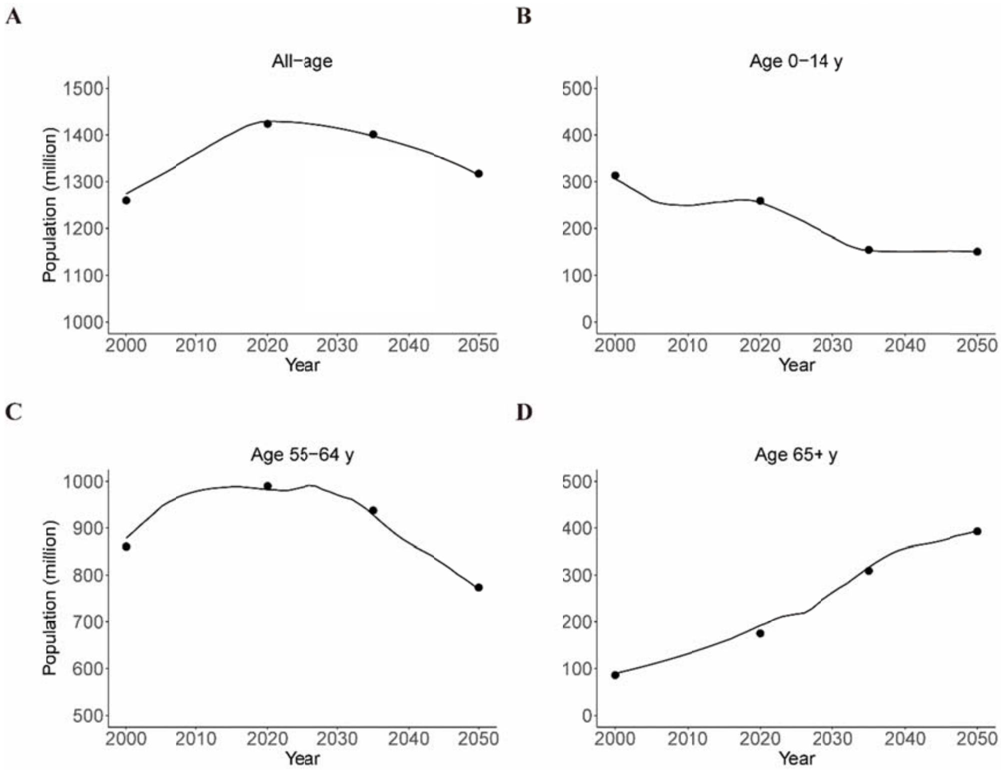

Figure S2. Model calibration and status quo projection of the population in China. (A) the overall population, (B) 0-14 years, (C) 15-64 years, (D) ≥65 years.

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Table S9. Epidemiological calibration targets.

Targets	Microbiologically-positive pulmonary TB prevalence rate (/100,000/yr)[32]				TB incidence rate (/100,000/yr)[33]	TB mortality rate (/100,000/yr)[34]					
Age (yr) / Year	≥15	15-44	45-59	60+	All	All	0-14	15-29	30-44	45-59	60+
2000	178 (163, 195)	106 (91, 123)	213 (174, 260)	596 (510, 698)	/	/	/	/	/	/	/
2005	/	/	/	/	96.9 (77.5, 116.3)	/	/	/	/	/	/
2010	116 (101, 132)	67 (53, 84)	133 (106, 168)	346 (294, 407)	74.3 (59.4, 89.1)	3.37 (3.25, 3.50)	0.29 (0.21, 0.40)	0.88 (0.75, 1.03)	1.77 (1.59, 1.97)	3.24 (2.97, 3.53)	15.7 (14.9, 16.5)
2014	/	/	/	/	65.6 (52.5, 78.8)	/	/	/	/	/	/
2018	/	/	/	/	59.3 (47.4, 71.1)	/	/	/	/	/	/

TB, tuberculosis.

Figure S3

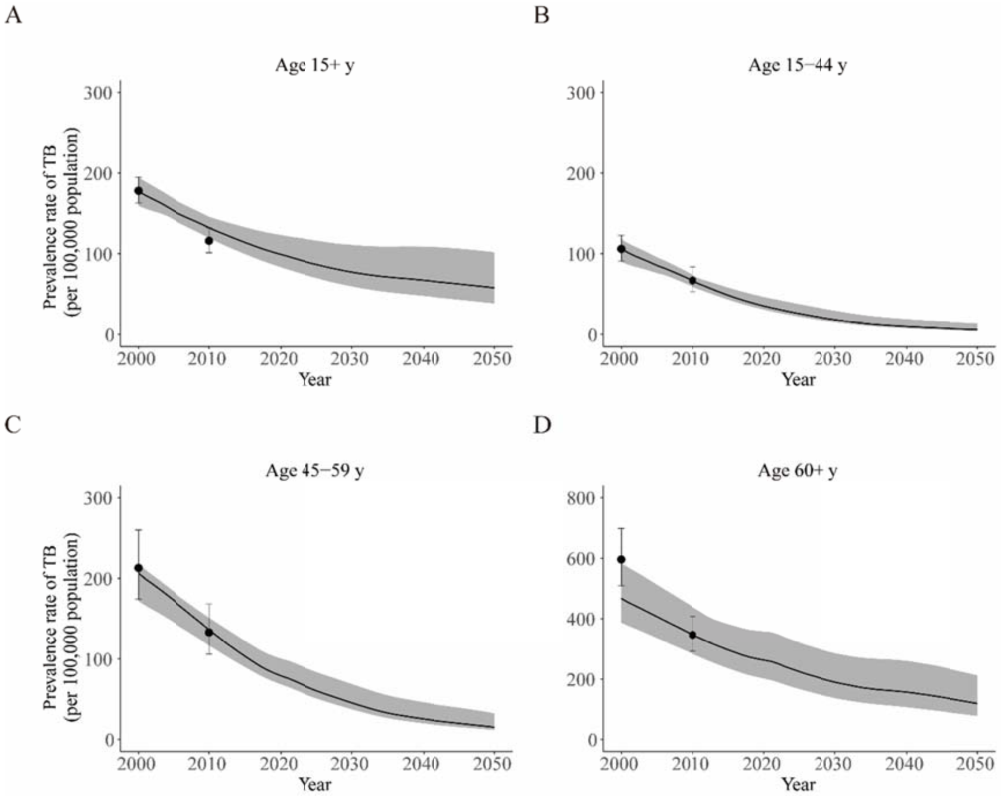

Figure S3. Model calibration and status quo projection of microbiologically-positive tuberculosis (TB) prevalence in China.

(A) the overall ≥15 years older population**,** (B) 15-44 years, (D) 44-59 years, (E) ≥60 years.

Data are presented as median and 95% CI.

Figure S4

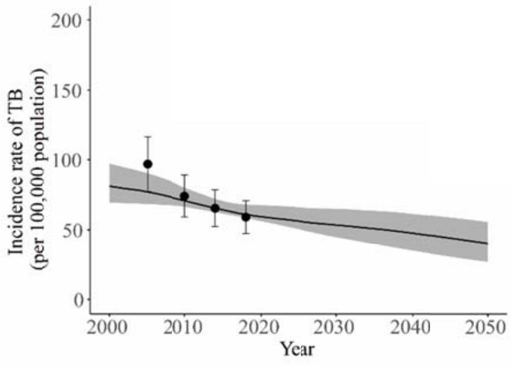

Figure S4. Model calibration and status quo projection of TB incidence in China. Data are presented as median and 95% CI.

Figure S5

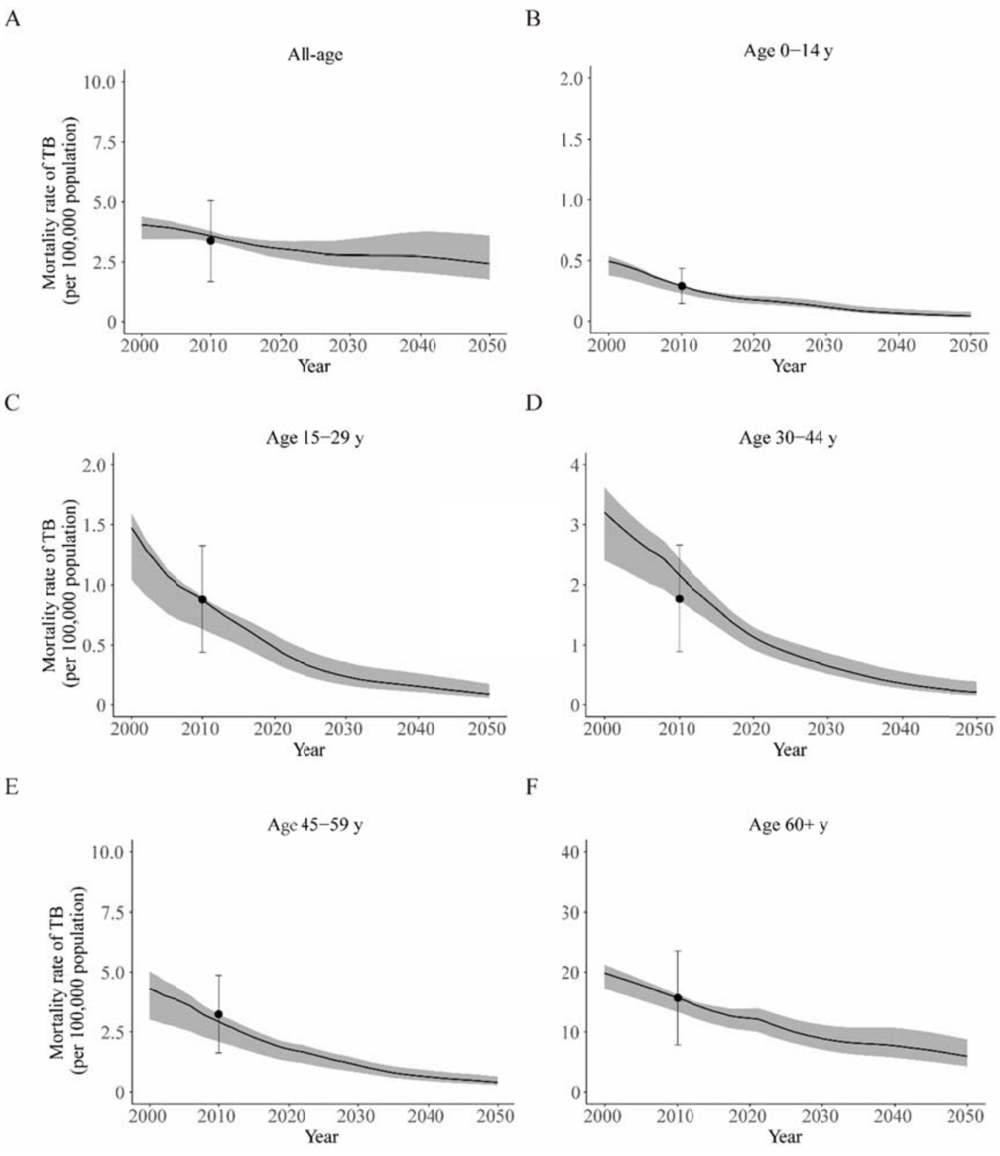

Figure S5. Model calibration and status quo projection of TB-related mortality in China.
(A) the overall population, (B) 0-14 years, (C) 15-29 years, (D) 30-44 years, (E) 45-59 years, (F) ≥60 years.
Data are presented as median and 95% CI.

Figure S6

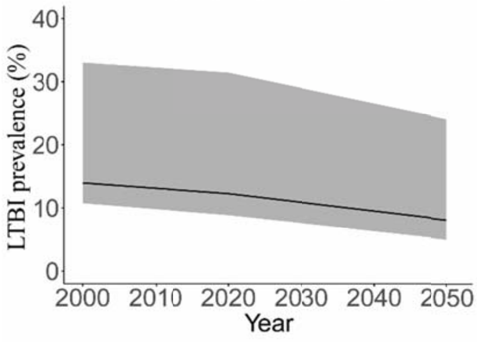

Figure S6. Status quo projection of latent **t**uberculosis infection (LTBI) prevalen**c**e in China. Data are presented as median and 95% CI.

Figure S7

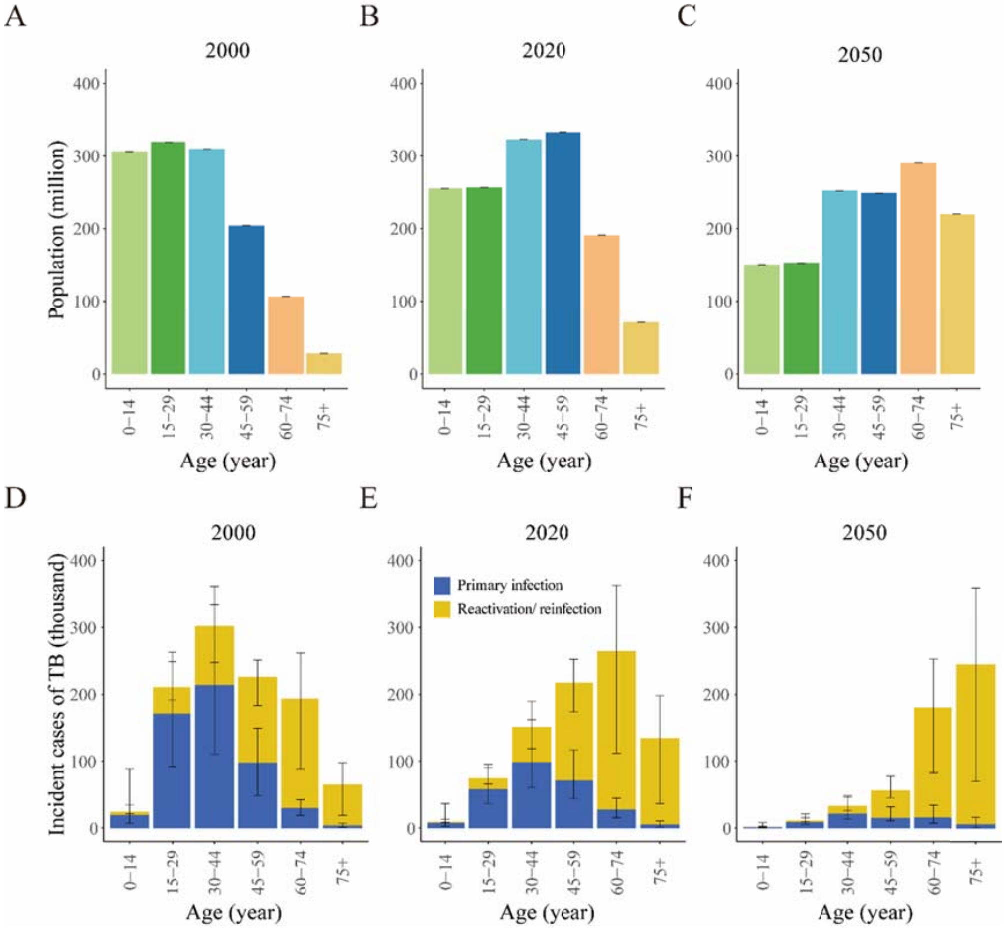

Figure S7. Estimated national population size and incident TB cases by age in China.
(A-C) Estimated China population size by age in 2000, 2020 and 2050. (D-F) Estimated incident cases of TB caused by primary infection or reactivation/reinfection in 2000, 2020 and 2050.
Data are presented as median and 95% CI.

5. Vaccination strategies and epidemiological outcomes

Table S10. Health outcomes for routine vaccination targeting different ages, with PSI efficacy, conferring lifelong protection.

Outcome \ Targeted age	15-year-olds[a]	30-year-olds[b]	45-year-olds[c]	60-year-olds[d]	Kruskal-Wallis H test	
					Chi square	***P***
TB cases averted (million)	0.165 (0.080, 0.494)	1.02 (0.644, 2.18)	5.16 (3.89, 7.87)	8.35 (6.05, 12.2)	368.46	<0.001
(%)	0.366 (0.172, 0.810)	2.21 (1.38, 3.38)	11.4 (9.98, 12.2)	18.4 (13.9, 20.9)	374.05	<0.001
TB-related deaths averted (million)	0.002 (0.001, 0.003)	0.013 (0.009, 0.018)	0.110 (0.092, 0.145)	0.207 (0.172, 0.274)	374.05	<0.001
(%)	0.172 (0.090, 0.291)	1.28 (0.886, 1.58)	10.9 (10.0, 11.8)	20.8 (18.8, 22.5)	374.06	<0.001
TB cases averted per million doses	2158 (898, 5079)	4458 (2195, 8379)	11 471 (5036, 19 410)	13 193 (5902, 22 708)	307.90	<0.001
TB-related deaths averted per million doses	23.5 (10.4, 41.6)	53.7 (28.6, 82.3)	235 (119, 321)	332 (178, 436)	347.34	<0.001

TB, tuberculosis. PSI, postinfection vaccine efficacy.

Tuberculin skin test (TST) with 77.2% sensitivity was applied to screening for latent tuberculosis infection. We assumed that 100% those screened TST positive would accept the vaccine injection. We assumed vaccination coverage to be 90%.

Data are presented as median and 95% CI.

[a]15-y population each year and catch-up 16-29 y population in 2024;

[b]30-y population each year and catch-up 31-44 y population in 2024;

[c]45-y population each year and catch-up 46-59 y population in 2024;

[d]60-y population each year and catch-up 61-74 y population in 2024.

Table S11. Predicted incidence rate and mortality rate reduction in 2050 for government-funded national Vaccae vaccination in China.

Strategy	Incidence rate (per 10^5 population)	IRR (%)	Mortality rate (per 10^5 population)	MRR (%)
No Vaccae	39.96 (30.63, 54.08)	-	2.43 (1.99, 3.37)	-
Vaccae with 10-y protection				
PSI, Older adult routine	35.73 (27.11, 47.94)	10.9 (9.7, 12.6)	2.16 (1.77, 2.95)	11.5 (10.3, 12.7)
P&PI, Older adult routine	33.94 (24.74, 45.08)	15.7 (13.5, 20.0)	2.04 (1.69, 2.71)	16.6 (14.5, 20.2)
PSI, All age campaign	28.85 (21.27, 38.30)	28.3 (26.3, 31.7)	1.77 (1.46, 2.43)	27.1 (25.5, 29.1)
P&PI, All age campaign	22.86 (14.54, 31.25)	42.8 (37.9, 53.9)	1.47 (1.24, 1.94)	39.3 (36.7, 44.1)
Vaccae with 20-y protection				
PSI, Older adult routine	31.35 (24.16, 42.08)	21.7 (19.9, 23.2)	1.80 (1.47, 2.49)	26.3 (24.1, 27.6)
P&PI, Older adult routine	28.11 (20.83, 37.22)	30.3 (27.7, 33.2)	1.55 (1.29, 2.08)	36.4 (33.5, 39.8)
PSI, All age campaign	28.92 (21.36, 38.35)	28.1 (26.1, 31.3)	1.77 (1.45, 2.43)	27.3 (25.5, 29.1)
P&PI, All age campaign	22.89 (14.62, 31.22)	42.7 (37.8, 53.6)	1.46 (1.23, 1.93)	39.9 (37.5, 44.5)
Vaccae with lifelong protection				
PSI, Older adult routine	27.01 (21.40, 36.83)	32.0 (28.2, 34.0)	1.64 (1.35, 2.30)	32.6 (30.1, 34.2)
P&PI, Older adult routine	22.34 (17.60, 30.30)	44.0 (41.0, 45.7)	1.35 (1.11, 1.84)	44.8 (42.2, 47.3)
PSI, All age campaign	26.47 (20.71, 36.04)	33.4 (30.9, 35.4)	1.60 (1.31, 2.25)	34.0 (31.9, 35.5)
P&PI, All age campaign	19.33 (13.44, 26.23)	51.8 (49.2, 56.0)	1.22 (1.00, 1.64)	49.9 (47.7, 52.9)

PSI, postinfection vaccine efficacy; P&PI, both pre- and postinfection vaccine efficacy; IRR, incidence rate reduction; MRR, mortality rate reduction.

Data are presented as median and 95% CI.

Table S12. Predicted number needed to vaccinate (NNV) per case or death averted in China during 2024-2050.

Strategy	Cases averted (thousand)	Deaths averted (thousand)	NNV per case averted	NNV per death averted
Vaccae with 10-y protection				
PSI, Older adult routine	5300 (3971, 7928)	131 (109, 171)	20 (12, 43)	803 (622, 1468)
P&PI, Older adult routine	7608 (5722, 11 287)	185 (154, 256)	91 (61, 121)	3729 (2703, 4500)
PSI, All age campaign	9208 (7032, 13 814)	206 (172, 267)	29 (18, 66)	1337 (1009, 2637)
P&PI, All age campaign	14 155 (11 081, 22 183)	302 (253, 407)	207 (132, 265)	9698 (7196, 11 555)
Vaccae with 20-y protection				
PSI, Older adult routine	8009 (5820, 11 756)	199 (166, 264)	13 (8, 29)	522 (399, 968)
P&PI, Older adult routine	11 267 (8276, 16 536)	280 (233, 377)	61 (42, 84)	2469 (1833, 2968)
PSI, All age campaign	9737 (7398, 14 397)	220 (184, 283)	19 (11, 42)	823 (615, 1632)
P&PI, All age campaign	14 927 (11 652, 22 966)	323 (273, 431)	129 (84, 165)	5948 (4455, 7017)
Vaccae with lifelong protection				
PSI, Older adult routine	8353 (6045, 12 229)	207 (172, 274)	13 (7, 28)	502 (383, 934)
P&PI, Older adult routine	11 671 (8582, 17 173)	290 (241, 390)	59 (40, 81)	2380 (1772, 2866)
PSI, All age campaign	10 168 (7684, 14 889)	229 (192, 296)	11 (7, 25)	506 (382, 961)
P&PI, All age campaign	15 613 (12 073, 23 846)	337 (286, 448)	64 (42, 83)	2976 (2235, 3506)

PSI, postinfection vaccine efficacy; P&PI, both pre- and postinfection vaccine efficacy.

