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THE BROADER VALUE OF VACCINES

The Return on Investment From a Governmental Perspective

CONSULTING | REPORT
AUGUST 2020

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Executive Summary

The UK has a world-leading vaccination program. A comprehensive understanding of the returns generated by the investments made is needed to inform appropriate funding decisions today and in the future. Therefore, this study aimed to quantify the return on investment of vaccination to the UK government for a sample of three vaccination programs from the UK vaccination schedule.

To do so, we used a form of fiscal health modelling, which considers not only the relevant direct medical costs but also the loss in direct and indirect tax contributions due to morbidity and mortality of vaccine-preventable diseases, the associated pay-outs for sick days and the loss in informal care. The analysis is conducted from a government perspective, and therefore the target audience, besides health economists, includes ministers of finance and treasury.

A lifetable-based, closed cohort model was used to estimate the return on investment (ROI) per £1 spent on the following selected vaccination programs from a governmental perspective in the United Kingdom (UK), compared with a scenario of no vaccination.

- The **human papillomavirus (HPV)** vaccine that has been routinely offered to girls aged 12-13 years.
- The **shingles** vaccination program offered to senior citizens when they turn 70.
- The **pneumococcal disease** vaccination program which protects against 13 types of pneumococcal bacteria and which is administered to infants in their first year of life.

Each sub-model is populated with a hypothetical, gender-specific cohort of patients with a starting age equal to the eligible age for the specific vaccines and follows the individual until death. The average ROI per £1 spent on these three vaccination programs over the lifetime of each cohort is £2.18. Across these three models, the ROI per £1 spent (discounted at 3.5%) ranged from £0.23 to £4.45.

As expected, vaccination programs that address a young population and prevent fatal events generate a high ROI from a government perspective, most of which are not captured within the health care system but rather accrues as tax income (which could be redistributed to any department).

This fiscal health model is intended to serve as a complement to other (often more complex) types of models that aim to assess the cost-effectiveness of a single vaccine from a health-system perspective. Its results demonstrate that a significant part of the value generated by vaccination programs accrues outside the healthcare system's perspective.

Therefore, if the concern is mainly a financial one, policymakers should consider basing their investment decisions for future vaccination programs not only on cost-effectiveness evaluations but also on a complementary fiscal analysis.

1 Introduction

The UK has a world-leading vaccination program in place. To maintain this, adequate long-term funding is required. However, as with any other health-related interventions, a comprehensive understanding of the returns generated by the investments made in vaccination programs is needed to inform appropriate funding decisions today and in the future.

When assessing the value of vaccination programs, authoritative health economists argued that the 'standard' methods that are used for other health-related interventions, may not apply (see for example Bloom et al. (2005), Drummond et al. (2007), Jit et al. (2015) and Luyten and Beutels (2016)). There are various reasons for this, which are discussed in greater detail elsewhere[1]. Of particular interest to this study is that vaccination programs' social, ethical, and economic impacts affect societies at large, not just the vaccinated individual and the health system around them (Luyten and Beutels, 2016). Notably, the impact of vaccination programs on long-term economic behaviour at the household or macroeconomic level are highly important yet difficult to quantify (Jit et al., 2015).

Therefore, this study aimed to quantify the return on investment (ROI) of vaccination to the UK government, leveraging existing published data that are fed into an economic model. We used a form of fiscal health modelling (Mauskopf et al., 2018), which considers changes in the net present value of government revenues and expenditures attributable to vaccination programs. This provides complementary information to results of other modelling approaches, notably cost-utility analysis (CUA) which is typically used to inform decisions on the allocation of resources from a health system's perspective and does not include the impact on tax revenue distribution among public programs.

The key outcomes measure of this analysis is the return on investment (ROI) of vaccination from a public sector (i.e. government) perspective, comparing population health benefits, total health care costs including vaccination costs, taxes, and sick day pay-outs of a hypothetical unvaccinated UK cohort versus a cohort receiving a selection of recently introduced vaccination programs. It is intended to contribute to a broader recognition of the true value of vaccination programs in the UK.

