# Supplementary Information: Reassessing the Evidence for Universal School-age Bacillus Calmette Guerin (BCG) Vaccination in England and Wales

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## Model assumptions

The Sutherland et al. model required several additional assumptions on top of those detailed in the methods.[11] Firstly, as incidence rates for those ineligible for the BCG schools scheme are not published, We assumed that they were equal to those in the unvaccinated population. In addition, in order to reproduce the distribution of cases annually (rather than by generation or overall) reported in Sutherland et al. we introduced an additional model step and parameter; the proportion of secondary cases in the first generation that occurred in the first year (). This modelling step was only required to reproduce the final table from [11] and did not impact our estimates of the impact of ending the BCG schools scheme. It is included only for validation purposes.

The annual distribution of secondary notifications () was modelled by first estimating the number of secondary notifications that occurred in the current year () due to primary notifications in that year () and then estimating how many secondary notifications occurred 5 years later (). was estimated using the number of primary notifications () multiplied by the number of total expected number of secondary notifications per primary notification (), the proportion of secondary cases in the first generation that occurred in the first year (), and the relative size of the first generation (). was then estimated by assuming that it was equal to the number of secondary notifications, minus notifications occurring in the first year, that occurred (the expected average interval between each primary notification and all secondary notifications) years ago. As this used the overall number of notifications from the previous time step a decay of was applied. This approach can be summarised as follows,

We fitted the proportion of secondary cases in the first generation that occurred in the first year () using least squares to the original estimates of the total notifications due to ending the scheme under several scenarios, for several years. We validated the fitted model by comparing the results with those from the original implementation using the mean absolute percentage error, normalised by the original estimate, as the performance metric.

## Model validation

The percentage of cases in the first year was fitted to the Sutherland et al. estimates using the least squares method, such that . Our model produced estimates that were comparable with those from [11]. The median annual decrease estimated using notifications was 3.06% (2.5, 97.5% Quantiles (Q): -8.32%, 11.45%), with a maximum of 15.14% (2.5, 97.5% Q: 14.22%, 16.03%) in 1987 and a minimum of -10.17% (2.5, 97.5% Q: -10.82%, -9.52%) in 2005. Using age-specific incidence rates we estimated the median annual decrease in incidence rates for 15-19 year olds was 1.65% (2.5, 97.5% Q: -40.49%, 39.97%), 3.16% (2.5, 97.5% Q: -33.95%, 38.30%) for 20-24 year olds, and 2.63% (2.5, 97.5% Q: -36.28%, 37.17%) for 25-29 year olds. There was substantial variation between years and a high degree of uncertainty.

Supplementary Table S1: Comparison of results published by Sutherland et al. vs. our recreated model. This table shows the total notifications including primary and secondary effects from ending the BCG schools scheme at various times in ethnic White adults aged 15-29 years old in England and Wales.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Year of Ending Scheme | 1988 | | | 1993 | | | 1998 | | | 2003 | | | 2008 | | | 2013 | | |
| Original | Recreated | Difference | Original | Recreated | Difference | Original | Recreated | Difference | Original | Recreated | Difference | Original | Recreated | Difference | Original | Recreated | Difference |
| 1986 | 288 | 296 | 8 | 226 | 226 | 0 | 208 | 205 | -3 | 181 | 175 | -6 | 128 | 123 | -5 | 80 | 78 | -2 |
| 1991 | 288 | 296 | 8 | 165 | 166 | 1 | 130 | 131 | 1 | 128 | 126 | -2 | 115 | 111 | -4 | 80 | 78 | -2 |
| 1996 | 288 | 296 | 8 | 165 | 166 | 1 | 90 | 91 | 1 | 77 | 76 | -1 | 80 | 80 | 0 | 72 | 70 | -2 |