Data are presented as median and 95% CI.

6. Costs and cost-effectiveness analyses

Table S13. Unit cost parameters.

Unit cost	Value (US$)	Range (US$)	Source	Government-funded		Self-paid	
				HCS	SOC	HCS	SOC
Direct costs							
Direct medical costs[a]							
Direct medical costs, self-paid	805.5	465.2-1145.8	[35 36]	✔	✔	✔	✔
Direct medical costs, covered by health insurance	419.1	147.6-690.6	[35 36]	✔	✔	✔	✔
Direct non-medical costs							
Transportation cost	55	±20%	[37]	✘	✔	NA	✔
Accommodation and food	46	±20%	[37]	✘	✔	NA	✔
Nutrition cost	367	±20%	[37]	✘	✔	NA	✔
Indirect costs (productivity loss)							
Patient ≤19 years[b]	12 458	±20%	[38]	NA	✔	NA	✔
Patient 20-59 years[c]	6229	±20%	[38]	NA	✔	NA	✔
Caregiver	79.5	±20%	[39]	NA	✔	NA	✔
Premature death ≤59 years[d]	12 458	±20%	[38]	NA	✔	NA	✔
Vaccination program costs							
TST screening	3.08	2.3-4.3	[40-42]	✔	✔	✔	✔
Vaccine cost, paid by patient	372			NA	NA	✔	✔
Vaccine cost, paid by government	180			✔	✔	NA	NA
Wastage	15%	12%-18%	Assumed	✔	✔	NA	NA
Buffer stock	5%	4%-6%	Assumed	✔	✔	NA	NA
Administrative cost[e]	19.08	±20%	[43]	✔	✔	NA	NA
Delivery cost[f]	2.32	1.60-2.80	[44]	✔	✔	NA	NA
Vaccine campaign cost[g]	1.55	±20%	[45]	✔	✔	NA	NA

Note: Costs are converted to U.S. dollars at the average exchange rate of 1:6.5 in 2021.

HCS, healthcare sector perspective; SOC, societal perspective; TST, tuberculin skin test.

[a]Medical costs of TB diagnosis and treatment, including outpatient and inpatient expenses. Among new cases of tuberculosis, 5.7% patients have multidrug-resistant (MDR) tuberculosis.[36]

[b]Patients younger than 20 years would start working one year late because of their TB-related long-term sick leave. It would lead to productivity losses based on per capita GDP for one year.

[c]Patients older than 20 years would return to work from six months' TB-related sick leave. It would lead to productivity losses based on per capita GDP for a half year.

[d]Lifelong productivity loss due to premature death was calculated by per capita GDP × working years.

[e]Including total cost of administration, regular maintenance, low-value consumables and materials, immunization digital system maintenance.

[f]Assumed delivery costs per person immunised to be the same in mass campaign or routine settings.

[g]Variable cost per vaccinated individual through mass campaigns.

Table S14. Estimated Chinese life expectancy during 2024-50.

Year \ Age	0	1-4	5-9	10-14	15-19	20-24	25-29-	30-34	35-39	40-44	45-49
2024	78.9932	78.4306	74.5206	69.6048	64.6999	59.8128	54.9634	50.1392	45.3161	40.5043	35.7734
2025	79.1949	78.6196	74.7069	69.7886	64.8810	59.9911	55.1383	50.3104	45.4840	40.6690	35.9337
2026	79.3961	78.8087	74.8935	69.9728	65.0625	60.1700	55.3139	50.4824	45.6527	40.8345	36.0949
2027	79.5962	78.9968	75.0792	70.1561	65.2432	60.3479	55.4886	50.6536	45.8205	40.9992	36.2552
2028	79.7894	79.1786	75.2586	70.3333	65.4179	60.5200	55.6576	50.8190	45.9828	41.1585	36.4102
2029	79.9842	79.3619	75.4396	70.5120	65.5941	60.6936	55.8280	50.9859	46.1465	41.3191	36.5666
2030	80.1834	79.5504	75.6258	70.6961	65.7757	60.8727	56.0040	51.1584	46.3157	41.4852	36.7285
2031	80.3747	79.7316	75.8049	70.8731	65.9504	61.0450	56.1733	51.3243	46.4786	41.6451	36.8843
2032	80.5704	79.9172	75.9884	71.0545	66.1294	61.2216	56.3468	51.4945	46.6455	41.8090	37.0441
2033	80.7636	80.1009	76.1701	71.2343	66.3070	61.3968	56.5190	51.6634	46.8113	41.9718	37.2028
2034	80.9540	80.2823	76.3496	71.4119	66.4825	61.5700	56.6893	51.8304	46.9754	42.1329	37.3598
2035	81.1433	80.4625	76.5279	71.5884	66.6568	61.7420	56.8586	51.9964	47.1383	42.2929	37.5159
2036	81.3332	80.6437	76.7073	71.7660	66.8323	61.9153	57.0290	52.1637	47.3026	42.4543	37.6732
2037	81.5198	80.8223	76.8842	71.9412	67.0055	62.0863	57.1973	52.3289	47.4649	42.6137	37.8287
2038	81.7027	80.9972	77.0574	72.1127	67.1751	62.2539	57.3622	52.4907	47.6238	42.7698	37.9809
2039	81.8853	81.1722	77.2309	72.2846	67.3451	62.4219	57.5276	52.6532	47.7834	42.9266	38.1339
2040	82.0665	81.3460	77.4030	72.4552	67.5139	62.5887	57.6918	52.8145	47.9420	43.0823	38.2858
2041	82.2462	81.5205	77.5762	72.6269	67.6840	62.7569	57.8577	52.9775	48.1024	43.2401	38.4399
2042	82.4254	81.6935	77.7479	72.7973	67.8527	62.9238	58.0223	53.1394	48.2617	43.3968	38.5930
2043	82.5988	81.8612	77.9142	72.9623	68.0162	63.0857	58.1819	53.2965	48.4163	43.5489	38.7416
2044	82.7735	82.0299	78.0817	73.1285	68.1809	63.2486	58.3426	53.4546	48.5719	43.7020	38.8912
2045	82.9460	82.1969	78.2475	73.2930	68.3440	63.4101	58.5020	53.6115	48.7264	43.8541	39.0398
2046	83.1196	82.3653	78.4148	73.4591	68.5087	63.5732	58.6630	53.7702	48.8827	44.0081	39.1906
2047	83.2781	82.5193	78.5677	73.6110	68.6593	63.7224	58.8104	53.9154	49.0258	44.1490	39.3285
2048	83.4375	82.6744	78.7219	73.7641	68.8112	63.8730	58.9592	54.0620	49.1704	44.2915	39.4679
2049	83.5961	82.8287	78.8752	73.9165	68.9624	64.0228	59.1072	54.2079	49.3142	44.4332	39.6067
2050	83.7542	82.9828	79.0284	74.0686	69.1134	64.1725	59.2552	54.3539	49.4582	44.5751	39.7456

Year \ Age	50-54	55-59	60-64	65-69	70-74	75-79	80-84	85-89	90-94	95-99	100
2024	31.1382	26.6707	22.3299	18.2895	14.5132	11.1370	8.1710	5.8222	4.0068	2.7111	2.0531
2025	31.2928	26.8171	22.4668	18.4122	14.6196	11.2239	8.2350	5.8653	4.0345	2.7262	2.0612
2026	31.4483	26.9644	22.6046	18.5358	14.7270	11.3125	8.3010	5.9105	4.0637	2.7431	2.0714
2027	31.6030	27.1109	22.7416	18.6587	14.8334	11.4002	8.3657	5.9548	4.0903	2.7584	2.0801
2028	31.7525	27.2526	22.8741	18.7774	14.9360	11.4847	8.4287	5.9975	4.1152	2.7729	2.0883
2029	31.9035	27.3955	23.0077	18.8972	15.0393	11.5694	8.4933	6.0403	4.1405	2.7875	2.0968
2030	32.0598	27.5438	23.1466	19.0220	15.1477	11.6589	8.5633	6.0877	4.1699	2.8051	2.107
2031	32.2103	27.6865	23.2801	19.1421	15.2519	11.7445	8.6306	6.1331	4.1978	2.8207	2.116
2032	32.3647	27.8328	23.4171	19.2654	15.3588	11.8321	8.6994	6.1794	4.2268	2.8359	2.1255
2033	32.5181	27.9784	23.5534	19.3881	15.4655	11.9197	8.7686	6.2273	4.2570	2.8520	2.1364
2034	32.6700	28.1226	23.6885	19.5099	15.5715	12.0068	8.8372	6.2761	4.2869	2.8678	2.1462

2035	32.8209	28.2658	23.8226	19.6306	15.6763	12.0927	8.9042	6.3243	4.3159	2.8832	2.1555
2036	32.9731	28.4104	23.9580	19.7526	15.7825	12.1799	8.9721	6.3737	4.3460	2.8995	2.1648
2037	33.1235	28.5533	24.0920	19.8734	15.8879	12.2668	9.0401	6.4235	4.3768	2.9176	2.1751
2038	33.2708	28.6934	24.2232	19.9916	15.9908	12.3512	9.1055	6.4707	4.4059	2.9334	2.1831
2039	33.4188	28.8341	24.3552	20.1107	16.0948	12.4371	9.1724	6.5194	4.4381	2.9510	2.1931
2040	33.5658	28.9740	24.4864	20.2291	16.1981	12.5221	9.2384	6.5666	4.4696	2.9674	2.202
2041	33.7153	29.1167	24.6208	20.3510	16.3050	12.6110	9.3082	6.6171	4.5041	2.9865	2.213
2042	33.8637	29.2584	24.7543	20.4721	16.4113	12.6996	9.3778	6.6673	4.5382	3.0052	2.2241
2043	34.0079	29.3961	24.8842	20.5902	16.5153	12.7865	9.4465	6.7169	4.5719	3.0247	2.2354
2044	34.1529	29.5346	25.0148	20.7088	16.6194	12.8731	9.5143	6.7651	4.6035	3.0433	2.2447
2045	34.2971	29.6724	25.1449	20.8273	16.7241	12.9608	9.5839	6.8154	4.6372	3.0648	2.2564
2046	34.4435	29.8127	25.2777	20.9487	16.8313	13.0508	9.6553	6.8670	4.6710	3.0860	2.2678
2047	34.5775	29.9410	25.3992	21.0597	16.9296	13.1333	9.7209	6.9144	4.7020	3.1053	2.2782
2048	34.7130	30.0708	25.5222	21.1727	17.0301	13.2184	9.7893	6.9647	4.7354	3.1264	2.2907
2049	34.8479	30.2001	25.6449	21.2853	17.1304	13.3033	9.8575	7.0149	4.7689	3.1473	2.3047
2050	34.9830	30.3296	25.7679	21.3985	17.2315	13.3893	9.9271	7.0667	4.8038	3.1687	2.3194

Source: Adapted from UN World Population Prospects (2022). Table "WPP2022_MORT_F07_1_ABRIDGED_LIFE_TABLE_BOTH_SEXE.csv" https://population.un.org/wpp/Download/Standard/Mortality/

Table S15. Cost-effectiveness for routine vaccination targeting different ages, with PSI vaccine conferring lifelong protection, from healthcare sector perspective.

Outcome \ Targeted age	15-year-olds[a]	30-year-olds[b]	45-year-olds[c]	60-year-olds[d]
DALY averted (million)	0.086	0.457	2.38	3.91
	(0.047, 0.195)	(0.292, 0.766)	(1.99, 3.19)	(3.23, 5.17)
CCA	25 888	9194	2763	1916
	(9738, 53 911)	(4805, 17 979)	(1387, 6670)	(851, 5066)
CDA	2 360 200	742 398	131 348	79 726
	(1 421 450, 4 740 227)	(496 862, 1 329 723)	(84 513, 278 157)	(46 048, 166 641)
ICER (vs. status quo)	46 036	19 990	6093	4234
	(23 974, 96 327)	(12 129, 38 229)	(3363, 13 574)	(2097, 9833)
ICER (vs. next best strategy)	46 036	19 990	6093	1161
	(23 974, 96 327)	(12 129, 38 229)	(3363, 13 574)	(-83, 3339)

PSI, postinfection vaccine efficacy; DALY, disability-adjusted life year; CCA, cost per case averted; CDA, cost per death averted; ICER, incremental cost-effectiveness ratio.

The government contact price of Vaccae was assumed to be US$30 per dose. Coverage 90% and efficacy 54.7%.

[a]15-y populations each year and catch-up 16-29 y populations in 2024;

[b]30-y populations each year and catch-up 31-44 y populations in 2024;

[c]45-y populations each year and catch-up 46-59 y populations in 2024;

[d]60-y populations each year and catch-up 61-74 y populations in 2024.

Data are presented as median and 95% CI.

Table S16. Cost-effectiveness for routine vaccination targeting different ages, with PSI vaccine conferring lifelong protection, from societal perspective.

Outcome \ Targeted age	15-year-olds[a]	30-year-olds[b]	45-year-olds[c]	60-year-olds[d]
DALY averted (million)	0.086	0.457	2.38	3.91
	(0.047, 0.195)	(0.292, 0.766)	(1.99, 3.19)	(3.23, 5.17)
CCA	19 883	5462	1489	1288
	(4577, 47 897)	(1151, 14 660)	(180, 5254)	(229, 4327)
CDA	1 805 691	441 869	68 675	50 796
	(698 362, 4 224 289)	(141 045, 1 059 995)	(10 765, 215 593)	(12 424, 142 094)
ICER (vs. status quo)	34 754	12 158	3214	2723
	(11 541, 85 430)	(3009, 31 122)	(429, 10 550)	(563, 8321)
ICER (vs. next best strategy)	34 754	12 158	1396	1590
	(11 541, 85 430)	(3009, 31 122)	(-580, 5969)	(-346, 5537)

PSI, postinfection vaccine efficacy; DALY, disability-adjusted life year; CCA, cost per case averted; CDA, cost per death averted; ICER, incremental cost-effectiveness ratio.

The government contact price of Vaccae was assumed to be US$30 per dose. Coverage 90% and efficacy 54.7%

[a]15-y populations each year and catch-up 16-29 y populations in 2024;

[b]30-y populations each year and catch-up 31-44 y populations in 2024;

[c]45-y populations each year and catch-up 46-59 y populations in 2024;

[d]60-y populations each year and catch-up 61-74 y populations in 2024.

Data are presented as median and 95% CI.

Table S17. Predicted cost per case averted (CCA) and cost per death averted (CDA) for government-funded national Vaccae vaccination in China during 2024-50.

Strategy	CCA (US$ per case averted)		CDA (US$ per death averted)	
	Healthcare sector perspective	Societal perspective	Healthcare sector perspective	Societal perspective
Vaccae with 10-y protection				
PSI, Older adult routine	3479 (1755, 8061)	2667 (1021, 7117)	141 384 (94 617, 273 569)	106 166 (53 018, 241 756)
PSI, All age campaign	5696 (3295, 12 866)	4434 (2028, 11 283)	261 169 (188 127, 511 966)	197 446 (117 846, 444 729)
P&PI, Older adult routine	16 222 (10 667, 21 855)	15 400 (9653, 20 999)	666 674 (480 296, 807 299)	633 163 (435 756, 772 855)
P&PI, All age campaign	38 050 (23 987, 48 875)	36 352 (22 248, 47 165)	1 786 306 (1 317 462, 2 127 316)	1 701 795 (1 207 116, 2 040 491)
Vaccae with 20-y protection				
PSI, Older adult routine	2022 (915, 5279)	1376 (276, 4516)	83 733 (49 337, 173 388)	54 380 (14 948, 148 331)
PSI, All age campaign	3461 (1832, 8230)	2217 (640, 6738)	154 161 (104 098, 318 118)	95 101 (37 884, 256 750)
P&PI, Older adult routine	10 729 (7067, 14 907)	10 063 (6371, 14 182)	431 977 (313 866, 528 122)	401 246 (279 512, 500 423)
P&PI, All age campaign	23 797 (15 180, 30 735)	22 319 (13 538, 29 044)	1 101 463 (816 362, 1 301 968)	1 023 653 (730 065, 1 223 088)
Vaccae with lifelong protection				
PSI, Older adult routine	1916 (851, 5066)	1288 (229, 4327)	79 726 (46 048, 166 641)	50 796 (12 424, 142 094)
PSI, All age campaign	2300 (1112, 5693)	1085 (-13, 4251)	101 827 (63 003, 217 130)	46 613 (-873, 158 465)
P&PI, Older adult routine	10 337 (6783, 14 356)	9678 (6103, 13 647)	415 691 (303 075, 509 108)	384 653 (268 598, 481 432)
P&PI, All age campaign	14 823 (9429, 19 414)	13 453 (7907, 17 783)	687 647 (503 337, 814 516)	611 575 (429 758, 742 504)

PSI, postinfection vaccine efficacy; P&PI, both pre- and postinfection vaccine efficacy.

Data are presented as median and 95% CI.

Table S18. Cost-effectiveness for government-funded national Vaccae vaccination in China during 2024-50, from societal perspective.

Strategy	TB cases (million)		TB-related deaths (million)		Cost (US$ million)	DALY (million)		
No Vaccae (status quo)	45.59 (34.20, 74.18)		1.02 (0.87, 1.27)		133 712 (98 857, 213 263)	24.50 (20.73, 32.56)		
	TB cases averted		**TB-related deaths averted**		**Incremental cost**	**DALY averted[a]**	**ICER (US$ per DALY averted) relative**	
	n (million)	**%**	**n (million)**	**%**	**(US$ million)**	**(million)**	**to status quo**	**to next best strategy[b]**
Vaccae with 10-y protection								
PSI, Older adult (60-y routine + 61-74 y catch-up)	5.30 (3.97, 7.93)	11.7 (9.4, 12.9)	0.13 (0.11, 0.17)	13.0 (11.9, 14.0)	13 847 (6983, 34 713)	2.79 (2.32, 3.67)	5006 (2206, 12 363)	5007 (2208, 12 364)
P&PI, Older adult (60-y routine + 61-74 y catch-up)	7.61 (5.72, 11.29)	16.6 (14.0, 18.7)	0.19 (0.15, 0.26)	18.3 (17.0, 20.7)	117 395 (110 628, 120 194)	4.01 (3.32, 5.41)	29 215 (20 684, 36 216)	88 875 (48 350, 114 634)
PSI, All age (15-74 y, 10-yearly campaigns)	9.21 (7.03, 13.81)	20.1 (17.8, 21.4)	0.21 (0.17, 0.27)	20.3 (19.0, 21.6)	40 780 (23 942, 100 566)	4.46 (3.81, 5.96)	8844 (4580, 21 382)	15 906 (8272, 34 828)
P&PI, All age ((15-74 y, 10-yearly campaigns)	14.16 (11.08, 22.18)	31.1 (29.2, 33.6)	0.30 (0.25, 0.41)	30.0 (28.3, 32.5)	512 655 (490 891, 522 187)	7.05 (6.01, 9.63)	72 746 (51 390, 86 827)	113 745 (78 934, 142 254)
Vaccae with 20~y protection								
PSI, Older adult (60-y routine + 61-74 y catch-up)	8.01 (5.82, 11.76)	17.7 (13.4, 20.0)	0.20 (0.17, 0.26)	20.0 (18.1, 21.6)	10 986 (2920, 32 096)	3.83 (3.16, 5.04)	2867 (668, 8548)	2868 (669, 8549)
PSI, All age (15-74 y, 20-yearly campaigns)	9.74 (7.40, 14.40)	21.2 (18.4, 22.6)	0.22 (0.18, 0.28)	21.8 (20.2, 23.1)	21 227 (8304, 62 093)	4.63 (3.91, 6.10)	4544 (1519, 12 823)	13 742 (4838, 34 489)
P&PI, Older adult (60-y routine + 61-74 y catch-up)	11.27 (8.28, 16.54)	24.7 (19.9, 27.5)	0.28 (0.23, 0.38)	27.8 (25.7, 30.3)	112 940 (104 547, 117 279)	5.42 (4.44, 7.05)	20 856 (14 578, 26 372)	67 563 (38 753, 85 517)
P&PI, All age (15-74 y, 20-yearly campaigns)	14.93 (11.65, 22.97)	32.7 (30.6, 35.1)	0.32 (0.27, 0.43)	32.0 (30.4, 34.6)	329 527 (308 761, 338 883)	7.29 (6.22, 9.87)	45 505 (31 634, 54 248)	90 904 (59 682, 113 390)
Vaccae with lifelong protection								
PSI, Older adult (60-y routine + 61-74 y catch-up)	8.35 (6.05, 12.23)	18.4 (13.9, 20.9)	0.21 (0.17, 0.27)	20.8 (18.8, 22.5)	10 676 (2523, 31 861)	3.91 (3.23, 5.17)	2723 (563, 8321)	2724 (564, 8322)
PSI, All age (15-74 y, one campaign)	10.20 (7.68, 14.90)	22.0 (18.9, 23.6)	0.23 (0.19, 0.30)	22.8 (21.1, 24.2)	10 403 (-189, 40 783)	4.76 (3.99, 6.22)	2279 (-33, 8136)	1192 (-3699, 10 102)
P&PI, Older adult (60-y routine + 61-74 y catch-up)	11.70 (8.58, 17.20)	25.7 (20.6, 28.6)	0.29 (0.24, 0.39)	28.8 (26.6, 31.5)	112 513 (103 948, 117 002)	5.55 (4.53, 7.20)	20 272 (14 196, 25 752)	132 713 (66 360, 291 444)
P&PI, All age (15-74 y, one campaign)	15.60 (12.1, 23.90)	33.9 (31.6, 36.5)	0.34 (0.29, 0.45)	33.4 (31.7, 36.2)	205 908 (185 311, 215 138)	7.45 (6.34, 10.07)	27 897 (18 728, 33 644)	70 759 (43 035, 91 977)

[a]Strategies were in ascending order of effectiveness; [b] WTP was set at 1 × national pGDP (US$12 458).