[1] *Please see Brassel et al. (2020) (upcoming) on the readiness of the methods applied in the UK to capture the broader value of vaccines.*

2 Methodology

2.1 Overall model overview

A lifetable-based, static, closed-cohort model was used to estimate the return on investment (ROI) per £1 spent on selected vaccination programs from a governmental perspective in the United Kingdom (UK). It is important to mention that the model does not include the value of vaccination arising from effects of herd immunity (i.e. transmission value) and is, therefore, a conservative estimation of broader value of the three modelled vaccinations programs.

The model consists of three sub-models, one for each vaccination program. The members of the ABPI Vaccines Group provided a long-list of vaccination programs of interest. From these three programs were selected to achieve a balanced view on expected ROI, mainly driven by the age of the target population.

- The **human papillomavirus (HPV)** vaccine has been routinely offered to girls aged 12-13 years since 2008 and is since September 2019 also offered to boys[2] aged 12-13 (VOX, 2019a).
- The **shingles** vaccination program has been introduced in the UK in 2013 and is offered to senior citizens when they turn 70 (VOX, 2019c).
- The **pneumococcal disease** vaccination program which introduced a pneumococcal conjugate vaccine protecting against 13 types of pneumococcal bacteria in 2010 and which is administered to infants[3] in their first year of life (VOX, 2019b).

Each sub-model is populated with a hypothetical, gender-specific cohort of patients from the starting age that equals the eligible age for the specific vaccines, using the mid-2018 population estimate (ONS, 2019d). The costs and benefits associated with vaccinating these populations are then estimated and compared to an identical, non-vaccinated cohort. This allows the user to compute the ROI from a governmental perspective on the net present monetary costs and benefits. The comparator group of an unvaccinated cohort was chosen, as the objective is to demonstrate the value of vaccination to the government as such, rather than to estimate the potential cost-effectiveness of new vaccination programs against the current ones.

Each sub-model follows a similar structure and has several parameter inputs which are given in Table 1. These parameters are the same in each sub-model because they are independent of the vaccine that is modelled.

The ONS lifetables of 2015-2017 are used as the basis to estimate, for each specific cohort, the number of people alive by year and go up to a maximum age of 100 years (ONS, 2019c).

Disease and age-specific incidence and mortality rates that occur if no vaccination is in place are then applied to estimate the number of fatal and non-fatal cases of the vaccine-preventable disease for the vaccinated and the unvaccinated cohort.

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[2] Please note that the model developed in this project only considers the vaccination of a female cohort as a broader evidence base is available here.
[3] Please note that there is an elderly vaccination program in place as well, which is out of scope of this model.

Each non-fatal case is associated with direct medical costs, pay-outs of sick pay and a loss of informal care that might otherwise have been provided by the patient during retirement. Concerning fatal cases, the government loses out on direct and indirect taxes contributed by the patient during their working age.

Each sub-model estimates the gender-specific monetary costs and benefits which are averaged using the specific gender ratios as a weighting factor. This then allows us to compute the ROI on vaccination per £1 spent from a governmental perspective based on the net present values of cost and benefits.

Table 1: Input parameters that are the same for each sub-model.

Parameter	Value	Source
Start working age	16	School leaving age (GOV.UK, 2019c)
Retirement age	66	Assumption, as default retirement age in the UK does not exist anymore (GOV.UK, 2019a)
Discount rate for costs	3.5%	NICE reference case (NICE, 2013)
Discount rate for effects	3.5%	
Long-term inflation	2%	Assumption based on the target inflation rate of the Bank of England (Bank of England, 2019)
Maximum Statutory Sick Pay (SSP) per day	£17.64	(GOV.UK, 2018). Adjusted for unemployment and assuming a five-day working week
Fraction of Gross Income spent on Indirect Taxes	18%	(ONS, 2017)
Average annual value of informal care (e.g. childcare or elderly care) provided by an older person (>65)	£3,091.67	(Franklin and Hochlaf, 2018)
Average duration of informal care (e.g. childcare or elderly care) provided by an older person (>65)	2.6 years	

The specific cost (or value) elements associated with each sub-model are given in Figure 1.