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## Results

Supplementary Table S2: The median number (with the 2.5% and 97.% quantiles) of vaccines required to prevent a single case of Tuberculosis within 15 years in a ethnic White UK born adult vaccinated at 13 years old.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Year of Vaccination | 9% decrease (original parameters) | 9% decrease | 3.9% decrease | 1.9% decrease | 0% decrease | Notifications | Incidence Rates |
| 1969 | 460 | 460 (390, 540) | 460 (390, 540) | 460 (390, 540) | 460 (390, 540) | 460 (390, 540) | 460 (390, 540) |
| 1974 | 940 | 940 (780, 1200) | 880 (720, 1100) | 850 (700, 1100) | 830 (680, 1000) | 860 (710, 1100) | 860 (640, 1100) |
| 1979 | 1400 | 1400 (1100, 1800) | 1100 (910, 1400) | 1000 (820, 1300) | 900 (740, 1100) | 1000 (860, 1300) | 1100 (680, 1700) |
| 1984 | 2200 | 2200 (1800, 2900) | 1300 (1100, 1700) | 1100 (900, 1400) | 900 (740, 1100) | 1600 (1300, 2000) | 1400 (730, 2900) |
| 1989 | 3600 | 3600 (2900, 4600) | 1600 (1300, 2100) | 1200 (990, 1500) | 900 (740, 1100) | 1800 (1500, 2200) | 1700 (760, 3800) |
| 1994 | 5800 | 5800 (4700, 7300) | 2000 (1600, 2500) | 1300 (1100, 1700) | 900 (740, 1100) | 1700 (1400, 2200) | 1600 (640, 4200) |
| 1999 | 9300 | 9200 (7600, 12000) | 2500 (2000, 3100) | 1500 (1200, 1900) | 900 (740, 1100) | 1600 (1300, 2000) | 1500 (510, 4200) |
| 2004 | 15000 | 15000 (12000, 19000) | 3000 (2400, 3800) | 1600 (1300, 2000) | 900 (740, 1100) | 1400 (1100, 1700) | 1500 (460, 4900) |
| 2009 | 24000 | 24000 (19000, 30000) | 3600 (3000, 4600) | 1800 (1500, 2200) | 900 (740, 1100) | 1200 (960, 1500) | 1200 (350, 4300) |
| 2014 | 38000 | 38000 (31000, 48000) | 4500 (3600, 5600) | 2000 (1600, 2500) | 900 (740, 1100) | 1500 (1200, 1900) | 1500 (390, 6000) |
| 2019 | 61000 | 61000 (50000, 78000) | 5400 (4400, 6900) | 2200 (1800, 2700) | 900 (740, 1100) | 2100 (1800, 2700) | 2300 (470, 11000) |
| 2024 | 98000 | 98000 (80000, 120000) | 6600 (5400, 8400) | 2400 (1900, 3000) | 900 (740, 1100) | 3200 (2600, 4100) | 3300 (550, 18000) |

Supplementary Table S3: The median number (with the 2.5% and 97.% quantiles) of additional annual primary notifications due to ending the BCG schools scheme in selected years.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Year Ending Scheme | 9% decrease (original parameters) | 9% decrease | 3.9% decrease | 1.9% decrease |
| 1971 | 111 | 111 (88, 135) | 204 (161, 249) | 286 (226, 350) |
| 1976 | 90 | 90 (71, 110) | 187 (148, 229) | 276 (219, 337) |
| 1981 | 55 | 55 (44, 68) | 152 (120, 185) | 244 (193, 298) |
| 1986 | 35 | 35 (28, 43) | 125 (99, 152) | 218 (172, 266) |
| 1991 | 25 | 25 (19, 30) | 109 (86, 133) | 203 (161, 247) |
| 1996 | 17 | 17 (13, 21) | 93 (74, 114) | 185 (147, 225) |
| 2001 | 12 | 12 (9, 15) | 79 (62, 96) | 166 (132, 203) |
| 2006 | 8 | 8 (6, 10) | 65 (51, 79) | 145 (115, 177) |
| 2011 | 6 | 5 (4, 7) | 50 (39, 62) | 118 (92, 145) |
| 2016 | 3 | 3 (2, 4) | 32 (23, 40) | 78 (58, 99) |
| 2021 | 1 | 1 (1, 2) | 15 (9, 21) | 39 (24, 54) |

Supplementary Table S4: The median number (with the 2.5% and 97.% quantiles) of additional annual secondary notifications due to ending the BCG schools scheme in selected years. Secondary notifications are reported assuming they occurred in the same year as the primary notifications that caused them.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Year Ending Scheme | 9% decrease (original parameters) | 9% decrease | 3.9% decrease | 1.9% decrease |
| 1971 | 107 | 889 (702, 1115) | 3760 (2945, 4735) | 10855 (8454, 13697) |
| 1976 | 74 | 616 (472, 786) | 3179 (2439, 4045) | 9852 (7584, 12514) |
| 1981 | 46 | 380 (291, 485) | 2575 (1976, 3275) | 8705 (6703, 11063) |
| 1986 | 29 | 240 (184, 306) | 2118 (1625, 2693) | 7772 (5980, 9874) |
| 1991 | 20 | 169 (130, 216) | 1848 (1417, 2348) | 7229 (5553, 9185) |
| 1996 | 14 | 118 (90, 150) | 1583 (1214, 2008) | 6602 (5072, 8385) |
| 2001 | 10 | 82 (62, 104) | 1338 (1026, 1697) | 5933 (4553, 7522) |
| 2006 | 7 | 56 (43, 72) | 1101 (843, 1397) | 5168 (3965, 6554) |
| 2011 | 4 | 37 (28, 48) | 851 (647, 1086) | 4209 (3221, 5357) |
| 2016 | 2 | 21 (15, 28) | 539 (391, 710) | 2772 (2015, 3642) |
| 2021 | 1 | 9 (6, 13) | 257 (160, 370) | 1368 (853, 1966) |