TB, tuberculosis. PSI, postinfection vaccine efficacy; P&PI, both pre- and postinfection vaccine efficacy; DALY, disability-adjusted life year.

ICER, incremental cost-effectiveness ratio, was calculated from societal perspective, with government contract price of US$30/dose, and costs and effectiveness discounted with 3% per year.

Data are presented as median and 95% CI.

Figure S8

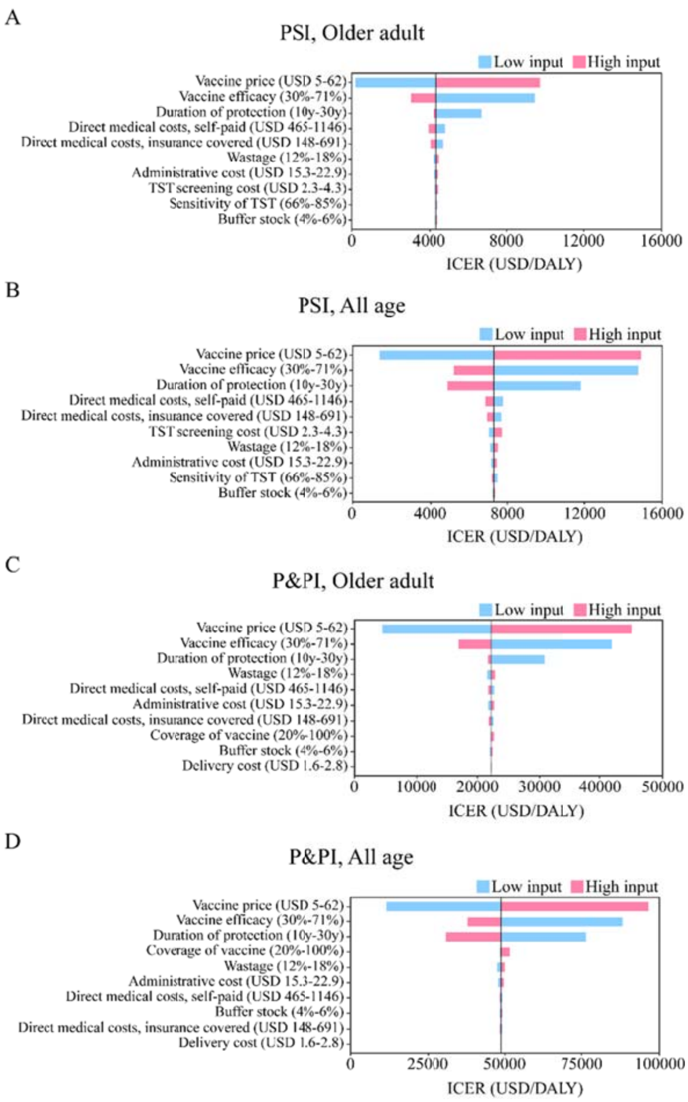

Figure S8. One-way sensitivity analyses compared with status quo, from healthcare sector perspective.

ICER, incremental cost effectiveness ratio; DALY, disability-adjusted life year.

Figure S9

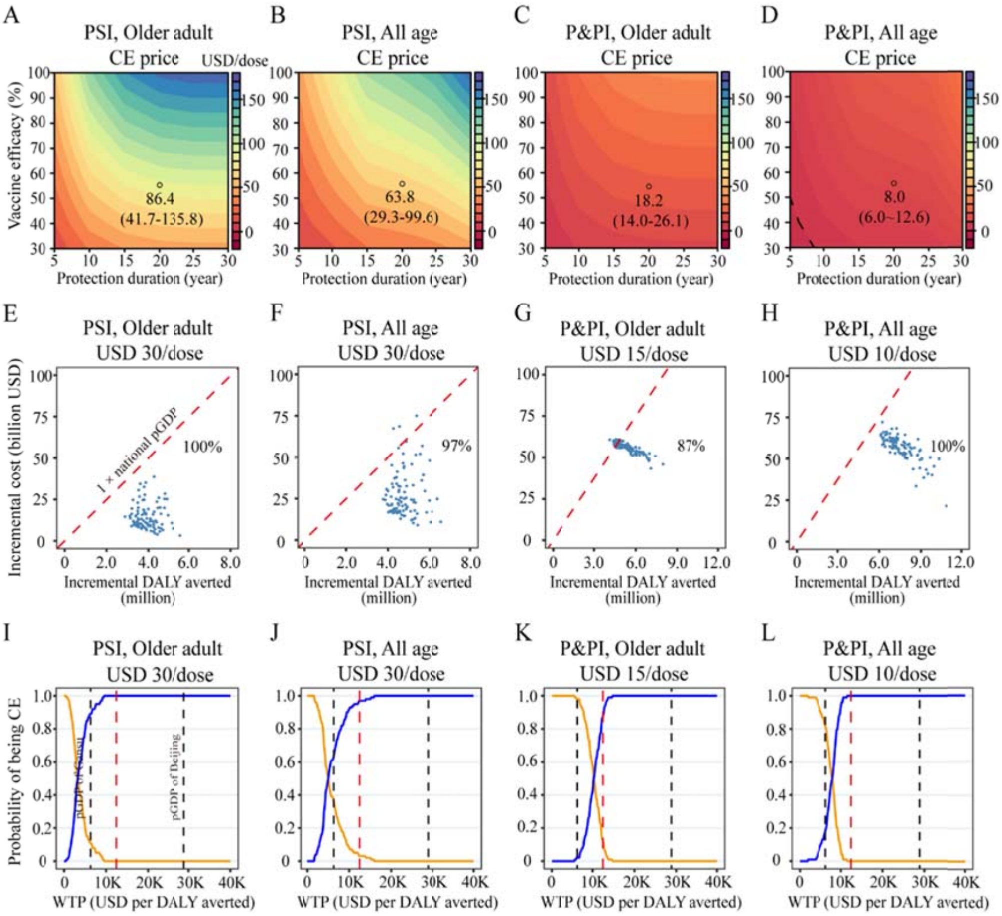

Figure S9. Cost-effectiveness analyses of Vaccae vaccination in China, from societal perspective. (A-D) Contour plots showing the cost-effective vaccine prices that lead to the incremental cost per DALY averted equal to 1 × GDP per capita, for specified vaccine efficacy and protection duration settings. The values below the dashed black line (D) denote that no price would be cost-effective. (E-H) Cost-effectiveness planes for vaccination strategies. (I-L) cost-effectiveness acceptability curves. PSI, postinfection vaccine efficacy; P&PI, both pre- and postinfection vaccine efficacy. CE, cost-effective; DALY, disability-adjusted life year; WTP willingness to pay; P&PI, both pre- and postinfection; K, thousand.

Figure S10

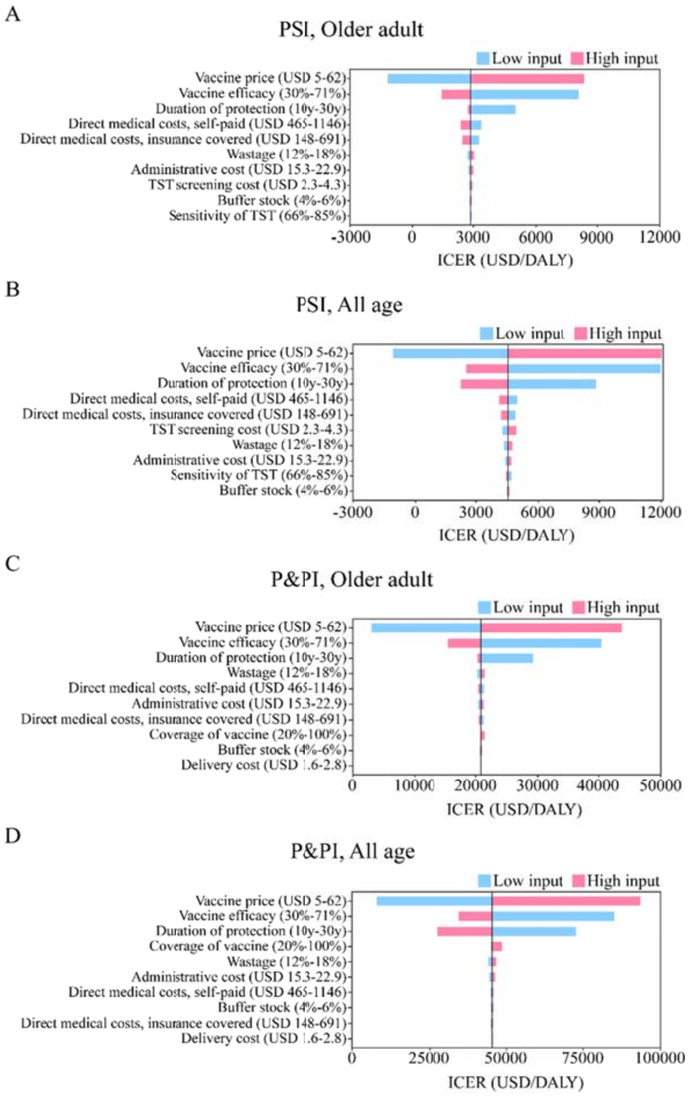

Figure S10. One-way sensitivity analyses compared with status quo, from societal perspective. ICER, incremental cost effectiveness ratio; DALY, disability-adjusted life year.

Figure S11

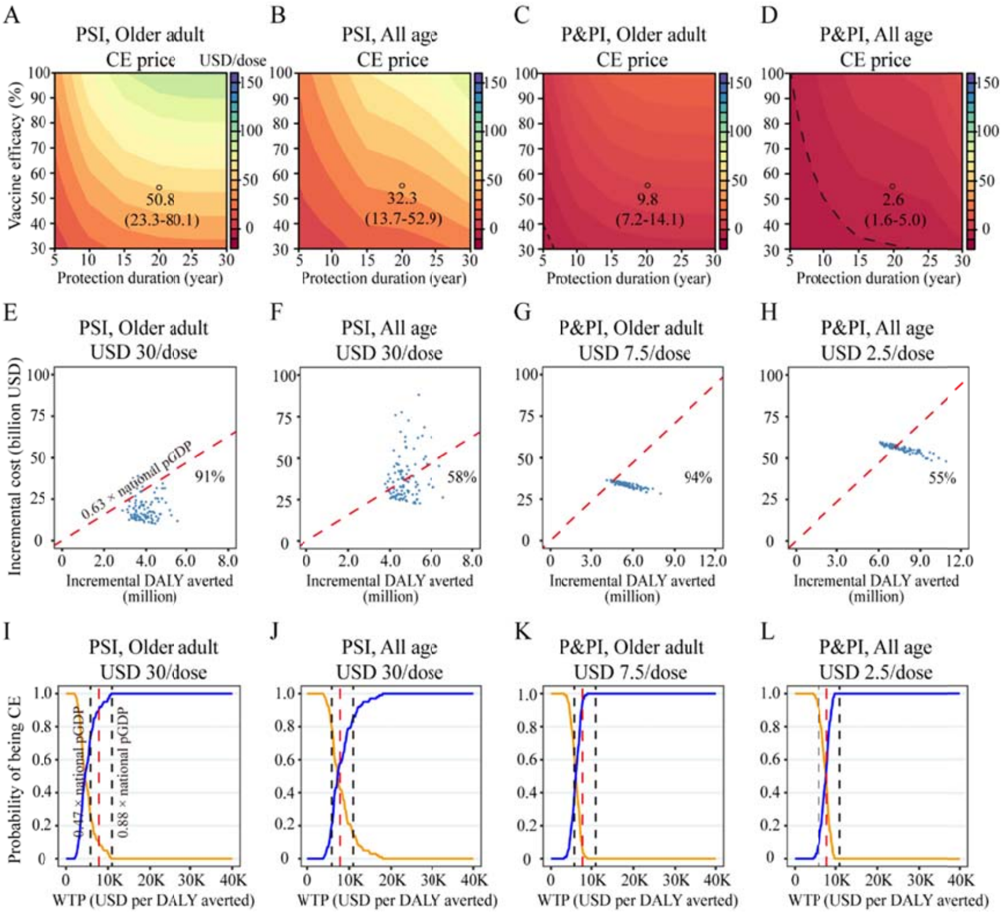

Figure S11. Cost-effectiveness analyses of Vaccae vaccination in China, from healthcare sector perspective (WTP=US$7849).

(A-D) Contour plots showing the cost-effective vaccine prices that lead to the incremental cost per DALY averted equal to 0.63 × GDP per capita, for specified vaccine efficacy and protection duration settings. The values below the dashed black line (D) denote that no price would be cost-effective. (E-H) Cost-effectiveness planes for vaccination strategies. (I-L) cost-effectiveness acceptability curves. PSI, postinfection vaccine efficacy; P&PI, both pre- and postinfection vaccine efficacy. CE, cost-effective; DALY, disability-adjusted life year; WTP willingness to pay; P&PI, both pre- and postinfection; K, thousand.

Figure S12

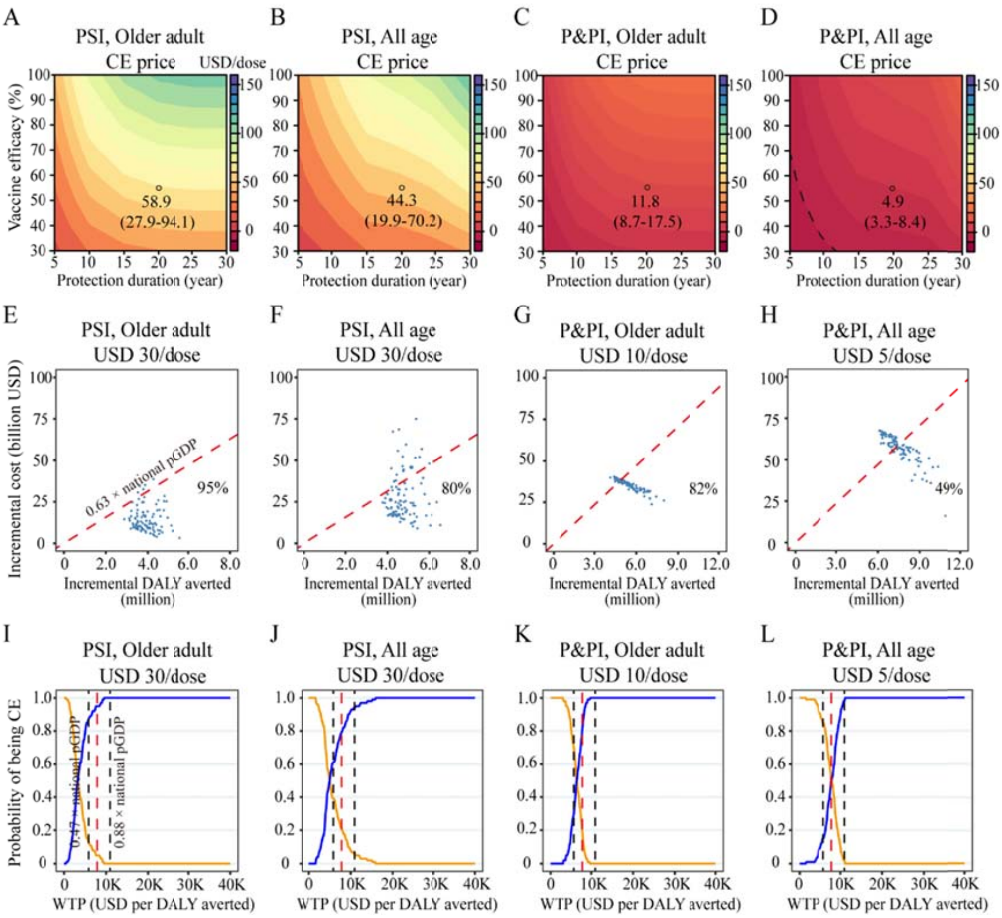

Figure S12. Cost-effectiveness analyses of Vaccae vaccination in China, from societal perspective (WTP=US$7849).

(A-D) Contour plots showing the cost-effective vaccine prices that lead to the incremental cost per DALY averted equal to 0.63 × GDP per capita, for specified vaccine efficacy and protection duration settings. The values below the dashed black line (D) denote that no price would be cost-effective. (E-H) Cost-effectiveness planes for vaccination strategies. (I-L) cost-effectiveness acceptability curves. PSI, postinfection vaccine efficacy; P&PI, both pre- and postinfection vaccine efficacy. CE, cost-effective; DALY, disability-adjusted life year; WTP willingness to pay; P&PI, both pre- and postinfection; K, thousand.

Table S19. Cost-effectiveness for vaccination with Vaccae provided through private market during 2024-50, from healthcare sector perspective.

Strategy	TB cases (million)		TB-related deaths (million)		Cost (US$ million)	DALY (million)		
No Vaccae (status quo)	45.587 (34.195, 74.175)		1.016 (0.869, 1.273)		40 352 (30 942, 64 094)	24.50 (20.73, 32.56)		
	TB cases averted		**TB-related deaths averted**		**Incremental cost**	**DALY averted[a]**	**ICER (US$ per DALY averted) relative**	
	n (million)	**%**	**n (million)**	**%**	**(US$ million)**	**(million)**	**to status quo**	**to next best strategy[b]**
Vaccae with 10-y protection								
PSI, Older adult (60-y routine + 61-74 y catch-up)	1.184 (0.884, 1.767)	2.6 (2.1, 2.9)	0.029 (0.024, 0.038)	2.9 (2.6, 3.1)	6562 (4630, 13 750)	0.62 (0.52, 0.82)	10 826 (6619, 22 011)	10 826 (6619, 22 011)
P&PI, Older adult (60-y routine + 61-74 y catch-up)	1.741 (1.300, 2.568)	3.8 (3.2, 4.3)	0.042 (0.035, 0.060)	4.2 (3.8, 4.8)	42 933 (42 228, 43 320)	0.91 (0.75, 1.25)	47 172 (33 909, 57 520)	132 474 (71 007, 173 982)
PSI, All age (15-74 y, 10-yearly campaigns)	2.056 (1.574, 3.077)	4.5 (4.0, 4.8)	0.046 (0.038, 0.060)	4.5 (4.2, 4.9)	18 166 (13 056, 38 752)	0.99 (0.85, 1.33)	18 116 (11 777, 37 267)	29 799 (20 083, 59 613)
P&PI, All age ((15-74 y, 10-yearly campaigns)	3.350 (2.618, 5.259)	7.4 (6.8, 8.2)	0.070 (0.059, 0.100)	7.0 (6.5, 7.8)	184 233 (182 639, 184 868)	1.68 (1.41, 2.32)	110 063 (78 982, 130 818)	165 285 (114 955, 206 126)
Vaccae with 20-y protection								
PSI, Older adult (60-y routine + 61-74 y catch-up)	1.791 (1.299, 2.620)	3.9 (3.0, 4.5)	0.044 (0.037, 0.059)	4.4 (4.0, 4.8)	6194 (4088, 13 398)	0.85 (0.70, 1.12)	7407 (4234, 16 015)	7407 (4234, 16 015)
PSI, All age (15-74 y, 20-yearly campaigns)	2.171 (1.650, 3.209)	4.7 (4.1, 5.0)	0.049 (0.041, 0.063)	4.9 (4.5, 5.2)	11 797 (8 200, 25 807)	1.03 (0.87, 1.36)	11 534 (7084, 24 422)	31 483 (18 855, 62 172)
P&PI, Older adult (60-y routine + 61-74 y catch-up)	2.557 (1.881, 3.745)	5.6 (4.5, 6.4)	0.063 (0.053, 0.087)	6.3 (5.8, 7.0)	42 360 (41 403, 42 916)	1.23 (1.01, 1.64)	34 405 (25 402, 42 518)	101 586 (55 514, 129 075)
P&PI, All age (15-74 y, 20-yearly campaigns)	3.487 (2.738, 5.414)	7.7 (7.2, 8.5)	0.075 (0.063, 0.104)	7.4 (7.0, 8.3)	121 992 (120 404, 122 620)	1.72 (1.45, 2.36)	71 104 (51 218, 84 245)	132 758 (86 502, 165 164)
Vaccae with lifelong protection								
PSI, Older adult (60-y routine + 61-74 y catch-up)	1.862 (1.349, 2.726)	4.1 (3.1, 4.7)	0.046 (0.038, 0.061)	4.6 (4.2, 5.0)	6156 (4025, 13 363)	0.87 (0.72, 1.15)	7172 (4052, 15 642)	7172 (4052, 15 642)
PSI, All age (15-74 y, one campaign)	2.266 (1.710, 3.314)	4.9 (4.2, 5.3)	0.051 (0.043, 0.066)	5.1 (4.7, 5.4)	8434 (5654, 18 596)	1.06 (0.89, 1.39)	8076 (4730, 17 227)	13 005 (7153, 25 576)
P&PI, Older adult (60-y routine + 61-74 y catch-up)	2.663 (1.950, 3.888)	5.8 (4.7, 6.6)	0.065 (0.055, 0.090)	6.5 (6.0, 7.3)	42 297 (41 317, 42 874)	1.26 (1.03, 1.67)	33 643 (24 901, 41 590)	99 767 (54 639, 126 140)
P&PI, All age (15-74 y, one campaign)	3.625 (2.834, 5.586)	7.9 (7.4, 8.7)	0.078 (0.066, 0.107)	7.7 (7.3, 8.6)	79 989 (78 403, 80 632)	1.75 (1.48, 2.40)	45 884 (32 952, 54 297)	83 140 (52 900, 104 211)

[a]Strategies were in ascending order of effectiveness; [b] WTP was set at 1 × national pGDP (US$12 458).