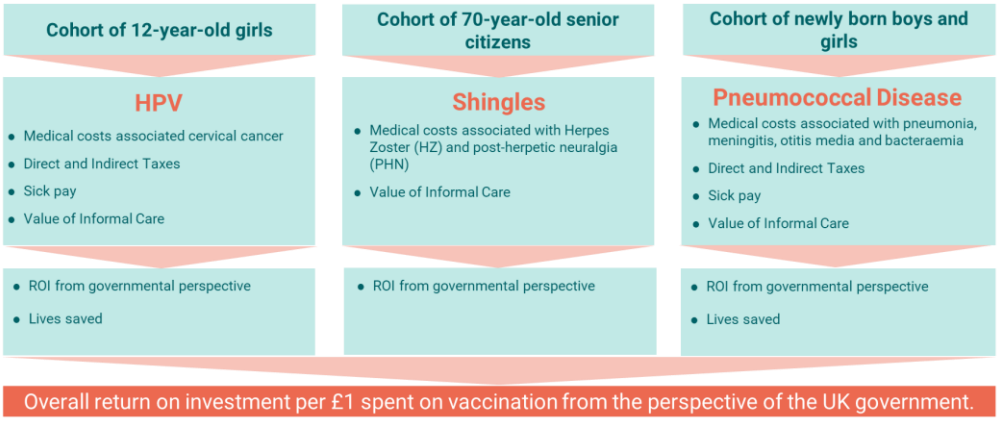

Figure 1: Sub-model overview

Costs

All costs are reported in 2018 GBP using consumer price inflation indices from the ONS (2019b).

Forgone taxes

The lost direct and indirect taxes to the government are estimated by summing the respective tax contribution from the time of premature deaths until the general life expectancy of the individual using the ONS lifetables. In case of direct taxes, individuals enter the workforce at the age of 16 and retire at the age of 66, while the average of indirect taxes per individual is paid until the death of that individual.

The latest available distribution of mean income and associated direct tax by age and gender for the year 2016-2017 were taken from publicly available information (GOV.UK, 2019b).

By subtracting the mean tax from the mean income an estimate of the disposable income was retrieved. A fixed fraction of 18% of the age-dependent specific income for males and females was assumed to be paid in indirect taxes (ONS, 2017).

All retrieved values were inflated to the year 2018 using CPI information and adjusted for unemployment based on unemployment rates in the year of 2018 (ONS, 2019a). The average unemployment rates are given in the appendix Table A10.

All other relevant input data is given in the appendices Table A11.

Paid-out of sick pay

The pay-outs per sick day were taken from publicly available information (GOV.UK, 2018) and multiplied with the number of sick-days associated with the individual vaccine-preventable disease. The model assumes a five-day workweek. The final pay-out has been adjusted for unemployment based on unemployment data in the year 2018 (ONS, 2019a). The resulting daily rate of statutory sick pay (SSP) per sick day is £17.64.

The model assumes that every disease leads to an absence of at least 4 days in a row so that the SSP payment is triggered and that no disease leads to more average sick days than the maximum of 28 weeks that SSP is paid out (GOV.UK, 2018).

Forgone value in informal care

While most human capital approaches ignore the output of the retired population, our model is in alignment with prior work by Franklin and Hochlaf (2018) and assumes their average of £3,091.67 (inflated to 2018 prices) of yearly economic value added through informal care provided by senior citizens. Examples of informal care include grandparents caring for their grandchildren or senior couples who care for each other. The model assumes that if this kind of informal care is lost due to premature death, it would instead be provided by either i) other family members who are likely part of the workforce, or ii) formal social care. This incurs costs to the government, in the form of lost taxes as family members are now caring instead of participating in the labour force or through direct expenses for social care. For reasons of simplicity, we assume that the incurred costs to the government equal the average economic value added by a senior citizen. We are aware, that this is a slight overestimation, as potentially, family members outside of the workforce could replace the lost value of informal care. This lost value of informal care is estimated by summing the yearly value of informal care that would be provided by a retired person for 2.6 years (Franklin and Hochlaf, 2018) if they would not have died prematurely.