TB, tuberculosis. PSI, postinfection vaccine efficacy; P&PI, both pre- and postinfection vaccine efficacy. DALY, disability-adjusted life year;

ICER, incremental cost-effectiveness ratio, was calculated from healthcare sector perspective, with government contract price of US$62/dose, coverage 20%, efficacy 54.7%, and costs and effectiveness discounted with 3% per year.

Data are presented as median and 95% CI.

Table S20. Cost-effectiveness for vaccination with Vaccae provided through private market during 2024-50, from societal perspective.

Strategy	TB cases (million)		TB-related deaths (million)		Cost (US$ million)	DALY (million)		
No Vaccae (status quo)	45.587 (34.195, 74.175)		1.016 (0.869-1.273)		133 712 (98 857, 213 263)	24.50 (20.73, 32.56)		
	TB cases averted		**TB-related deaths averted**		**Incremental cost**	**DALY averted[a]**	**ICER (US$ per DALY averted) relative**	
	n (million)	**%**	**n (million)**	**%**	**(US$ million)**	**(million)**	**to status quo**	**to next best strategy[b]**
Vaccae with 10-y protection								
PSI, Older adult (60-y routine + 61-74 y catch-up)	1.184 (0.884, 1.767)	2.6 (2.1, 2.9)	0.029 (0.024, 0.038)	2.9 (2.6, 3.1)	5637 (3511, 12 728)	0.62 (0.52, 0.82)	9239 (4980, 20 279)	9239 (4980, 20 279)
P&PI, Older adult (60-y routine + 61-74 y catch-up)	1.741 (1.300, 2.568)	3.8 (3.2, 4.3)	0.042 (0.035, 0.060)	4.2 (3.8, 4.8)	41 590 (40 046, 42 235)	0.91 (0.75, 1.25)	45 582 (32 221, 56 062)	130 953 (68 809, 172 430)
PSI, All age (15-74 y, 10-yearly campaigns)	2.056 (1.574, 3.077)	4.5 (4.0, 4.8)	0.046 (0.038, 0.060)	4.5 (4.2, 4.9)	15 614 (10 068, 35 859)	0.99 (0.85, 1.33)	15 143 (8 912, 34 072)	26 152 (14 978, 54 281)
P&PI, All age ((15-74 y, 10-yearly campaigns)	3.350 (2.618, 5.259)	7.4 (6.8, 8.2)	0.070 (0.059, 0.100)	7.0 (6.5, 7.8)	177 733 (172 375, 180 092)	1.68 (1.41, 2.32)	106 384 (75 356, 127 448)	160 257 (110 072, 201 494)
Vaccae with 20-y protection								
PSI, Older adult (60-y routine + 61-74 y catch-up)	1.791 (1.299, 2.620)	3.9 (3.0, 4.5)	0.044 (0.037, 0.059)	4.4 (4.0, 4.8)	5009 (2628, 12 143)	0.85 (0.70, 1.12)	6034 (2703, 14 453)	6034 (2703, 14 453)
PSI, All age (15-74 y, 20-yearly campaigns)	2.171 (1.650, 3.209)	4.7 (4.1, 5.0)	0.049 (0.041, 0.063)	4.9 (4.5, 5.2)	9187 (5228, 22 987)	1.03 (0.87, 1.36)	8718 (4400, 21 380)	24 140 (10 832, 54 651)
P&PI, Older adult (60-y routine + 61-74 y catch-up)	2.557 (1.881, 3.745)	5.6 (4.5, 6.4)	0.063 (0.053, 0.087)	6.3 (5.8, 7.0)	40 572 (38 668, 41 556)	1.23 (1.01, 1.64)	32 900 (23 504, 41 173)	100 041 (54 003, 127 654)
P&PI, All age (15-74 y, 20-yearly campaigns)	3.487 (2.738, 5.414)	7.7 (7.2, 8.5)	0.075 (0.063, 0.104)	7.4 (7.0, 8.3)	115 640 (110 519, 117 962)	1.72 (1.45, 2.36)	67 775 (47 775, 81 088)	126 728 (81 371, 159 993)
Vaccae with lifelong protection								
PSI, Older adult (60-y routine + 61-74 y catch-up)	1.862 (1.349, 2.726)	4.1 (3.1, 4.7)	0.046 (0.038, 0.061)	4.6 (4.2, 5.0)	4950 (2539, 12 091)	0.87 (0.72, 1.15)	5823 (2548, 14 113)	5823 (2548, 14 113)
PSI, All age (15-74 y, one campaign)	2.266 (1.710, 3.314)	4.9 (4.2, 5.3)	0.051 (0.043, 0.066)	5.1 (4.7, 5.4)	5608 (2545, 15 793)	1.06 (0.89, 1.39)	5298 (2064, 14 254)	5310 (-809, 18 217)
P&PI, Older adult (60-y routine + 61-74 y catch-up)	2.663 (1.950, 3.888)	5.8 (4.7, 6.6)	0.065 (0.055, 0.090)	6.5 (6.0, 7.3)	40 474 (38 533, 41 494)	1.26 (1.03, 1.67)	32 185 (23 018, 40 252)	182 312 (79 099, 369 943)
P&PI, All age (15-74 y, one campaign)	3.625 (2.834, 5.586)	7.9 (7.4, 8.7)	0.078 (0.066, 0.107)	7.7 (7.3, 8.6)	73 702 (68 627, 75 991)	1.75 (1.48, 2.40)	42 647 (29 351, 51 128)	102 746 (61 233, 131 809)

[a]Strategies were in ascending order of effectiveness; [b] WTP was set at 1 × national pGDP (US$12 458).

TB, tuberculosis. PSI, postinfection vaccine efficacy; P&PI, both pre- and postinfection vaccine efficacy. DALY, disability-adjusted life year; ICER, incremental cost-effectiveness ratio.

ICER, incremental cost-effectiveness ratio, was calculated from societal perspective, with government contract price of US$62/dose, coverage 20%, efficacy 54.7%, and costs and effectiveness discounted with 3% per year.

Data are presented as median and 95% CI.

Table S21. Cost-effectiveness for government-funded national Vaccae vaccination in China during 2024-2100, from healthcare sector perspective.

Strategy	TB cases (million)		TB-related deaths (million)		Cost (US$ million)	DALY (million)		
No Vaccae (status quo)	76.17 (56.03, 124.34)		1.81 (1.49, 2.57)		51 218 (39 381, 82 293)	30.88 (25.80, 42.59)		
	TB cases averted		**TB-related deaths averted**		**Incremental cost (US$ million)**	**DALY averted[a] (million)**	**ICER (US$ per DALY averted) relative**	
	n (million)	**%**	**n (million)**	**%**			**to status quo**	**to next best strategy[b]**
Vaccae with 10-y protection								
PSI, Older adult (60-y routine + 61-74 y catch-up)	9.13 (6.54, 14.43)	11.9 (10.6, 13.0)	0.23 (0.18, 0.35)	12.5 (11.6, 13.7)	19 304 (12 311, 42 765)	3.75 (2.98, 4.98)	5295 (3018, 10 803)	5295 (3018, 10 803)
P&PI, Older adult (60-y routine + 61-74 y catch-up)	13.37 (9.49, 21.23)	17.0 (15.2, 19.8)	0.32 (0.25, 0.53)	17.9 (16.2, 21.2)	160 025 (155 561, 162 340)	5.38 (4.29, 7.80)	29 864 (20 075, 37 750)	90 258 (46 592, 121 236)
PSI, All age (15-74 y, 10-yearly campaigns)	18.18 (13.63, 29.55)	23.9 (22.3, 26.3)	0.43 (0.34, 0.66)	24.1 (22.5, 26.3)	59 428 (41 405, 129 799)	6.53 (5.42, 9.31)	9071 (5824, 17 877)	13 797 (9226, 26 202)
P&PI, All age (15-74 y, 10-yearly campaigns)	28.52 (20.83, 46.83)	37.1 (33.5, 42.2)	0.65 (0.49, 1.04)	35.8 (32.4, 41.0)	741 389 (731 250, 745 372)	10.32 (8.37, 14.75)	71 795 (49 733, 89 069)	110 146 (72 226, 139 828)
Vaccae with 20~y protection								
PSI, Older adult (60-y routine + 61-74 y catch-up)	15.83 (11.15, 24.42)	20.7 (17.0, 22.6)	0.41 (0.32, 0.60)	22.3 (20.7, 24.1)	16 317 (7983, 39 749)	5.62 (4.47, 7.56)	2929 (1271, 6796)	2929 (1271, 6796)
PSI, All age (15-74 y, 20-yearly campaigns)	19.85 (14.55, 31.24)	25.9 (23.6, 27.9)	0.48 (0.38, 0.72)	26.4 (24.9, 28.7)	32 986 (20 613, 77 047)	6.88 (5.64, 9.62)	4854 (2727, 10 259)	13 265 (8216, 23 840)
P&PI, Older adult (60-y routine + 61-74 y catch-up)	22.20 (15.47, 33.99)	28.6 (25.0, 32.2)	0.56 (0.44, 0.88)	31.0 (28.6, 35.0)	155 575 (149 251, 159 315)	7.91 (6.25, 11.04)	19 540 (13 652, 25 431)	64 708 (34 739, 83 182)
P&PI, All age (15-74 y, 20-yearly campaigns)	30.53 (22.54, 49.81)	39.7 (36.7, 44.3)	0.71 (0.54, 1.11)	39.2 (36.1, 44.0)	426 086 (415 732, 430 257)	10.75 (8.74, 15.40)	39 636 (27 247, 49 150)	79 546 (49 625, 102 675)
Vaccae with lifelong protection								
PSI, Older adult (60-y routine + 61-74 y catch-up)	19.19 (13.66, 29.74)	25.4 (20.4, 27.8)	0.50 (0.39, 0.74)	27.6 (25.3, 29.7)	14 866 (6280, 38 627)	6.20 (4.94, 8.40)	2443 (897, 6014)	2443 (897, 6014)
PSI, All age (15-74 y, one campaign)	20.00 (14.33, 29.89)	25.8 (22.6, 27.4)	0.48 (0.38, 0.69)	26.6 (24.6, 28.2)	19 837 (9708, 49 676)	6.88 (5.66, 9.33)	2902 (1248, 6747)	7608 (3233, 22 857)
P&PI, Older adult (60-y routine + 61-74 y catch-up)	26.97 (18.72, 40.56)	34.7 (29.4, 38.9)	0.68 (0.53, 1.06)	37.8 (35.2, 41.7)	154 000 (146 780, 158 189)	8.77 (6.86, 12.02)	17 529 (12 390, 22 988)	77 414 (40 126, 128 296)
P&PI, All age (15-74 y, one campaign)	31.42 (23.36, 50.85)	41.0 (38.6, 44.3)	0.75 (0.60, 1.15)	41.3 (39.3, 45.1)	225 601 (215 014, 229 941)	10.98 (8.97, 15.54)	20 615 (14 111, 25 691)	51 295 (29 509, 66 179)

[a]Strategies were in ascending order of effectiveness; [b] WTP was set at 1 × national pGDP (US$12 458).

TB, tuberculosis. PSI, post-infection vaccine efficacy; P&PI, both pre- and post-infection vaccine efficacy; DALY, disability-adjusted life year.

ICER, incremental cost-effectiveness ratio, was calculated from healthcare sector perspective, with government contract price of US$30/dose, and costs and effectiveness discounted with 3% per year.

Data are presented as median and 95%CI.

Table S22. Cost-effectiveness for government-funded national Vaccae vaccination in China during 2024-2100, from societal perspective.

Strategy	TB cases (million)		TB-related deaths (million)		Cost (US$ million)	DALY (million)		
No Vaccae (status quo)	76.17 (56.03, 124.34)		1.81 (1.49, 2.57)		156 976 (115 565, 254 394)	30.88 (25.80, 42.59)		
	TB cases averted		**TB-related deaths averted**		**Incremental cost (US$ million)**	**DALY averted[a] (million)**	**ICER (US$ per DALY averted) relative**	
	n (million)	**%**	**n (million)**	**%**			**to status quo**	**to next best strategy[b]**
Vaccae with 10-y protection								
PSI, Older adult (60-y routine + 61-74 y catch-up)	9.13 (6.54, 14.43)	11.9 (10.6, 13.0)	0.23 (0.18, 0.35)	12.5 (11.6, 13.7)	13 052 (5105, 36 279)	3.75 (2.98, 4.98)	3534 (1208, 9014)	3534 (1208, 9014)
P&PI, Older adult (60-y routine + 61-74 y catch-up)	13.37 (9.49, 21.23)	17.0 (15.2, 19.8)	0.32 (0.25, 0.53)	17.9 (16.2, 21.2)	151 774 (142 138, 156 052)	5.38 (4.29, 7.80)	28 283 (18 361, 36 288)	88 559 (44 420, 119 694)
PSI, All age (15-74 y, 10-yearly campaigns)	18.18 (13.63, 29.55)	23.9 (22.3, 26.3)	0.43 (0.34, 0.66)	24.1 (22.5, 26.3)	42 566 (22 749, 112 134)	6.53 (5.42, 9.31)	6452 (3087, 15 023)	10 396 (4965, 22 102)
P&PI, All age ((15-74 y, 10-yearly campaigns)	28.52 (20.83, 46.83)	37.1 (33.5, 42.2)	0.65 (0.49, 1.04)	35.8 (32.4, 41.0)	707 892 (676 638, 721 571)	10.32 (8.37, 14.75)	68 862 (46 913, 86 253)	182 057 (104 150, 245 102)
Vaccae with 20~y protection								
PSI, Older adult (60-y routine + 61-74 y catch-up)	15.83 (11.15, 24.42)	20.7 (17.0, 22.6)	0.41 (0.32, 0.60)	22.3 (20.7, 24.1)	7 713 (-2168, 31 098)	5.62 (4.47, 7.56)	1437 (-337, 5206)	1437 (-337, 5206)
PSI, All age (15-74 y, 20-yearly campaigns)	19.85 (14.55, 31.24)	25.9 (23.6, 27.9)	0.48 (0.38, 0.72)	26.4 (24.9, 28.7)	16 115 (1208, 59 652)	6.88 (5.64, 9.62)	2358 (158, 7554)	7416 (1747, 18 458)
P&PI, Older adult (60-y routine + 61-74 y catch-up)	22.20 (15.47, 33.99)	28.6 (25.0, 32.2)	0.56 (0.44, 0.88)	31.0 (28.6, 35.0)	144 674 (131 268, 150 821)	7.91 (6.25, 11.04)	18 101 (11 870, 24 106)	139 445 (55 287, 339 652)
P&PI, All age (15-74 y, 20-yearly campaigns)	30.53 (22.54, 49.81)	39.7 (36.7, 44.3)	0.71 (0.54, 1.11)	39.2 (36.1, 44.0)	393 428 (363 006, 406 491)	10.75 (8.74, 15.4)	36 815 (24 278, 46 385)	100 031 (56 424, 133 169)
Vaccae with lifelong protection								
PSI, Older adult (60-y routine + 61-74 y catch-up)	19.19 (13.66, 29.74)	25.4 (20.4, 27.8)	0.50 (0.39, 0.74)	27.6 (25.3, 29.7)	5837 (-4808, 29 326)	6.20 (4.94, 8.40)	949 (-672, 4458)	949 (-672, 4458)
PSI, All age (15-74 y, one campaign)	20.00 (14.33, 29.89)	25.8 (22.6, 27.4)	0.48 (0.38, 0.69)	26.6 (24.6, 28.2)	3635 (-9571, 32 916)	6.88 (5.66, 9.33)	562 (-1180, 4269)	-1834 (-6869, 9793)
P&PI, Older adult (60-y routine + 61-74 y catch-up)	26.97 (18.72, 40.56)	34.7 (29.4, 38.9)	0.68 (0.53, 1.06)	37.8 (35.2, 41.7)	141 812 (127 274, 149 072)	8.77 (6.86, 12.02)	16 165 (10 529, 21 685)	78 226 (40 480, 132 363)
P&PI, All age (15-74 y, one campaign)	31.42 (23.36, 50.85)	41.0 (38.6, 44.3)	0.75 (0.60, 1.15)	41.3 (39.3, 45.1)	194 265 (165 984, 206 263)	10.98 (8.97, 15.54)	17 828 (11 103, 22 734)	47 319 (25 913, 62 738)

[a]Strategies were in ascending order of effectiveness; [b] WTP was set at 1 × national pGDP (US$12 458).

TB, tuberculosis. PSI, post-infection vaccine efficacy; P&PI, both pre- and post-infection vaccine efficacy; DALY, disability-adjusted life year.

ICER, incremental cost-effectiveness ratio, was calculated from societal perspective, with government contract price of US$30/dose, and costs and effectiveness discounted with 3% per year.

Data are presented as median and 95% CI.

Table S23. Cost-effectiveness for government-funded national Vaccae vaccination in China during 2024-50, from healthcare sector perspective (WTP=US$7849).

Strategy	**TB cases (million)**		**TB-related deaths (million)**		**Cost (US$ million)**	**DALY (million)**		
No Vaccae (status quo)	45.59 (34.20, 74.18)		1.02 (0.87, 1.27)		40 352 (30 942, 64 094)	24.5 (20.7, 32.6)		
	TB cases averted		**TB-related deaths averted**		**Incremental cost**	**DALY averted[a]**	**ICER (US$ per DALY averted) relative**	
	n (million)	**%**	**n (million)**	**%**	**(US$ million)**	**(million)**	**to status quo**	**to next best strategy[b]**
Vaccae with 10-y protection								
PSI, Older adult (60-y routine + 61-74 y catch-up)	5.30 (3.97, 7.93)	11.7 (9.4, 12.9)	0.13 (0.11, 0.17)	13.0 (11.9, 14.0)	18 305 (12 172, 39 281)	2.79 (2.32, 3.67)	6723 (3829, 14 098)	6723 (3829, 14 098)
P&PI, Older adult (60-y routine + 61-74 y catch-up)	7.61 (5.72, 11.29)	16.6 (14.0, 18.7)	0.19 (0.15, 0.26)	18.3 (17.0, 20.7)	123 403 (120 282, 125 036)	4.01 (3.32, 5.41)	30 797 (22 387, 37 671)	90 458 (50 443, 116 174)
PSI, All age (15-74 y, 10-yearly campaigns)	9.21 (7.03, 13.81)	20.1 (17.8, 21.4)	0.21 (0.17, 0.27)	20.3 (19.0, 21.6)	52 908 (37 527, 113 380)	4.46 (3.81, 5.96)	11 815 (7506, 24 567)	20 135 (13 367, 40 165)
P&PI, All age ((15-74 y, 10-yearly campaigns)	14.16 (11.08, 22.18)	31.1 (29.2, 33.6)	0.30 (0.25, 0.41)	30.0 (28.3, 32.5)	538 652 (532 094, 541 311)	7.05 (6.01, 9.63)	76 430 (55 350, 89 932)	118 681 (84 464, 146 564)
Vaccae with 20-y protection								
PSI, Older adult (60-y routine + 61-74 y catch-up)	8.01 (5.82, 11.76)	17.7 (13.4, 20.0)	0.20 (0.17, 0.26)	20.0 (18.1, 21.6)	16 715 (9539, 37 704)	3.83 (3.16, 5.04)	4387 (2217, 10 085)	4387 (2217, 10 085)
PSI, All age (15-74 y, 20-yearly campaigns)	9.74 (7.40, 14.40)	21.2 (18.4, 22.6)	0.22 (0.18, 0.28)	21.8 (20.2, 23.1)	33 663 (22 432, 74 632)	4.63 (3.91, 6.10)	7315 (4259, 15 860)	21 450 (12 797, 42 019)
P&PI, Older adult (60-y routine + 61-74 y catch-up)	11.27 (8.28, 16.54)	24.7 (19.9, 27.5)	0.28 (0.23, 0.38)	27.8 (25.7, 30.3)	120 883 (116 642, 123 262)	5.42 (4.44, 7.05)	22 205 (16 616, 27 715)	69 036 (40 418, 86 908)
P&PI, All age (15-74 y, 20-yearly campaigns)	14.93 (11.65, 22.97)	32.7 (30.6, 35.1)	0.32 (0.27, 0.43)	32.0 (30.4, 34.6)	355 192 (348 620, 357 923)	7.29 (6.22, 9.87)	48 746 (35 414, 57 384)	96 300 (65 229, 118 322)
Vaccae with lifelong protection								
PSI, Older adult (60-y routine + 61-74 y catch-up)	8.35 (6.05, 12.23)	18.4 (13.9, 20.9)	0.21 (0.17, 0.27)	20.8 (18.8, 22.5)	16 556 (9263, 37 547)	3.91 (3.23, 5.17)	4234 (2097, 9833)	4234 (2097, 9833)
PSI, All age (15-74 y, one campaign)	10.20 (7.68, 14.90)	22.0 (18.9, 23.6)	0.23 (0.19, 0.30)	22.8 (21.1, 24.2)	23 204 (14 279, 53 276)	4.76 (3.99, 6.22)	4933 (2644, 11 071)	8788 (4675, 17 409)
P&PI, Older adult (60-y routine + 61-74 y catch-up)	11.70 (8.58, 17.20)	25.7 (20.6, 28.6)	0.29 (0.24, 0.39)	28.8 (26.6, 31.5)	120 639 (116 258, 123 078)	5.55 (4.53, 7.20)	21 667 (16 207, 27 089)	67 664 (39 862, 85 144)
P&PI, All age (15-74 y, one campaign)	15.60 (12.10, 23.90)	33.9 (31.6, 36.5)	0.34 (0.29, 0.45)	33.4 (31.7, 36.2)	231 423 (224 826, 234 259)	7.45 (6.34, 10.07)	31 091 (22 428, 36 845)	59 694 (39 583, 73 943)

[a]Strategies were in ascending order of effectiveness; [b] WTP was set at 0.63 × national pGDP (US$7849).

TB, tuberculosis. PSI, post-infection vaccine efficacy; P&PI, both pre- and post-infection vaccine efficacy; DALY, disability-adjusted life year.

ICER, incremental cost-effectiveness ratio, was calculated from healthcare sector perspective, with government contract price of US$ 30, and costs and effectiveness discounted with 3% per year. WTP was set at 0.63 × GDP per capita.

Data are presented as median and 95% CI.

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Table S24. Cost-effectiveness for government-funded national Vaccae vaccination in China during 2024-50, from societal perspective (WTP=US$7849).

Strategy	TB cases (million)		TB-related deaths (million)		Cost (US$ million)	DALY (million)		
No Vaccae (status quo)	45.59 (34.20, 74.18)		1.02 (0.87, 1.27)		133 712 (98 857, 213 263)	24.50 (20.73, 32.56)		
	TB cases averted		**TB-related deaths averted**		**Incremental cost (US$ million)**	**DALY averted[a] (million)**	**ICER (US$ per DALY averted) relative**	
	n (million)	**%**	**n (million)**	**%**			**to status quo**	**to next best strategy[b]**
Vaccae with 10-y protection								
PSI, Older adult (60-y routine + 61-74 y catch-up)	5.30 (3.97, 7.93)	11.7 (9.4, 12.9)	0.13 (0.11, 0.17)	13.0 (11.9, 14.0)	13 847 (6983, 34 713)	2.79 (2.32, 3.67)	5006 (2206, 12 363)	5007 (2208, 12 364)
P&PI, Older adult (60-y routine + 61-74 y catch-up)	7.61 (5.72, 11.29)	16.6 (14.0, 18.7)	0.19 (0.15, 0.26)	18.3 (17.0, 20.7)	117 395 (110 628, 120 194)	4.01 (3.32, 5.41)	29 215 (20 684, 36 216)	88 875 (48 350, 114 634)
PSI, All age (15-74 y, 10-yearly campaigns)	9.21 (7.03, 13.81)	20.1 (17.8, 21.4)	0.21 (0.17, 0.27)	20.3 (19.0, 21.6)	40 780 (23 942, 100 566)	4.46 (3.81, 5.96)	8844 (4580, 21 382)	15 906 (8272, 34 828)
P&PI, All age ((15-74 y, 10-yearly campaigns)	14.16 (11.08, 22.18)	31.1 (29.2, 33.6)	0.30 (0.25, 0.41)	30.0 (28.3, 32.5)	512 655 (490 891, 522 187)	7.05 (6.01, 9.63)	72 746 (51 390, 86 827)	113 745 (78 934, 142 254)
Vaccae with 20~y protection								
PSI, Older adult (60-y routine + 61-74 y catch-up)	8.01 (5.82, 11.76)	17.7 (13.4, 20.0)	0.20 (0.17, 0.26)	20.0 (18.1, 21.6)	10 986 (2920, 32 096)	3.83 (3.16, 5.04)	2867 (668, 8548)	2868 (669, 8549)
PSI, All age (15-74 y, 20-yearly campaigns)	9.74 (7.40, 14.40)	21.2 (18.4, 22.6)	0.22 (0.18, 0.28)	21.8 (20.2, 23.1)	21 227 (8304, 62 093)	4.63 (3.91, 6.10)	4544 (1519, 12 823)	13 742 (4838, 34 489)
P&PI, Older adult (60-y routine + 61-74 y catch-up)	11.27 (8.28, 16.54)	24.7 (19.9, 27.5)	0.28 (0.23, 0.38)	27.8 (25.7, 30.3)	112 940 (104 547, 117 279)	5.42 (4.44, 7.05)	20 856 (14 578, 26 372)	67 563 (38 753, 85 517)
P&PI, All age (15-74 y, 20-yearly campaigns)	14.93 (11.65, 22.97)	32.7 (30.6, 35.1)	0.32 (0.27, 0.43)	32.0 (30.4, 34.6)	329 527 (308 761, 338 883)	7.29 (6.22, 9.87)	45 505 (31 634, 54 248)	90 904 (59 682, 113 390)
Vaccae with lifelong protection								
PSI, Older adult (60-y routine + 61-74 y catch-up)	8.35 (6.05, 12.23)	18.4 (13.9, 20.9)	0.21 (0.17, 0.27)	20.8 (18.8, 22.5)	10 676 (2523, 31 861)	3.91 (3.23, 5.17)	2723 (563, 8321)	2724 (564, 8322)
PSI, All age (15-74 y, one campaign)	10.20 (7.68, 14.90)	22.0 (18.9, 23.6)	0.23 (0.19, 0.30)	22.8 (21.1, 24.2)	10 403 (-189, 40 783)	4.76 (3.99, 6.22)	2279 (-33, 8136)	1192 (-3699, 10 102)
P&PI, Older adult (60-y routine + 61-74 y catch-up)	11.70 (8.58, 17.20)	25.7 (20.6, 28.6)	0.29 (0.24, 0.39)	28.8 (26.6, 31.5)	112 513 (103 948, 117 002)	5.55 (4.53, 7.20)	20 272 (14 196, 25 752)	132 713 (66 360, 291 444)
P&PI, All age (15-74 y, one campaign)	15.60 (12.1, 23.90)	33.9 (31.6, 36.5)	0.34 (0.29, 0.45)	33.4 (31.7, 36.2)	205 908 (185 311, 215 138)	7.45 (6.34, 10.07)	27 897 (18 728, 33 644)	70 759 (43 035, 91 977)

[a]Strategies were in ascending order of effectiveness; [b] WTP was set at 0.63 × national pGDP (US$7849).

TB, tuberculosis. PSI, post-infection vaccine efficacy; P&PI, both pre- and post-infection vaccine efficacy; DALY, disability-adjusted life year.

ICER, incremental cost-effectiveness ratio, was calculated from societal perspective, with government contract price of US$30/dose, and costs and effectiveness discounted with 3% per year.
Data are presented as median and 95%CI.

Table S25. Budget impact of Vaccae older adult routine vaccination program in China during 2024-50, with PSI vaccine conferring 10-y protection, from healthcare sector perspective.

Year	Screened population[a] (million)	Vaccinated population (million)	Vaccination program budget[b] (US$ million)	Direct medical costs averted (US$ million)	Net cost[c] (US$ million)
Undiscounted					
2024	216.46 (216.18, 216.63)	40.15 (31.77, 75.75)	10 303 (8277, 18 906)	12.9 (9.03, 19.0)	10 291 (8265, 18 896)
2025	22.12 (22.09, 22.13)	3.50 (2.67, 6.90)	906 (707, 1729)	62.0 (44.0, 91.7)	846 (627, 1677)
2026	21.73 (21.71, 21.74)	3.35 (2.55, 6.67)	870 (677, 1673)	107 (76.9, 160)	768 (538, 1582)
2027	20.65 (20.63, 20.66)	3.11 (2.36, 6.24)	808 (627, 1565)	150 (108, 223)	668 (433, 1436)
2028	23.88 (23.86, 23.89)	3.51 (2.65, 7.09)	914 (706, 1780)	191 (138, 284)	733 (459, 1616)
2029	23.62 (23.60, 23.63)	3.39 (2.55, 6.90)	884 (680, 1732)	231 (165, 342)	659 (381, 1533)
2030	24.36 (24.33, 24.37)	3.41 (2.55, 6.99)	892 (684, 1756)	267 (192, 396)	630 (335, 1524)
2031	23.27 (23.25, 23.28)	3.18 (2.37, 6.56)	834 (637, 1649)	300 (216, 446)	538 (240, 1386)
2032	22.59 (22.57, 22.60)	3.02 (2.23, 6.25)	791 (602, 1573)	331 (240, 491)	465 (164, 1281)
2033	22.08 (22.06, 22.09)	2.88 (2.12, 5.99)	756 (574, 1509)	360 (262, 533)	398 (101, 1191)
2034	20.75 (20.74, 20.76)	2.64 (1.94, 5.52)	694 (525, 1392)	375 (274, 552)	314 (35, 1058)
2035	18.79 (18.77, 18.80)	2.33 (1.70, 4.90)	614 (463, 1236)	353 (261, 523)	255 (-3, 915)
2036	18.07 (18.06, 18.08)	2.18 (1.59, 4.62)	577 (434, 1165)	336 (252, 499)	237 (-5, 856)
2037	16.84 (16.83, 16.85)	1.98 (1.44, 4.21)	525 (393, 1064)	321 (242, 477)	204 (-21, 765)
2038	16.91 (16.90, 16.92)	1.93 (1.40, 4.13)	514 (384, 1045)	307 (230, 456)	207 (-7, 757)
2039	17.89 (17.88, 17.90)	1.99 (1.43, 4.27)	530 (395, 1082)	291 (219, 437)	238 (27, 804)
2040	18.58 (18.57, 18.59)	2.00 (1.44, 4.34)	535 (399, 1099)	279 (209, 418)	258 (51, 830)
2041	19.43 (19.42, 19.44)	2.03 (1.46, 4.43)	545 (406, 1124)	264 (199, 400)	281 (77, 865)
2042	21.04 (21.03, 21.05)	2.13 (1.53, 4.68)	574 (427, 1189)	251 (190, 384)	323 (117, 939)
2043	18.76 (18.75, 18.77)	1.84 (1.32, 4.07)	497 (370, 1035)	239 (180, 369)	257 (76, 795)
2044	19.78 (19.77, 19.79)	1.88 (1.34, 4.18)	509 (379, 1065)	230 (172, 356)	281 (101, 834)
2045	20.86 (20.85, 20.87)	1.92 (1.37, 4.29)	522 (388, 1095)	219 (164, 344)	304 (124, 873)
2046	22.55 (22.53, 22.56)	2.01 (1.42, 4.51)	547 (406, 1153)	210 (156, 333)	340 (156, 939)
2047	23.87 (23.85, 23.88)	2.05 (1.45, 4.65)	562 (417, 1189)	203 (149, 323)	361 (178, 981)
2048	22.87 (22.86, 22.88)	1.90 (1.34, 4.33)	522 (387, 1109)	196 (144, 316)	329 (156, 907)
2049	23.60 (23.59, 23.61)	1.89 (1.33, 4.34)	523 (387, 1113)	190 (139, 309)	334 (164, 916)
2050	24.54 (24.52, 24.54)	1.90 (1.33, 4.37)	526 (389, 1125)	185 (135, 303)	341 (173, 932)
Total	765.87 (765.14, 766.24)	104.39 (78.60, 211.15)	27 353 (21 119, 53 153)	6490 (4863, 9708)	21 040 (13 182, 47 088)
Discounted (3%)					
Total	765.87 (765.14, 766.24)	104.39 (78.60, 211.15)	22 552 (17 554, 43 371)	4436 (3295, 6597)	18 305 (12 172, 39 281)

PSI, postinfection vaccine efficacy. Data are presented as median and 95% CI.

The government contact price of Vaccae was assumed to be US$30 per dose. Coverage 90% and efficacy 54.7%.
Six doses of vaccine required per person, plus buffer stock (5%) and vaccine wastage (15%)
[a]Screening population: 60-74 y olds in 2024, then 60-y olds from 2025 to 2050.
[b]Vaccination program budget = screening cost + vaccine cost + delivery and administrative cost
[c]Net cost (healthcare sector perspective) = vaccination program budget - direct medical costs averted

Mao J-J, et al. BMJ Global Health 2023; 8:e012306. doi: 10.1136/bmjgh-2023-012306

Table S26. Budget impact of Vaccae older adult routine vaccination program in China during 2024-50, with PSI vaccine conferring lifelong protection, from healthcare sector perspective.

Year	Screened population[a] (million)	Vaccinated population (million)	Vaccination program budget[b] (US$ million)	Direct medical costs averted (US$ million)	Net cost[c] (US$ million)
Undiscounted					
2024	216.46 (216.18, 216.63)	40.15 (31.77, 75.75)	10 303 (8277, 18 906)	12.9 (9.03, 19.0)	10 291 (8265, 18 896)
2025	22.12 (22.09, 22.13)	3.49 (2.67, 6.90)	906 (707, 1729)	62.0 (44.0, 91.7)	846 (627, 1677)
2026	21.73 (21.71, 21.74)	3.35 (2.55, 6.67)	870 (677, 1673)	107 (76.9, 160)	768 (538, 1582)
2027	20.65 (20.63, 20.66)	3.11 (2.36, 6.24)	808 (627, 1565)	150 (108, 223)	668 (433, 1436)
2028	23.88 (23.86, 23.89)	3.51 (2.65, 7.09)	914 (706, 1780)	191 (138, 284)	733 (459, 1616)
2029	23.62 (23.60, 23.63)	3.39 (2.55, 6.90)	884 (680, 1732)	231 (165, 342)	659 (381, 1533)
2030	24.36 (24.33, 24.37)	3.41 (2.55, 6.99)	892 (684, 1756)	267 (192, 396)	630 (335, 1524)
2031	23.27 (23.25, 23.28)	3.18 (2.37, 6.56)	834 (637, 1649)	300 (216, 446)	538 (240, 1386)
2032	22.59 (22.57, 22.60)	3.02 (2.23, 6.25)	791 (602, 1573)	331 (240, 491)	465 (164, 1281)
2033	22.08 (22.06, 22.09)	2.88 (2.12, 5.99)	756 (574, 1509)	360 (262, 533)	398 (101, 1191)
2034	20.75 (20.74, 20.76)	2.64 (1.94, 5.52)	694 (525, 1392)	388 (282, 570)	301 (19, 1049)
2035	18.79 (18.77, 18.80)	2.33 (1.70, 4.90)	614 (463, 1236)	412 (300, 605)	205 (-76, 870)
2036	18.07 (18.06, 18.08)	2.18 (1.59, 4.61)	577 (434, 1165)	433 (315, 635)	147 (-133, 779)
2037	16.84 (16.83, 16.85)	1.98 (1.44, 4.21)	524 (393, 1064)	452 (329, 661)	74 (-198, 660)
2038	16.91 (16.90, 16.92)	1.93 (1.40, 4.13)	514 (384, 1045)	469 (341, 684)	49 (-228, 626)
2039	17.89 (17.88, 17.90)	1.99 (1.43, 4.27)	530 (395, 1082)	483 (350, 703)	52 (-234, 650)
2040	18.58 (18.57, 18.59)	2.00 (1.44, 4.33)	535 (399, 1099)	495 (358, 719)	49 (-243, 656)
2041	19.43 (19.42, 19.44)	2.03 (1.46, 4.42)	544 (406, 1123)	504 (364, 732)	51 (-246, 671)
2042	21.04 (21.03, 21.05)	2.13 (1.53, 4.67)	573 (427, 1188)	511 (369, 741)	75 (-231, 730)
2043	18.76 (18.75, 18.77)	1.84 (1.32, 4.06)	497 (370, 1034)	515 (371, 748)	-16 (-294, 571)
2044	19.78 (19.77, 19.79)	1.88 (1.34, 4.17)	509 (378, 1063)	516 (370, 751)	-3 (-285, 598)
2045	20.86 (20.85, 20.87)	1.92 (1.36, 4.28)	521 (387, 1093)	515 (369, 752)	12 (-275, 627)
2046	22.55 (22.53, 22.56)	2.00 (1.42, 4.50)	546 (406, 1151)	513 (367, 752)	45 (-252, 685)
2047	23.87 (23.85, 23.88)	2.05 (1.45, 4.64)	561 (416, 1186)	509 (364, 750)	66 (-236, 722)
2048	22.87 (22.86, 22.88)	1.89 (1.34, 4.32)	521 (386, 1106)	504 (360, 746)	22 (-260, 643)
2049	23.60 (23.59, 23.61)	1.89 (1.33, 4.32)	521 (386, 1110)	500 (355, 742)	27 (-253, 650)
2050	24.54 (24.52, 24.54)	1.89 (1.33, 4.36)	524 (388, 1121)	494 (350, 736)	38 (-242, 664)
Total	765.87 (765.14, 766.24)	104.34 (78.58, 211.06)	27 340 (21 113, 53 131)	10 229 (7403, 14 975)	17 702 (8147, 43 974)
Discounted (3%)					
Total	765.87 (765.14, 766.24)	104.34 (78.58, 211.06)	22 545 (17 550, 43 359)	6508 (4716, 9539)	16 556 (9263, 37 547)

PSI, postinfection vaccine efficacy. Data are presented as median and 95% CI.

The government contact price of Vaccae was assumed to be US$30 per dose. Coverage 90% and efficacy 54.7%.
Six doses of vaccine required per person, plus buffer stock (5%) and vaccine wastage (15%)
[a]Screened population: 60-74 y olds in 2024, then 60-y olds from 2025 to 2050.
[b]Vaccination program budget = screening cost + vaccine cost + delivery and administrative cost
[c]Net cost (healthcare sector perspective) = vaccination program budget - direct medical costs averted

Table S27. Budget impact of Vaccae older adult routine vaccination program in China during 2024-50, with PSI vaccine conferring 10-y protection, from societal perspective.

Year	Screened population[a] (million)	Vaccinated population (million)	Vaccination program budget[b] (US$ million)	Direct and indirect costs averted (US$ million)	Net cost[c] (US$ million)
Undiscounted					
2024	216.46 (216.18, 216.63)	40.15 (31.77, 75.75)	10 303 (8277, 18 906)	18.6 (13.1, 27.5)	10 286 (8258, 18 891)
2025	22.12 (22.09, 22.13)	3.50 (2.67, 6.90)	906 (707, 1,729)	94.6 (67.2, 138)	815 (586, 1649)
2026	21.73 (21.71, 21.74)	3.35 (2.55, 6.67)	870 (677, 1,673)	173 (126, 253)	702 (457, 1522)
2027	20.65 (20.63, 20.66)	3.11 (2.36, 6.24)	808 (627, 1,565)	251 (186, 368)	559 (301, 1340)
2028	23.88 (23.86, 23.89)	3.51 (2.65, 7.09)	914 (706, 1,780)	334 (246, 481)	587 (277, 1481)
2029	23.62 (23.60, 23.63)	3.39 (2.55, 6.90)	884 (680, 1,732)	414 (306, 596)	483 (153, 1360)
2030	24.36 (24.33, 24.37)	3.41 (2.55, 6.99)	892 (684, 1,756)	485 (362, 712)	414 (69, 1313)
2031	23.27 (23.25, 23.28)	3.18 (2.37, 6.56)	834 (637, 1,649)	555 (413, 821)	285 (-67, 1138)
2032	22.59 (22.57, 22.60)	3.02 (2.23, 6.25)	791 (602, 1,573)	620 (460, 922)	180 (-185, 998)
2033	22.08 (22.06, 22.09)	2.88 (2.12, 5.99)	756 (574, 1,509)	681 (503, 1015)	68 (-290, 876)
2034	20.75 (20.74, 20.76)	2.64 (1.94, 5.52)	694 (525, 1,392)	709 (534, 1078)	-29 (-382, 720)
2035	18.79 (18.77, 18.80)	2.33 (1.70, 4.90)	614 (463, 1,236)	692 (529, 1050)	-101 (-439, 568)
2036	18.07 (18.06, 18.08)	2.18 (1.59, 4.62)	577 (434, 1,165)	671 (514, 1019)	-113 (-440, 505)
2037	16.84 (16.83, 16.85)	1.98 (1.44, 4.21)	525 (393, 1,064)	647 (498, 988)	-135 (-451, 414)
2038	16.91 (16.90, 16.92)	1.93 (1.40, 4.13)	514 (384, 1,045)	624 (482, 958)	-126 (-431, 407)
2039	17.89 (17.88, 17.90)	1.99 (1.43, 4.27)	530 (395, 1,082)	603 (465, 928)	-93 (-388, 457)
2040	18.58 (18.57, 18.59)	2.00 (1.44, 4.34)	535 (399, 1,099)	585 (448, 899)	-68 (-354, 488)
2041	19.43 (19.42, 19.44)	2.03 (1.46, 4.43)	545 (406, 1,124)	565 (429, 869)	-39 (-316, 528)
2042	21.04 (21.03, 21.05)	2.13 (1.53, 4.68)	574 (427, 1,189)	544 (411, 840)	6 (-263, 609)
2043	18.76 (18.75, 18.77)	1.84 (1.32, 4.07)	497 (370, 1,035)	527 (393, 811)	-39 (-299, 472)
2044	19.78 (19.77, 19.79)	1.88 (1.34, 4.18)	509 (379, 1,065)	508 (376, 784)	-9 (-260, 518)
2045	20.86 (20.85, 20.87)	1.92 (1.37, 4.29)	522 (388, 1,095)	488 (360, 758)	19 (-222, 564)
2046	22.55 (22.53, 22.56)	2.01 (1.42, 4.51)	547 (406, 1,153)	470 (345, 733)	60 (-174, 639)
2047	23.87 (23.85, 23.88)	2.05 (1.45, 4.65)	562 (417, 1,189)	455 (331, 711)	94 (-139, 690)
2048	22.87 (22.86, 22.88)	1.90 (1.34, 4.33)	522 (387, 1,109)	439 (319, 692)	69 (-151, 623)
2049	23.60 (23.59, 23.61)	1.89 (1.33, 4.34)	523 (387, 1,113)	424 (308, 674)	83 (-132, 640)
2050	24.54 (24.52, 24.54)	1.90 (1.33, 4.37)	526 (389, 1,125)	411 (298, 658)	103 (-111, 664)
Total	765.87 (765.14, 766.24)	104.39 (78.60, 211.15)	27 353 (21 119, 53 153)	12 932 (9895, 19 953)	14 190 (5395, 40 072)
Discounted (3%)					
Total	765.87 (765.14, 766.24)	104.39 (78.60, 211.15)	22 552 (17 554, 43 371)	8690 (6652, 13 365)	13 847 (6983, 34 713)

PSI, postinfection vaccine efficacy. Data are presented as median and 95% CI.
The government contact price of Vaccae was assumed to be US$30 per dose. Coverage 90% and efficacy 54.7%.
Six doses of vaccine required per person, plus buffer stock (5%) and vaccine wastage (15%)
[a]Screened population: 60-74 y olds in 2024, then 60-y olds from 2025 to 2050.
[b]Vaccination program budget = screening cost + vaccine cost + delivery and administrative cost
[c]Net cost (societal perspective) = vaccination program budget - direct and indirect costs averted

Table S28. Budget impact of Vaccae older adult routine vaccination program in China during 2024-50, with PSI vaccine conferring 20-y protection, from societal perspective.

Year	Screened population[a] (million)	Vaccinated population (million)	Vaccination program budget[b] (US$ million)	Direct and indirect costs averted (US$ million)	Net cost[c] (US$ million)
Undiscounted					
2024	216.46 (216.18, 216.63)	40.15 (31.77, 75.75)	10 303 (8277, 18 906)	18.6 (13.1, 27.5)	10 286 (8258, 18 891)
2025	22.12 (22.09, 22.13)	3.49 (2.67, 6.90)	906 (707, 1729)	94.6 (67.2, 138)	815 (586, 1649)
2026	21.73 (21.71, 21.74)	3.35 (2.55, 6.67)	870 (677, 1673)	173 (126, 253)	702 (457, 1522)
2027	20.65 (20.63, 20.66)	3.11 (2.36, 6.24)	808 (627, 1565)	251 (186, 368)	559 (301, 1340)
2028	23.88 (23.86, 23.89)	3.51 (2.65, 7.09)	914 (706, 1780)	334 (246, 481)	587 (277, 1481)
2029	23.62 (23.60, 23.63)	3.39 (2.55, 6.90)	884 (680, 1732)	414 (306, 596)	483 (153, 1360)
2030	24.36 (24.33, 24.37)	3.41 (2.55, 6.99)	892 (684, 1756)	485 (362, 712)	414 (69, 1313)
2031	23.27 (23.25, 23.28)	3.18 (2.37, 6.56)	834 (637, 1649)	555 (413, 821)	285 (-67, 1138)
2032	22.59 (22.57, 22.60)	3.02 (2.23, 6.25)	791 (602, 1573)	620 (460, 922)	180 (-185, 998)
2033	22.08 (22.06, 22.09)	2.88 (2.12, 5.99)	756 (574, 1509)	681 (503, 1015)	68 (-290, 876)
2034	20.75 (20.74, 20.76)	2.64 (1.94, 5.52)	694 (525, 1392)	730 (545, 1100)	-45 (-406, 706)
2035	18.79 (18.77, 18.80)	2.33 (1.70, 4.90)	614 (463, 1236)	773 (582, 1177)	-166 (-549, 502)
2036	18.07 (18.06, 18.08)	2.18 (1.59, 4.61)	577 (434, 1165)	811 (615, 1245)	-239 (-635, 389)
2037	16.84 (16.83, 16.85)	1.98 (1.44, 4.21)	524 (393, 1064)	846 (642, 1301)	-313 (-730, 249)
2038	16.91 (16.90, 16.92)	1.93 (1.40, 4.13)	514 (384, 1045)	878 (662, 1349)	-350 (-786, 199)
2039	17.89 (17.88, 17.90)	1.99 (1.43, 4.27)	530 (395, 1082)	903 (678, 1389)	-358 (-807, 210)
2040	18.58 (18.57, 18.59)	2.00 (1.44, 4.33)	535 (399, 1099)	922 (690, 1420)	-367 (-831, 205)
2041	19.43 (19.42, 19.44)	2.03 (1.46, 4.42)	544 (406, 1123)	933 (698, 1445)	-369 (-844, 212)
2042	21.04 (21.03, 21.05)	2.13 (1.53, 4.67)	573 (427, 1188)	942 (703, 1462)	-351 (-831, 264)
2043	18.76 (18.75, 18.77)	1.84 (1.32, 4.06)	497 (370, 1034)	950 (705, 1474)	-418 (-915, 105)
2044	19.78 (19.77, 19.79)	1.88 (1.34, 4.17)	509 (378, 1063)	948 (698, 1465)	-398 (-893, 136)
2045	20.86 (20.85, 20.87)	1.92 (1.36, 4.28)	521 (387, 1093)	915 (671, 1415)	-352 (-833, 187)
2046	22.55 (22.53, 22.56)	2.00 (1.42, 4.50)	546 (406, 1151)	883 (646, 1368)	-302 (-762, 268)
2047	23.87 (23.85, 23.88)	2.05 (1.45, 4.64)	561 (416, 1186)	851 (622, 1325)	-260 (-705, 326)
2048	22.87 (22.86, 22.88)	1.89 (1.34, 4.32)	521 (386, 1106)	823 (600, 1286)	-269 (-703, 268)
2049	23.60 (23.59, 23.61)	1.89 (1.33, 4.32)	521 (386, 1110)	792 (578, 1248)	-243 (-665, 293)
2050	24.54 (24.52, 24.54)	1.89 (1.33, 4.36)	525 (388, 1121)	765 (557, 1212)	-215 (-624, 325)
Total	765.87 (765.14, 766.24)	104.34 (78.58, 211.06)	27 340 (21 113, 53 132)	18 274 (13 679, 28 250)	9124 (-1807, 35 409)
Discounted (3%)					
Total	765.87 (765.14, 766.24)	104.34 (78.58, 211.06)	22 545 (17 550, 43 359)	11 655 (8788, 18 048)	10 986 (2920, 32 096)

PSI, postinfection vaccine efficacy. Data are presented as median and 95% CI.
The government contact price of Vaccae was assumed to be US$30 per dose. Coverage 90% and efficacy 54.7%.
Six doses of vaccine required per person, plus buffer stock (5%) and vaccine wastage (15%)
[a]Screened population: 60-74 y olds in 2024, then 60-y olds from 2025 to 2050.
[b]Vaccination program budget = screening cost + vaccine cost + delivery and administrative cost
[c]Net cost (societal perspective) = vaccination program budget - direct and indirect costs averted

Table S29. Budget impact of Vaccae older adult routine vaccination program in China during 2024-50, with PSI vaccine conferring lifelong protection, from societal perspective.

Year	Screened population[a] (million)	Vaccinated population (million)	Vaccination program budget[b] (US$ million)	Direct and indirect costs averted (US$ million)	Net cost[c] (US$ million)
Undiscounted					
2024	216.46 (216.18, 216.63)	40.15 (31.77, 75.75)	10 303 (8277, 18 906)	18.6 (13.1, 27.5)	10 286 (8258, 18 891)
2025	22.12 (22.09, 22.13)	3.49 (2.67, 6.90)	906 (707, 1729)	94.6 (67.2, 138)	815 (586, 1649)
2026	21.73 (21.71, 21.74)	3.35 (2.55, 6.67)	870 (677, 1673)	173 (126, 253)	702 (457, 1522)
2027	20.65 (20.63, 20.66)	3.11 (2.36, 6.24)	808 (627, 1565)	251 (186, 368)	559 (301, 1340)
2028	23.88 (23.86, 23.89)	3.51 (2.65, 7.09)	914 (706, 1780)	334 (246, 481)	587 (277, 1481)
2029	23.62 (23.60, 23.63)	3.39 (2.55, 6.90)	884 (680, 1732)	414 (306, 596)	483 (153, 1360)
2030	24.36 (24.33, 24.37)	3.41 (2.55, 6.99)	892 (684, 1756)	485 (362, 712)	414 (69, 1313)
2031	23.27 (23.25, 23.28)	3.18 (2.37, 6.56)	834 (637, 1649)	555 (413, 821)	285 (-67, 1138)
2032	22.59 (22.57, 22.60)	3.02 (2.23, 6.25)	791 (602, 1573)	620 (460, 922)	180 (-185, 998)
2033	22.08 (22.06, 22.09)	2.88 (2.12, 5.99)	756 (574, 1509)	681 (503, 1015)	68 (-290, 876)
2034	20.75 (20.74, 20.76)	2.64 (1.94, 5.52)	694 (525, 1392)	730 (545, 1100)	-45 (-406, 706)
2035	18.79 (18.77, 18.80)	2.33 (1.70, 4.90)	614 (463, 1236)	773 (582, 1177)	-166 (-549, 502)
2036	18.07 (18.06, 18.08)	2.18 (1.59, 4.61)	577 (434, 1165)	811 (615, 1245)	-239 (-635, 389)
2037	16.84 (16.83, 16.85)	1.98 (1.44, 4.21)	524 (393, 1064)	846 (642, 1301)	-313 (-730, 249)
2038	16.91 (16.90, 16.92)	1.93 (1.40, 4.13)	514 (384, 1045)	878 (662, 1349)	-350 (-786, 199)
2039	17.89 (17.88, 17.90)	1.99 (1.43, 4.27)	530 (395, 1082)	903 (678, 1389)	-358 (-807, 210)
2040	18.58 (18.57, 18.59)	2.00 (1.44, 4.33)	535 (399, 1099)	922 (690, 1420)	-367 (-831, 205)
2041	19.43 (19.42, 19.44)	2.03 (1.46, 4.42)	544 (406, 1123)	933 (698, 1445)	-369 (-844, 212)
2042	21.04 (21.03, 21.05)	2.13 (1.53, 4.67)	573 (427, 1188)	942 (703, 1462)	-351 (-831, 264)
2043	18.76 (18.75, 18.77)	1.84 (1.32, 4.06)	497 (370, 1034)	950 (705, 1474)	-418 (-915, 105)
2044	19.78 (19.77, 19.79)	1.88 (1.34, 4.17)	509 (378, 1063)	955 (704, 1480)	-407 (-907, 129)
2045	20.86 (20.85, 20.87)	1.92 (1.36, 4.28)	521 (387, 1093)	957 (701, 1481)	-394 (-894, 155)
2046	22.55 (22.53, 22.56)	2.00 (1.42, 4.50)	546 (406, 1151)	955 (695, 1477)	-363 (-863, 213)
2047	23.87 (23.85, 23.88)	2.05 (1.45, 4.64)	561 (416, 1186)	949 (688, 1469)	-341 (-839, 253)
2048	22.87 (22.86, 22.88)	1.89 (1.34, 4.32)	521 (386, 1106)	939 (679, 1459)	-372 (-865, 178)
2049	23.60 (23.59, 23.61)	1.89 (1.33, 4.32)	521 (386, 1110)	926 (669, 1446)	-362 (-850, 190)
2050	24.54 (24.52, 24.54)	1.89 (1.33, 4.36)	524 (388, 1121)	912 (657, 1430)	-348 (-829, 210)
Total	765.87 (765.14, 766.24)	104.34 (78.58, 211.06)	27 340 (21 113, 53 131)	18 812 (14 100, 29 185)	8493 (-2661, 34 932)
Discounted (3%)					
Total	765.87 (765.14, 766.24)	104.34 (78.58, 211.06)	22 545 (17 550, 43 359)	11 968 (8995, 18 519)	10 676 (2523, 31 861)

PSI, postinfection vaccine efficacy. Data are presented as median and 95% CI.
The government contact price of Vaccae was assumed to be US$30 per dose. Coverage 90% and efficacy 54.7%.
Six doses of vaccine required per person, plus buffer stock (5%) and vaccine wastage (15%)
[a]Screened population: 60-74 y olds in 2024, then 60-y olds from 2025 to 2050.
[b]Vaccination program budget = screening cost + vaccine cost + delivery and administrative cost
[c]Net cost (societal perspective) = vaccination program budget - direct and indirect costs averted

Table S30. Budget impact of Vaccae older adult routine vaccination program in China during 2024-50, with P&PI vaccine conferring 10-y protection, from healthcare sector perspective.

Year	Vaccinated population[a] (million)	Vaccination program budget[b] (US$ million)	Direct medical costs averted (US$ million)	Net cost[c] (US$ million)
Undiscounted				
2024	195.58 (195.32, 195.74)	47 269 (47 206, 47 307)	18.5 (13.6, 26.8)	47 250 (47 181, 47 292)
2025	19.95 (19.93, 19.96)	4821 (4817, 4824)	89.1 (65.9, 129)	4732 (4688, 4756)
2026	19.60 (19.58, 19.61)	4737 (4732, 4739)	155 (115, 223)	4582 (4509, 4623)
2027	18.63 (18.61, 18.64)	4502 (4498, 4504)	217 (162, 312)	4286 (4186, 4341)
2028	21.54 (21.52, 21.55)	5206 (5201, 5208)	274 (207, 395)	4932 (4806, 5001)
2029	21.30 (21.28, 21.31)	5148 (5143, 5150)	327 (248, 473)	4821 (4670, 4902)
2030	21.97 (21.95, 21.98)	5309 (5304, 5311)	378 (286, 548)	4930 (4756, 5024)
2031	20.99 (20.97, 20.99)	5072 (5067, 5074)	425 (322, 617)	4646 (4449, 4751)
2032	20.37 (20.35, 20.38)	4923 (4919, 4925)	469 (355, 682)	4453 (4,237, 4570)
2033	19.91 (19.90, 19.92)	4813 (4808, 4814)	510 (385, 741)	4301 (4067, 4429)
2034	18.71 (18.70, 18.72)	4523 (4519, 4524)	532 (400, 772)	3991 (3747, 4123)
2035	16.94 (16.92, 16.95)	4094 (4090, 4095)	503 (381, 735)	3591 (3355, 3714)
2036	16.29 (16.28, 16.30)	3938 (3934, 3939)	481 (363, 703)	3456 (3232, 3576)
2037	15.19 (15.17, 15.19)	3670 (3667, 3672)	460 (346, 674)	3210 (2994, 3324)
2038	15.25 (15.23, 15.25)	3684 (3681, 3686)	440 (331, 648)	3244 (3033, 3354)
2039	16.13 (16.12, 16.14)	3898 (3895, 3900)	423 (316, 627)	3476 (3268, 3583)
2040	16.75 (16.74, 16.76)	4048 (4045, 4050)	406 (302, 606)	3643 (3439, 3748)
2041	17.52 (17.50, 17.52)	4234 (4230, 4235)	389 (286, 585)	3845 (3645, 3949)
2042	18.97 (18.95, 18.97)	4584 (4581, 4585)	369 (271, 565)	4215 (4015, 4314)
2043	16.91 (16.90, 16.92)	4088 (4085, 4089)	351 (257, 546)	3737 (3539, 3832)
2044	17.83 (17.82, 17.84)	4309 (4306, 4311)	334 (244, 528)	3976 (3779, 4067)
2045	18.80 (18.79, 18.81)	4544 (4541, 4545)	319 (232, 511)	4225 (4031, 4313)
2046	20.32 (20.31, 20.33)	4911 (4908, 4913)	306 (221, 493)	4606 (4416, 4691)
2047	21.51 (21.50, 21.52)	5199 (5196, 5200)	294 (212, 478)	4905 (4720, 4988)
2048	20.61 (20.60, 20.62)	4982 (4979, 4983)	283 (205, 465)	4699 (4516, 4778)
2049	21.27 (21.26, 21.28)	5140 (5138, 5142)	274 (198, 453)	4866 (4686, 4943)
2050	22.11 (22.10, 22.12)	5344 (5341, 5345)	267 (193, 444)	5077 (4899, 5152)
Total	690.94 (690.28, 691.28)	166 987 (166 827, 167 068)	9316 (7007, 13 822)	157 635 (153 012, 160 023)
Discounted (3%)				
Total	690.94 (690.28, 691.28)	129 785 (129 650, 129 852)	6377 (4784, 9370)	123 403 (120 282, 125 036)

P&PI, both pre- and postinfection vaccine efficacy. Data are presented as median and 95% CI.
The government contact price of Vaccae was assumed to be US$30 per dose. Coverage 90% and efficacy 54.7%. Six doses of vaccine required per person, plus buffer stock (5%) and vaccine wastage (15%)
[a] Vaccinated population: 60-74 y olds in 2024, then 60-y olds from 2025 to 2050.
[b]Vaccination program budget = screening cost + vaccine cost + delivery and administrative cost
[c]Net cost (healthcare sector perspective) = vaccination program budget - direct medical costs averted

Table S31. Budget impact of Vaccae older adult routine vaccination program in China during 2024-50, with P&PI vaccine conferring 20-y protection, from healthcare sector perspective.

Year	Vaccinated population[a] (million)	Vaccination program budget[b] (US$ million)	Direct medical costs averted (US$ million)	Net cost[c] (US$ million)
Undiscounted				
2024	195.58 (195.32, 195.74)	47 269 (47 206, 47 307)	18.5 (13.6, 26.8)	47 250 (47 181, 47 292)
2025	19.95 (19.93, 19.96)	4821 (4817. 4824)	89.1 (65.9, 129)	4732 (4688, 4756)
2026	19.60 (19.58, 19.61)	4737 (4732. 4739)	155 (115, 223)	4582 (4509, 4623)
2027	18.63 (18.61, 18.64)	4502 (4498. 4504)	217 (162, 312)	4286 (4186, 4341)
2028	21.54 (21.52, 21.55)	5206 (5201. 5208)	274 (207, 395)	4932 (4806, 5001)
2029	21.30 (21.28, 21.31)	5148 (5143, 5150)	327 (248, 473)	4821 (4670, 4902)
2030	21.97 (21.95, 21.98)	5309 (5304, 5311)	378 (286, 548)	4930 (4756, 5024)
2031	20.99 (20.97, 20.99)	5072 (5067, 5074)	425 (322, 617)	4646 (4449, 4751)
2032	20.37 (20.35, 20.38)	4923 (4919, 4925)	469 (355, 682)	4453 (4237, 4570)
2033	19.91 (19.90, 19.92)	4813 (4808, 4814)	510 (385, 741)	4301 (4067, 4429)
2034	18.71 (18.70, 18.72)	4523 (4519, 4524)	547 (412, 795)	3975 (3724, 4112)
2035	16.94 (16.93, 16.95)	4094 (4090, 4095)	580 (435, 845)	3513 (3246, 3660)
2036	16.29 (16.28, 16.30)	3938 (3934, 3939)	608 (455, 889)	3329 (3046, 3483)
2037	15.19 (15.17, 15.19)	3670 (3667, 3672)	635 (472, 928)	3034 (2740, 3199)
2038	15.25 (15.23, 15.25)	3684 (3681, 3686)	658 (486, 961)	3025 (2721, 3199)
2039	16.13 (16.12, 16.14)	3898 (3895, 3900)	676 (497, 989)	3221 (2907, 3401)
2040	16.75 (16.74, 16.76)	4048 (4045, 4050)	690 (506, 1012)	3357 (3034, 3543)
2041	17.52 (17.50, 17.52)	4234 (4230, 4235)	701 (512, 1030)	3533 (3201, 3722)
2042	18.97 (18.95, 18.97)	4584 (4581, 4586)	706 (515, 1043)	3877 (3539, 4070)
2043	16.91 (16.90, 16.92)	4088 (4085, 4089)	709 (516, 1052)	3379 (3034, 3572)
2044	17.83 (17.82, 17.84)	4309 (4306, 4311)	704 (509, 1044)	3606 (3263, 3801)
2045	18.80 (18.79, 18.81)	4544 (4541, 4545)	675 (486, 1001)	3870 (3540, 4059)
2046	20.32 (20.31, 20.33)	4911 (4908, 4913)	648 (465, 964)	4263 (3946, 4447)
2047	21.51 (21.50, 21.52)	5199 (5196, 5200)	622 (446, 930)	4577 (4266, 4754)
2048	20.61 (20.60, 20.62)	4982 (4979, 4983)	598 (428, 901)	4384 (4079, 4554)
2049	21.27 (21.26, 21.28)	5140 (5138, 5142)	581 (412, 873)	4560 (4265, 4729)
2050	22.11 (22.10, 22.12)	5344 (5341, 5345)	561 (397, 847)	4782 (4494, 4947)
Total	690.95 (690.28 691.28)	166 988 (166 827, 167 068)	13 798 (10 135, 20 250)	153 190 (146 585, 156 895)
Discounted (3%)				
Total	690.95 (690.28, 691.28)	129 786 (129 651, 129 852)	8877 (6558, 13 010)	120 883 (116 642, 123 262)

P&PI, both pre- and postinfection vaccine efficacy. Data are presented as median and 95% CI.
The government contact price of Vaccae was assumed to be US$30 per dose. Coverage 90% and efficacy 54.7%.
Six doses of vaccine required per person, plus buffer stock (5%) and vaccine wastage (15%)
[a]Vaccinated population: 60-74 y olds in 2024, then 60-y olds from 2025 to 2050.
[b]Vaccination program budget = screening cost + vaccine cost + delivery and administrative cost
[c]Net cost (healthcare sector perspective) = vaccination program budget - direct medical costs averted

Table S32. Budget impact of Vaccae older adult routine vaccination program in China during 2024-50, with P&PI vaccine conferring lifelong protection, from healthcare sector perspective.

Year	Vaccinated population[a] (million)	Vaccination program budget[b] (US$ million)	Direct medical costs averted (US$ million)	Net cost[c] (US$ million)
Undiscounted				
2024	195.58 (195.32, 195.74)	47 269 (47 206, 47 307)	18.5 (13.6, 26.8)	47 250 (47 181, 47 292)
2025	19.95 (19.93, 19.96)	4821 (4817, 4824)	89.1 (65.9, 129)	4732 (4688, 4756)
2026	19.60 (19.58, 19.61)	4737 (4732, 4739)	155 (115, 223)	4582 (4509, 4623)
2027	18.63 (18.61, 18.64)	4502 (4498, 4504)	217 (162, 312)	4286 (4186, 4341)
2028	21.54 (21.52, 21.55)	5206 (5201, 5208)	274 (207, 395)	4932 (4806, 5001)
2029	21.30 (21.28, 21.31)	5148 (5143, 5150)	327 (248, 473)	4821 (4670, 4902)
2030	21.97 (21.95, 21.98)	5309 (5304, 5311)	378 (286, 548)	4930 (4756, 5024)
2031	20.99 (20.97, 20.99)	5072 (5067, 5074)	425 (322, 617)	4646 (4449, 4751)
2032	20.37 (20.35, 20.38)	4923 (4919, 4925)	469 (355, 682)	4453 (4237, 4570)
2033	19.91 (19.90, 19.92)	4813 (4808, 4814)	510 (385, 741)	4301 (4067, 4429)
2034	18.71 (18.70, 18.72)	4523 (4519, 4524)	547 (412, 795)	3975 (3724, 4112)
2035	16.94 (16.93, 16.95)	4094 (4090, 4095)	580 (435, 845)	3513 (3246, 3660)
2036	16.29 (16.28, 16.30)	3938 (3934, 3939)	608 (455, 889)	3329 (3046, 3483)
2037	15.19 (15.17, 15.19)	3670 (3667, 3672)	635 (472, 928)	3034 (2740, 3199)
2038	15.25 (15.23, 15.25)	3684 (3681, 3686)	658 (486, 961)	3025 (2721, 3199)
2039	16.13 (16.12, 16.14)	3898 (3895, 3900)	676 (497, 989)	3221 (2907, 3401)
2040	16.75 (16.74, 16.76)	4048 (4045, 4050)	690 (506, 1012)	3357 (3034, 3543)
2041	17.52 (17.50, 17.52)	4234 (4230, 4235)	701 (512, 1030)	3533 (3201, 3722)
2042	18.97 (18.95, 18.97)	4584 (4581, 4586)	706 (515, 1043)	3877 (3539, 4070)
2043	16.91 (16.90, 16.92)	4088 (4085, 4089)	709 (516, 1052)	3379 (3034, 3572)
2044	17.83 (17.82, 17.84)	4309 (4306, 4311)	712 (515, 1056)	3599 (3251, 3795)
2045	18.80 (18.79, 18.81)	4544 (4541, 4545)	711 (513, 1058)	3833 (3484, 4032)
2046	20.32 (20.31, 20.33)	4911 (4908, 4913)	709 (509, 1056)	4202 (3853, 4403)
2047	21.51 (21.50, 21.52)	5199 (5196, 5200)	706 (505, 1053)	4493 (4144, 4695)
2048	20.61 (20.60, 20.62)	4982 (4979, 4983)	702 (499, 1047)	4281 (3932, 4484)
2049	21.27 (21.26, 21.28)	5140 (5138, 5142)	695 (492, 1040)	4446 (4099, 4649)
2050	22.11 (22.10, 22.12)	5344 (5341, 5345)	688 (485, 1030)	4657 (4311, 4860)
Total	690.95 (690.28 691.28)	166 988 (166 827, 167 068)	14 292 (10 509, 21 030)	152 668 (145 804, 156 521)
Discounted (3%)				
Total	690.95 (690.28, 691.28)	129 786 (129 651, 129 852)	9125 (6743, 13 395)	120 639 (116 258, 123 078)

P&PI, both pre- and postinfection vaccine efficacy. Data are presented as median and 95% CI.
The government contact price of Vaccae was assumed to be US$30 per dose. Coverage 90% and efficacy 54.7%.
Six doses of vaccine required per person, plus buffer stock (5%) and vaccine wastage (15%)
[a]Vaccinated population: 60-74 y olds in 2024, then 60-y olds from 2025 to 2050.
[b]Vaccination program budget = screening cost + vaccine cost + delivery and administrative cost
[c]Net cost (healtncare sector perspective) = vaccination program budget - direct medical costs averted

Table S33. Budget impact of Vaccae older adult routine vaccination program in China during 2024-50, with P&PI vaccine conferring 10-y protection, from societal perspective.

Year	Vaccinated population[a] (million)	Vaccination program budget[b] (US$ million)	Direct and indirect costs averted (US$ million)	Net cost[c] (US$ million)
Undiscounted				
2024	195.58 (195.32, 195.74)	47 269 (47 206, 47 307)	26.9 (19.8, 39.0)	47 241 (47 168, 47 286)
2025	19.95 (19.93, 19.96)	4821 (4817, 4824)	137 (101, 197)	4685 (4620, 4720)
2026	19.60 (19.58, 19.61)	4737 (4732, 4739)	253 (189, 361)	4483 (4371, 4548)
2027	18.63 (18.61, 18.64)	4502 (4498, 4504)	372 (281, 535)	4130 (3961, 4222)
2028	21.54 (21.52, 21.55)	5206 (5201, 5208)	486 (371, 713)	4720 (4486, 4837)
2029	21.30 (21.28, 21.31)	5148 (5143, 5150)	595 (457, 885)	4554 (4259, 4691)
2030	21.97 (21.95, 21.98)	5309 (5304, 5311)	705 (539, 1039)	4603 (4265, 4770)
2031	20.99 (20.97, 20.99)	5072 (5067, 5074)	808 (614, 1184)	4262 (3884, 4459)
2032	20.37 (20.35, 20.38)	4923 (4919, 4925)	896 (681, 1318)	4026 (3601, 4243)
2033	19.91 (19.90, 19.92)	4813 (4808, 4814)	976 (742, 1440)	3836 (3369, 4071)
2034	18.71 (18.70, 18.72)	4523 (4519, 4524)	1,028 (778, 1513)	3495 (3006, 3745)
2035	16.94 (16.92, 16.95)	4094 (4090, 4095)	991 (761, 1477)	3104 (2614, 3334)
2036	16.29 (16.28, 16.30)	3938 (3934, 3939)	951 (740, 1439)	2987 (2496, 3199)
2037	15.19 (15.17, 15.19)	3670 (3667, 3672)	919 (712, 1401)	2752 (2267, 2959)
2038	15.25 (15.23, 15.25)	3684 (3681, 3686)	895 (686, 1364)	2790 (2318, 2999)
2039	16.13 (16.12, 16.14)	3898 (3895, 3900)	873 (660, 1325)	3026 (2571, 3239)
2040	16.75 (16.74, 16.76)	4048 (4045, 4050)	853 (635, 1287)	3197 (2759, 3414)
2041	17.52 (17.50, 17.52)	4234 (4230, 4235)	824 (609, 1250)	3410 (2982, 3625)
2042	18.97 (18.95, 18.97)	4584 (4581, 4585)	791 (584, 1213)	3793 (3370, 4001)
2043	16.91 (16.90, 16.92)	4088 (4085, 4089)	765 (559, 1177)	3324 (2910, 3530)
2044	17.83 (17.82, 17.84)	4309 (4306, 4311)	734 (535, 1141)	3576 (3168, 3776)
2045	18.80 (18.79, 18.81)	4544 (4541, 4545)	707 (511, 1110)	3838 (3433, 4034)
2046	20.32 (20.31, 20.33)	4911 (4908, 4913)	684 (489, 1084)	4228 (3826, 4423)
2047	21.51 (21.50, 21.52)	5199 (5196, 5200)	661 (469, 1053)	4539 (4145, 4731)
2048	20.61 (20.60, 20.62)	4982 (4979, 4983)	640 (451, 1026)	4342 (3955, 4531)
2049	21.27 (21.26, 21.28)	5140 (5138, 5142)	621 (435, 1001)	4519 (4139, 4706)
2050	22.11 (22.10, 22.12)	5344 (5341, 5345)	602 (421, 977)	4742 (4365, 4924)
Total	690.94 (690.28, 691.28)	166 987 (166 827, 167 068)	18 408 (14 249, 28 461)	148 614 (138 380, 152 819)
Discounted (3%)				
Total	690.94 (690.28, 691.28)	129 785 (129 650, 129 852)	12 389 (9656, 19 031)	117 395 (110 628, 120 194)

P&PI, both pre- and postinfection vaccine efficacy. Data are presented as median and 95% CI.
The government contact price of Vaccae was assumed to be US$30 per dose. Coverage 90% and efficacy 54.7%.
Six doses of vaccine required per person, plus buffer stock (5%) and vaccine wastage (15%)
[a]Vaccinated population: 60-74 y olds in 2024, then 60-y olds from 2025 to 2050.
[b]Vaccination program budget = screening cost + vaccine cost + delivery and administrative cost
[c]Net cost (societal perspective) = vaccination program budget - direct and indirect costs averted

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Table S34. Budget impact of Vaccae older adult routine vaccination program in China during 2024-50, with P&PI vaccine conferring 20-y protection, from societal perspective.

Year	Vaccinated population[a] (million)	Vaccination program budget[b] (US$ million)	Direct and indirect costs averted (US$ million)	Net cost[c] (US$ million)
Undiscounted				
2024	195.58 (195.32, 195.74)	47 269 (47 206, 47 307)	26.9 (19.8, 39.0)	47 241 (47 168, 47 286)
2025	19.95 (19.93, 19.96)	4821 (4817, 4824)	137 (101, 197)	4685 (4620, 4720)
2026	19.60 (19.58, 19.61)	4737 (4732, 4739)	253 (189, 361)	4483 (4371, 4548)
2027	18.63 (18.61, 18.64)	4502 (4498, 4504)	372 (281, 535)	4130 (3961, 4222)
2028	21.54 (21.52, 21.55)	5206 (5201, 5208)	486 (371, 713)	4720 (4486, 4837)
2029	21.30 (21.28, 21.31)	5148 (5143, 5150)	595 (457, 885)	4554 (4259, 4691)
2030	21.97 (21.95, 21.98)	5309 (5304, 5311)	705 (539, 1039)	4603 (4265, 4770)
2031	20.99 (20.97, 20.99)	5072 (5067, 5074)	808 (614, 1184)	4262 (3884, 4459)
2032	20.37 (20.35, 20.38)	4923 (4919, 4925)	896 (681, 1318)	4026 (3601, 4243)
2033	19.91 (19.90, 19.92)	4813 (4808, 4814)	976 (742, 1440)	3836 (3369, 4071)
2034	18.71 (18.70, 18.72)	4523 (4519, 4524)	1052 (795, 1549)	3470 (2970, 3728)
2035	16.94 (16.93, 16.95)	4094 (4090, 4095)	1120 (842, 1648)	2974 (2443, 3253)
2036	16.29 (16.28, 16.30)	3938 (3934, 3939)	1176 (881, 1734)	2762 (2201, 3057)
2037	15.19 (15.17, 15.19)	3670 (3667, 3672)	1223 (915, 1808)	2447 (1859, 2756)
2038	15.25 (15.23, 15.25)	3684 (3681, 3686)	1263 (942, 1872)	2422 (1810, 2743)
2039	16.13 (16.12, 16.14)	3898 (3895, 3900)	1293 (963, 1924)	2606 (1971, 2936)
2040	16.75 (16.74, 16.76)	4048 (4045, 4050)	1317 (978, 1967)	2732 (2079, 3071)
2041	17.52 (17.50, 17.52)	4234 (4230, 4235)	1333 (988, 1999)	2901 (2232, 3246)
2042	18.97 (18.95, 18.97)	4584 (4581, 4586)	1343 (993, 2022)	3241 (2560, 3592)
2043	16.91 (16.90, 16.92)	4088 (4085, 4089)	1348 (995, 2037)	2740 (2049, 3094)
2044	17.83 (17.82, 17.84)	4309 (4306, 4311)	1334 (983, 2025)	2975 (2282, 3327)
2045	18.80 (18.79, 18.81)	4544 (4541, 4545)	1275 (946, 1957)	3269 (2585, 3599)
2046	20.32 (20.31, 20.33)	4911 (4908, 4913)	1234 (910, 1894)	3679 (3015, 4002)
2047	21.51 (21.50, 21.52)	5199 (5196, 5200)	1195 (877, 1836)	4005 (3361, 4323)
2048	20.61 (20.60, 20.62)	4982 (4979, 4983)	1157 (846, 1783)	3825 (3197, 4137)
2049	21.27 (21.26, 21.28)	5140 (5138, 5142)	1124 (815, 1731)	4017 (3407, 4327)
2050	22.11 (22.10, 22.12)	5344 (5341, 5345)	1090 (785, 1681)	4254 (3661, 4560)
Total	690.95 (690.28 691.28)	166 988 (166 827, 167 068)	26 207 (19 483, 39 239)	140 798 (127 605, 147 552)
Discounted (3%)				
Total	690.95 (690.28, 691.28)	129 786 (129 651, 129 852)	16 856 (12 546, 25 114)	112 940 (104 547, 117 279)

P&PI, both pre- and postinfection vaccine efficacy. Data are presented as median and 95% CI.
The government contact price of Vaccae was assumed to be US$30 per dose. Coverage 90% and efficacy 54.7%. Six doses of vaccine required per person, plus buffer stock (5%) and vaccine wastage (15%)
[a]Vaccinated population: 60-74 y olds in 2024, then 60-y olds from 2025 to 2050.
[b]Vaccination program budget = screening cost + vaccine cost + delivery and administrative cost
[c]Net cost (societal perspective) = vaccination program budget - direct and indirect costs averted

Table S35. Budget impact of Vaccae older adult routine vaccination program in China during 2024-50, with P&PI vaccine conferring lifelong protection, from societal perspective.

Year	Vaccinated population[a] (million)	Vaccination program budget[b] (US$ million)	Direct and indirect costs averted (US$ million)	Net cost[c] (US$ million)
Undiscounted				
2024	195.58 (195.32, 195.74)	47 269 (47 206, 47 307)	26.9 (19.8, 39.0)	47 241 (47 168, 47 286)
2025	19.95 (19.93, 19.96)	4821 (4817, 4824)	137 (101, 197)	4685 (4620, 4720)
2026	19.60 (19.58, 19.61)	4737 (4732, 4739)	253 (189, 361)	4483 (4371, 4548)
2027	18.63 (18.61, 18.64)	4502 (4498, 4504)	372 (281, 535)	4130 (3961, 4222)
2028	21.54 (21.52, 21.55)	5206 (5201, 5208)	486 (371, 713)	4720 (4486, 4837)
2029	21.30 (21.28, 21.31)	5148 (5143, 5150)	595 (457, 885)	4554 (4259, 4691)
2030	21.97 (21.95, 21.98)	5309 (5304, 5311)	705 (539, 1039)	4603 (4265, 4770)
2031	20.99 (20.97, 20.99)	5072 (5067, 5074)	808 (614, 1184)	4262 (3884, 4459)
2032	20.37 (20.35, 20.38)	4923 (4919, 4925)	896 (681, 1318)	4026 (3601, 4243)
2033	19.91 (19.90, 19.92)	4813 (4808, 4814)	976 (742, 1440)	3836 (3369, 4071)
2034	18.71 (18.70, 18.72)	4523 (4519, 4524)	1052 (795, 1549)	3470 (2970, 3728)
2035	16.94 (16.93, 16.95)	4094 (4090, 4095)	1120 (842, 1648)	2974 (2443, 3253)
2036	16.29 (16.28, 16.30)	3938 (3934, 3939)	1176 (881, 1734)	2762 (2201, 3057)
2037	15.19 (15.17, 15.19)	3670 (3667, 3672)	1223 (915, 1808)	2447 (1859, 2756)
2038	15.25 (15.23, 15.25)	3684 (3681, 3686)	1263 (942, 1872)	2422 (1810, 2743)
2039	16.13 (16.12, 16.14)	3898 (3895, 3900)	1293 (963, 1924)	2606 (1971, 2936)
2040	16.75 (16.74, 16.76)	4048 (4045, 4050)	1317 (978, 1967)	2732 (2079, 3071)
2041	17.52 (17.50, 17.52)	4234 (4230, 4235)	1333 (988, 1999)	2901 (2232, 3246)
2042	18.97 (18.95, 18.97)	4584 (4581, 4586)	1343 (993, 2022)	3241 (2560, 3592)
2043	16.91 (16.90, 16.92)	4088 (4085, 4089)	1348 (995, 2037)	2740 (2049, 3094)
2044	17.83 (17.82, 17.84)	4309 (4306, 4311)	1348 (992, 2044)	2962 (2263, 3318)
2045	18.80 (18.79, 18.81)	4544 (4541, 4545)	1343 (986, 2044)	3201 (2498, 3559)
2046	20.32 (20.31, 20.33)	4911 (4908, 4913)	1331 (977, 2038)	3580 (2871, 3935)
2047	21.51 (21.50, 21.52)	5199 (5196, 5200)	1317 (965, 2026)	3882 (3171, 4235)
2048	20.61 (20.60, 20.62)	4982 (4979, 4983)	1302 (952, 2011)	3680 (2969, 4031)
2049	21.27 (21.26, 21.28)	5140 (5138, 5142)	1287 (936, 1992)	3855 (3147, 4205)
2050	22.11 (22.10, 22.12)	5344 (5341, 5345)	1269 (919, 1969)	4076 (3373, 4425)
Total	690.95 (690.28 691.28)	166 988 (166 827, 167 068)	27 067 (20 045, 40 455)	139 932 (126 390, 146 990)
Discounted (3%)				
Total	690.95 (690.28, 691.28)	129 786 (129 651, 129 852)	17 286 (12 820, 25 712)	112 513 (103 948, 117 002)

P&PI, both pre- and postinfection vaccine efficacy. Data are presented as median and 95% CI.
The government contact price of Vaccae was assumed to be US$30 per dose. Coverage 90% and efficacy 54.7%.
Six doses of vaccine required per person, plus buffer stock (5%) and vaccine wastage (15%)
[a]Vaccinated population: 60-74 y olds in 2024, then 60-y olds from 2025 to 2050.
[b]Vaccination program budget = screening cost + vaccine cost + delivery and administrative cost
[c]Net cost (societal perspective) = vaccination program budget - direct and indirect costs averted

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Table S36. Budget impact of Vaccae all-age vaccination program in China during 2024-50, from healthcare sector perspective.

Year	Vaccinated population (thousand)	Doses of vaccine required[a] (thousand)	Vaccine cost[b] (US$ million)	Vaccination program budget[c] (US$ million)	Direct medical cost averted (US$ million)	Net cost[d] (US$ million)
PSI vaccine type						
Protection duration 10-y scenario						
Undiscounted						
2024	114.769 (86.215, 236.614)	826.334 (620.747, 1703.620)	24 968 (18 756, 51 475)	31 003 (24 057, 60 640)	18.7 (13.5, 27.1)	30 983 (24 037, 60 624)
2034	93.736 (68.055, 199.925)	674.897 (489.994, 1439.462)	20 392 (14 805, 43 494)	25 911 (19 664, 51 740)	489 (373, 716)	25 409 (19 083, 51 292)
2044	64.971 (46.069, 145.737)	467.791 (331.698, 1049.309)	14 134 (10 022, 31 705)	18 623 (14 025, 38 268)	542 (408, 824)	18 097 (13 385, 37 749)
2024-2050	274.600 (200.339, 582.277)	1977.117 (1442.439, 4192.392)	59 739 (43 584, 126 674)	75 803 (57 738, 150 640)	11 277 (8611, 16 916)	63 991 (44 136, 139 957)
Discounted (3%)						
2024-2050	274.6 (200.339, 582.277)	1977.117 (1442.439, 4192.392)	48 169 (35 322, 101 393)	60 813 (46 447, 120 321)	7347 (5644, 11 000)	52 908 (37 527, 113 380)
Protection duration 20-y scenario						
Undiscounted						
2024	114.769 (86.215, 236.614)	826.334 (620.747, 1703.620)	24 968 (18 756, 51 475)	31 003 (24 057, 60 640)	18.7 (13.5, 27.1)	30 983 (24 037, 60 624)
2044	64.954 (46.053, 145.723)	467.665 (331.578, 1049.206)	14 131 (10 019, 31 702)	18 619 (14 021, 38 265)	586 (436, 867)	18 052 (13 314, 37 719)
2024-2050	180.856 (132.267, 382.337)	1302.163 (952.325, 2752.827)	39 345 (28 775, 83 177)	49 892 (38 072, 98 899)	11 924 (9059, 17 631)	37 975 (23 631, 87 820)
Discounted (3%)						
2024-2050	180.856 (132.267, 382.337)	1302.163 (952.325, 2752.827)	32 984 (24 303, 69 028)	41 522 (31 815, 81 821)	7784 (5924, 11 460)	33 663 (22 432, 74 632)
Protection duration lifelong scenario						
Undiscounted						
2024	114.769 (86.215, 236.614)	826.334 (620.747, 1703.620)	24 968 (18 756, 51 475)	31 003 (24 057, 60 640)	18.7 (13.5, 27.1)	30 983 (24 037, 60 624)
2024-2050	114.769 (86.215, 236.614)	826.334 (620.747, 1703.620)	24 968 (18 756, 51 475)	30 999 (24 053, 60 636)	12 452 (9409, 18 233)	19 046 (8783, 49 212)
Discounted (3%)						
2024-2050	114.769 (86.215, 236.614)	826.334 (620.747, 1703.620)	24 968 (18 756, 51 475)	30 999 (24 053, 60 636)	8041 (6097, 11 758)	23 204 (14 279, 53 276)
P&PI vaccine type						
Protection duration 10-y scenario						
Undiscounted						
2024	1002.392 (1001.732, 1 002.745)	7217.220 (7212.468, 7219.763)	218 070 (217 927, 218 147)	243 812 (243 651, 243 898)	33.1 (25.6, 48.6)	243 780 (243 600, 243 872)
2034	1010.728 (1010.407, 1010.993)	7277.240 (7274.931, 7279.147)	219 884 (219 814, 219 941)	245 839 (245 761, 245 904)	767 (602, 1 158)	245 077 (244 606, 245 282)
2044	916.166 (915.947, 916.392)	6596.395 (6594.815, 6598.026)	199 312 (199 264, 199 361)	222 839 (222 786, 222 894)	804 (615, 1 284)	222 036 (221 515, 222 249)
2024-2050	2929.264 (2928.145, 2930.098)	21 090.704 (21 082.641, 21 096.708)	637 261 (637 018, 637 443)	712 485 (712 213, 712 688)	17 335 (13 570, 27 166)	695 150 (685 045, 699 134)
Discounted (3%)						
2024-2050	2929.264 (2928.145, 2930.098)	21 090.704 (21 082.641, 21 096.708)	492 035 (491 825, 492 180)	550 116 (549 881, 550 278)	11 471 (8978, 17 779)	538 652 (532 094, 541 311)
Protection duration 20-y scenario						
Undiscounted						
2024	1002.392 (1001.732, 1002.745)	7217.220 (7212.468, 7219.763)	218 070 (217 927, 218 147)	243 812 (243 651, 243 898)	33.1 (25.6, 48.6)	243 780 (243 600, 243 872)
2044	916.149 (915.931, 916.377)	6596.270 (6594.702, 6597.917)	199 308 (199 261, 199 358)	222 835 (222 782, 222 890)	880 (670, 1 372)	221 962 (221 423, 222 200)
2024-2050	1918.519 (1917.691, 1919.091)	13 813.335 (13 807.375, 13 817.452)	417 374 (417 194, 417 498)	466 641 (466 440, 466 780)	18 280 (14 269, 28 124)	448 390 (438 320, 452 526)
Discounted (3%)						
2024-2050	1918.519 (1917.691, 1919.091)	13 813.335 (13 807.375, 13 817.452)	328 419 (328 256, 328 522)	367 186 (367 004, 367 302)	12 005 (9391, 18 381)	355 192 (348 620, 357 923)
Protection duration lifelong scenario						
Undiscounted						
2024	1002.392 (1001.732, 1002.745)	7217.220 (212.468, 7219.763)	218 070 (217 927, 218 147)	243 812 (243 651, 243 898)	33.1 (25.6, 48.6)	243 780 (243 600, 243 872)
2024-2050	1002.392 (1001.732, 1002.745)	7217.220 (7212.468, 7219.763)	218 070 (217 927, 218 147)	243 812 (243 651, 243 898)	19 120 (14 784, 29 202)	224 708 (214 506, 229 120)
Discounted (3%)						
2024-2050	1002.392 (1001.732, 1002.745)	7217.220 (7212.468, 7219.763)	218 070 (217 927, 218 147)	243 812 (243 651, 243 898)	12 402 (9646, 18 880)	231 423 (224 826, 234 259)

PSI, postinfection vaccine efficacy; P&PI, both pre- and postinfection vaccine efficacy. Data are presented as median and 95% CI.
The government contact price of Vaccae was assumed to be US$30 per dose. Coverage 90% and efficacy 54.7%.
[a]Six doses of vaccine required per person, plus buffer stock (5%) and vaccine wastage (15%)
[b]Vaccine cost = vaccine price × doses of vaccine required + vaccine campaign cost (US$1.55 per person) × vaccinated population
[c]Vaccination program budget = screening cost + vaccine cost + delivery and administrative cost
[d]Net cost (healthcare sector perspective) = vaccination program budget - direct medical costs averted

Table S37. Budget impact of Vaccae all-age vaccination program in China during 2024-50, from societal perspective.

Year	Vaccinated population (thousand)	Doses of vaccine required[a] (thousand)	Vaccine cost[b] (US$ million)	Vaccination program budget[c] (US$ million)	Direct and indirect cost averted (US$ million)	Net cost[d] (US$ million)
PSI vaccine type						
Protection duration 10-y scenario						
Undiscounted						
2024	114.769 (86.215, 236.614)	826.334 (620.747, 1703.620)	24 968 (18 756, 51 475)	31 003 (24 057, 60 640)	56.0 (40.3, 86.5)	30 946 (23 995, 60 586)
2034	93.736 (68.055, 199.925)	674.897 (489.994, 1439.462)	20 392 (14 805, 43 494)	25 911 (19 664, 51 740)	1282 (987, 1969)	24 615 (18 209, 50 475)
2044	64.971 (46.069, 145.737)	467.791 (331.698, 1049.309)	14 134 (10 022, 31 705)	18 623 (14 025, 38 268)	1327 (1014, 2139)	17 313 (12 545, 36 887)
2024-2050	274.600 (200.339, 582.277)	1977.117 (1442.439, 4192.392)	59 739 (43 584, 126 674)	75 803 (57 738, 150 640)	29 686 (22 722, 47 046)	45 346 (23 383, 120 582)
Discounted (3%)						
2024-2050	274.600 (200.339, 582.277)	1977.117 (1442.439, 4192.392)	48 169 (35 322, 101 393)	60 813 (46 447, 120 321)	19 595 (15 114, 31 011)	40 780 (23 942, 100 566)
Protection duration 20-y scenario						
Undiscounted						
2024	114.769 (86.215, 236.614)	826.334 (620.747, 1703.620)	24 968 (18 756, 51 475)	31 003 (24 057, 60 640)	56.0 (40.3, 86.5)	30 946 (23 995, 60 586)
2044	64.954 (46.053, 145.723)	467.665 (331.578, 1049.206)	14 131 (10 019, 31 702)	18 619 (14 021, 38 265)	1326 (1011, 2043)	17 319 (12 503, 36 903)
2024-2050	180.856 (132.267, 382.337)	1302.163 (952.325, 2752.827)	39 345 (28 775, 83 177)	49 892 (38 072, 98 899)	29 800 (22 805, 46 217)	18 808 (2 088, 68 930)
Discounted (3%)						
2024-2050	180.856 (132.267, 382.337)	1302.163 (952.325, 2752.827)	32 984 (24 303, 69 028)	41 522 (31 815, 81 821)	19 637 (15 216, 30 576)	21 227 (8 304, 62 093)
Protection duration lifelong scenario						
Undiscounted						
2024	114.769 (86.215, 236.614)	826.334 (620.747, 1703.620)	24 968 (18 756, 51 475)	31 003 (24 057, 60 640)	56.0 (40.3, 86.5)	30 946 (23 995, 60 586)
2024-2050	114.769 (86.215, 236.614)	826.334 (620.747, 1703.620)	24 968 (18 756, 51 475)	30 999 (24 053, 60 636)	30 196 (23 085, 46 337)	374 (-14 011, 30 059)
Discounted (3%)						
2024-2050	114.769 (86.215, 236.614)	826.334 (620.747, 1703.620)	24 968 (18 756, 51 475)	30 999 (24 053, 60 636)	19 814 (15 355, 30 638)	10 403 (-189, 40 783)
P&PI vaccine type						
Protection duration 10-y scenario						
Undiscounted						
2024	1002.392 (1001.732, 1002.745)	7217.220 (7212.468, 7219.763)	218 070 (217 927, 218 147)	243 812 (243 651, 243 898)	124 (96.0, 202)	243 692 (243 449, 243 801)
2034	1010.728 (1010.407, 1010.993)	7277.240 (7274.931, 7279.147)	219 884 (219 814, 219 941)	245 839 (245 761, 245 904)	2477 (1893, 3854)	243 359 (241 921, 243 979)
2044	916.166 (915.947, 916.392)	6596.395 (6594.815, 6598.026)	199 312 (199 264, 199 361)	222 839 (222 786, 222 894)	2367 (1708, 3822)	220 470 (218 977, 221 133)
2024-2050	2929.264 (2928.145, 2930.098)	21 090.704 (21 082.641, 21 096.708)	637 261 (637 018, 637 443)	712 485 (712 213, 712 688)	55 621 (41 528, 88 313)	656 787 (623 920, 671 063)
Discounted (3%)						
2024-2050	2929.264 (2928.145, 2930.098)	21 090.704 (21 082.641, 21 096.708)	492 035 (491 825, 492 180)	550 116 (549 881, 550 278)	37 341 (28 016, 59 001)	512 655 (490 891, 522 187)
Protection duration 20-y scenario						
Undiscounted						
2024	1002.392 (1001.732, 1002.745)	7217.220 (7212.468, 7219.763)	218 070 (217 927, 218 147)	243 812 (243 651, 243 898)	124 (96.0, 202)	243 692 (243 449, 243 801)
2044	916.149 (915.931, 916.377)	6596.270 (6594.702, 6597.917)	199 308 (199 261, 199 358)	222 835 (222 782, 222 890)	2351 (1742, 3687)	220 491 (219 101, 221 111)
2024-2050	1918.519 (1917.691, 1919.091)	13 813.335 (13 807.375, 13 817.452)	417 374 (417 194, 417 498)	466 641 (466 440, 466 780)	55 626 (42 067, 86 942)	410 920 (379 510, 424 651)
Discounted (3%)						
2024-2050	1918.519 (1917.691, 1919.091)	13 813.335 (13 807.375, 13 817.452)	328 419 (328 256, 328 522)	367 186 (367 004, 367 302)	37 576 (28 370, 58 245)	329 527 (308 761, 338 883)
Protection duration lifelong scenario						
Undiscounted						
2024	1002.392 (1001.732, 1002.745)	7217.220 (7212.468, 7219.763)	218 070 (217 927, 218 147)	243 812 (243 651, 243 898)	124 (96.0, 202)	243 692 (243 449, 243 801)
2024-2050	1002.392 (1001.732, 1002.745)	7217.220 (7212.468, 7219.763)	218 070 (217 927, 218 147)	243 812 (243 651, 243 898)	56 356 (42 785, 87 108)	187 438 (156 532, 201 079)
Discounted (3%)						
2024-2050	1002.392 (1001.732, 1002.745)	7217.220 (7212.468, 7219.763)	218 070 (217 927, 218 147)	243 812 (243 651, 243 898)	37 868 (28 727, 58 329)	205 908 (185 311, 215 138)

PSI, postinfection vaccine efficacy; P&PI, both pre- and postinfection vaccine efficacy. Data are presented as median and 95% CI.
The government contact price of Vaccae was assumed to be US$30 per dose. Coverage 90% and efficacy 54.7%.

[a]Six doses of vaccine required per person, plus buffer stock (5%) and vaccine wastage (15%)

[b]Vaccine cost = vaccine price × doses of vaccine required + vaccine campaign cost (US$1.55 per person) × vaccinated population

[c]Vaccination program budget = screening cost + vaccine cost + delivery and administrative cost

[d]Net cost (societal perspective) = vaccination program budget - direct and indirect costs averted

7. Extended references

1 Zhifei Shengwu (ZFSW) Biological Products Co. L. Package Insert of Mycobacterium Vaccae for Injection, 2021. Available: http://www.zhifeishengwu.com/d/file/product/ybcp/2021-07-16/aaa5883dde4e566ef7328dbe8c7c29da.pdf. [Accessed 11 Nov 2022].

2 United Nations Department of Economic and Social Affairs PD. World Population Prospects 2022, Online Edition. Available: https://population.un.org/wpp/Download/Standard/CSV/ [Accessed 11 Nov 2022].

3 Harris RC, Sumner T, Knight GM, *et al*. Age-targeted tuberculosis vaccination in China and implications for vaccine development: a modelling study. *Lancet Glob Health* 2019;7:e209-e18. doi: 10.1016/S2214-109X(18)30452-2.

4 Read JM, Lessler J, Riley S, *et al*. Social mixing patterns in rural and urban areas of southern China. *Proc Biol Sci* 2014;281:20140268. doi: 10.1098/rspb.2014.0268.

5 Leung K, Jit M, Lau EHY, *et al*. Social contact patterns relevant to the spread of respiratory infectious diseases in Hong Kong. *Sci Rep* 2017;7:7974. doi: 10.1038/s41598-017-08241-1.

6 Zhang J, Klepac P, Read JM, *et al*. Patterns of human social contact and contact with animals in Shanghai, China. *Sci Rep* 2019;9:15141. doi: 10.1038/s41598-019-51609-8.

7 Prem K, Zandvoort KV, Klepac P, *et al*. Projecting contact matrices in 177 geographical regions: An update and comparison with empirical data for the COVID-19 era. *PLoS Comput Biol* 2021;17:e1009098. doi: 10.1371/journal.pcbi.1009098.

8 Dye C, Williams BG. Eliminating human tuberculosis in the twenty-first century. *J R Soc Interface* 2008;5:653-62. doi: 10.1098/rsif.2007.1138.

9 Abu-Raddad LJ, Sabatelli L, Achterberg JT, *et al*. Epidemiological benefits of more-effective tuberculosis vaccines, drugs, and diagnostics. *Proc Natl Acad Sci U S A* 2009;106:13980-5. doi: 10.1073/pnas.0901720106.

10 Knight GM, Griffiths UK, Sumner T, *et al*. Impact and cost-effectiveness of new tuberculosis vaccines in low- and middle-income countries. *Proc Natl Acad Sci U S A* 2014;111:15520-5. doi: 10.1073/pnas.1404386111.

11 Ferebee SH. Controlled chemoprophylaxis trials in tuberculosis. A general review. *Bibl Tuberc* 1970;26:28-106.

12 Comstock GW. Epidemiology of tuberculosis. *Am Rev Respir Dis* 1982;125:8-15. doi: 10.1164/arrd.1982.125.3P2.8.

13 Vynnycky EJLSoH, Medicine T. An investigation of the transmission dynamics of M. tuberculosis. 1996.

14 Vynnycky E, Fine PE. The natural history of tuberculosis: the implications of age-dependent risks of disease and the role of reinfection. *Epidemiol Infect* 1997;119:183-201. doi: 10.1017/s0950268897007917.

15 Dye C, Garnett GP, Sleeman K, *et al*. Prospects for worldwide tuberculosis control under the WHO DOTS strategy. Directly observed short-course therapy. *Lancet* 1998;352:1886-91. doi: 10.1016/s0140-6736(98)03199-7.

16 Sutherland I, Svandova E, Radhakrishna S. The development of clinical tuberculosis following infection with tubercle bacilli. 1. A theoretical model for the development of clinical tuberculosis following infection, linking from data on the risk of tuberculous infection and the incidence of

clinical tuberculosis in the Netherlands. *Tubercle* 1982;63:255-68. doi: 10.1016/s0041-3879(82)80013-5.
17 Gabriela MGM, Rodrigues P, Hilker FM, *et al*. Implications of partial immunity on the prospects for tuberculosis control by post-exposure interventions. *J Theor Biol* 2007;248:608-17. doi: 10.1016/j.jtbi.2007.06.005.
18 Schulzer M, Fitzgerald JM, Enarson DA, *et al*. An estimate of the future size of the tuberculosis problem in sub-Saharan Africa resulting from HIV infection. *Tuber Lung Dis* 1992;73:52-8. doi: 10.1016/0962-8479(92)90080-4.
19 Schaaf HS, Collins A, Bekker A, *et al*. Tuberculosis at extremes of age. *Respirology* 2010;15:747-63. doi: 10.1111/j.1440-1843.2010.01784.x.
20 Shea KM, Kammerer JS, Winston CA, *et al*. Estimated rate of reactivation of latent tuberculosis infection in the United States, overall and by population subgroup. *Am J Epidemiol* 2014;179:216-25. doi: 10.1093/aje/kwt246.
21 Yoshikawa TT. Tuberculosis in aging adults. *J Am Geriatr Soc* 1992;40:178-87. doi: 10.1111/j.1532-5415.1992.tb01941.x.
22 Rajagopalan S, Yoshikawa TT. Tuberculosis in the elderly. *Z Gerontol Geriatr* 2000;33:374-80. doi: 10.1007/s003910070034.
23 Marion CR, High KP. *Tuberculosis in Older Adults*: Infectious Disease in the Aging, 2009.
24 Tiemersma EW, van der Werf MJ, Borgdorff MW, *et al*. Natural history of tuberculosis: duration and fatality of untreated pulmonary tuberculosis in HIV negative patients: a systematic review. *PLoS One* 2011;6:e17601. doi: 10.1371/journal.pone.0017601.
25 Gomes MG, Franco AO, Gomes MC, *et al*. The reinfection threshold promotes variability in tuberculosis epidemiology and vaccine efficacy. *Proc Biol Sci* 2004;271:617-23. doi: 10.1098/rspb.2003.2606.
26 World Health Organization. WHO Tuberculosis data, 2022. Available: https://www.who.int/teams/global-tuberculosis-programme/data [Accessed 11 Nov 2022].
27 Krutikov M, Faust L, Nikolayevskyy V, *et al*. The diagnostic performance of novel skin-based in-vivo tests for tuberculosis infection compared with purified protein derivative tuberculin skin tests and blood-based in vitro interferon-gamma release assays: a systematic review and meta-analysis. *Lancet Infect Dis* 2022;22:250-64. doi: 10.1016/S1473-3099(21)00261-9.
28 Harris RC, Sumner T, Knight GM, *et al*. Potential impact of tuberculosis vaccines in China, South Africa, and India. *Sci Transl Med* 2020;12:eaax4607. doi: 10.1126/scitranslmed.aax4607.
29 Varadhan R, W. Borchers H, Bechard V. dfoptim: Derivative-Free Optimization, 2020. Available: https://cran.r-project.org/web/packages/dfoptim/index.html [Accessed 11 Nov 2022].
30 Zang X, Krebs E, Min JE, *et al*. Development and Calibration of a Dynamic HIV Transmission Model for 6 US Cities. *Med Decis Making* 2020;40:3-16. doi: 10.1177/0272989X19889356.
31 United Nations Department of Economic and Social Affairs PD. World Population Prospects 2022: Summary of Results. UN DESA/POP/2022/TR/NO. 3, 2022.
32 Wang L, Zhang H, Ruan Y, *et al*. Tuberculosis prevalence in China, 1990-2010; a longitudinal analysis of national survey data. *Lancet* 2014;383:2057-64. doi: 10.1016/S0140-6736(13)62639-2.
33 Chinese Center for Disease Control and Prevention. The Data-center of China Public Health Science. Avaliable: https://www.phsciencedata.cn/Share/en/index.jsp [Accessed 12 Dec 2022]
34 Zhang H, Huang F, Chen W, *et al*. Estimates of tuberculosis mortality rates in China using the disease surveillance point system, 2004-2010. *Biomed Environ Sci* 2012;25:483-8. doi:

10.3967/0895-3988.2012.04.015.

35 Qiu S, Pan H, Zhang S, *et al*. Is tuberculosis treatment really free in China? A study comparing two areas with different management models. *PLoS One* 2015;10:e0126770. doi: 10.1371/journal.pone.0126770.

36 Zhao Y, Xu S, Wang L, *et al*. National survey of drug-resistant tuberculosis in China. *N Engl J Med* 2012;366:2161-70. doi: 10.1056/NEJMoa1108789.

37 Wei X, Zou G, Yin J, *et al*. Providing financial incentives to rural-to-urban tuberculosis migrants in Shanghai: an intervention study. *Infect Dis Poverty* 2012;1:9. doi: 10.1186/2049-9957-1-9.

38 National Bureau of Statistics of China. China Statistical Yearbook. Beijing: China Statistics Press, 2021.

39 Pan HQ, Bele S, Feng Y, *et al*. Analysis of the economic burden of diagnosis and treatment of tuberculosis patients in rural China. *Int J Tuberc Lung Dis* 2013;17:1575-80. doi: 10.5588/ijtld.13.0144.

40 Henan Medical Security Bureau. Summary of medical service price items of public medical institutions managed by Henan Province, 2021. Available: https://ylbz.henan.gov.cn/2021/12-06/2360139.html [Accessed 12 Dec 2022].

41 Zhenjiang First People's Hospital. Jiangsu province medical service item price manual, 2022. Available: https://www.zjhospital.net/shehuigongkai/4028.html [Accessed 12 Dec 2022].

42 The Second Affiliated Hospital of Chongqing Medical University. Chongqing medical service price project, 2021. Available: https://www.sahcqmu.com/index.php?c=show&id=12882 [Accessed 12 Dec 2022].

43 Zeng Y, Luo M, Chen J, *et al*. An economic evaluation of the current measles vaccination program: A case study in Zhejiang Province, east China. *Vaccine* 2019;37:3071-77. doi: 10.1016/j.vaccine.2019.04.057.

44 Weerasuriya CK, Harris RC, McQuaid CF, *et al*. The epidemiologic impact and cost-effectiveness of new tuberculosis vaccines on multidrug-resistant tuberculosis in India and China. *BMC Med* 2021;19:60. doi: 10.1186/s12916-021-01932-7.

45 Hutton DW, So SK, Brandeau ML. Cost-effectiveness of nationwide hepatitis B catch-up vaccination among children and adolescents in China. *Hepatology* 2010;51:405-14. doi: 10.1002/hep.23310.