In the case of the shingles vaccination model, an exemption is made. Mortality due to shingles is negligibly low, but there is a significant proportion of patients affected by severe long-lasting sequelae. Therefore, for reasons of simplicity, the model assumes one full year of lost informal care for each severe episode. Further details are given in section 2.3.

Discounting and Inflation adjustment

Adjusting for inflation is usually not done in health economic modelling from a health system perspective and costs and effects are discounted based on constant prices to account for the concept of time preference – that people prefer generally to receive goods and services now rather than later.

However, due to the long-time horizon of our model and the broader perspective, we follow the recommendation from the Treasury's Green Book to account for inflation in addition to discounting cost and benefits over time (HM Treasury, 2018). We assume long-term inflation for all cost data over the model's time horizon (i.e. direct and indirect taxes from the year of vaccination to the year of premature death as well as medical costs) to account for productivity increases. The applied long-term inflation rate of 2% p.a. is based on the target of the Bank of England (2019).

All modelling was carried out using Microsoft Excel and Visual Basic for Applications.

2.2 HPV vaccination program

Disease description, vaccination program, and modelling

The human papillomavirus (HPV) is the world's most frequent sexually-transmitted infection (Koutsky, 1997; Baseman and Koutsky, 2005). Although most infections are relatively harmless and do not lead to any long-term sequelae, some strains (notably strain 16 and 18) can lead to different kind of cancers (Kohli et al., 2007). This does not only come at a high price for health care systems due to the associated health-care costs but also has a significant impact on the quality and length of life of the affected women. Since 2008, the UK routinely offers vaccination of 12 and13-year-old girls against the HPV virus and extended the program in 2019 to boys[4] of the same age (VOX, 2019a). Our model includes only the vaccination program targeting 12-year old

[4] *Please note that model only considers the initial program design of vaccinating 12-year old girls only.*

girls, as the boy's vaccination program has been introduced too recently to be included in this report.

The model considers the health and economic burden of cervical cancers in the UK as originating from a prior HPV infection. It compares a hypothetical unvaccinated birth cohort of 12-year old girls over their lifetime to an identical cohort that is vaccinated with the current vaccine applied within the NHS, which protects against four strains of HPV.

The HPV model captures the direct medical lifetime costs associated with a cervical cancer episode and the sick day pay-outs. In case of premature death due to cervical cancer, the model also captures the foregone direct and indirect taxes to the Government and the forgone value of informal care provided by senior citizens (e.g. taking care of grand-children or caring for spouses in times of disease).

Due to the static nature of the model, herd immunity is not considered. Also, the model does not include other types of adverse health outcomes related to an HPV infection (i.e. anal cancer or genital warts) and we did not model a male cohort due to its very recent introduction to this project. Therefore, the model underestimates the ROI of the HPV vaccination program to the government.

Table 2: Main parameters for the HPV model in 2018 GBP.

Parameter	Value	Source
Vaccination age	12	(NHS, 2019a)
Duration of protection	Lifelong	Assumption in alignment with (Chesson et al., 2008)
Coverage	87%	(PHE, 2018)
Cost of vaccine per dose	£85.06	(NICE, 2019a)
Cost of administration	£10.06	(Primary Care Strategy and NHS Contracts Group, 2019)
Number of doses	2	(NHS, 2017)
Lifetime cost of cervical cancer episode	£17,589	(Datta et al., 2019)
Sick days per cervical cancer case	151	(Mehnert, 2011)

Epidemiological data

Data on the age-dependent incidence of cervical cancer, the related age-dependent mortality rate and the proportion of cervical cancer cases that are due to an HPV infection (76%) was taken from Jit et al. (2014) and is given in Table A12. Data on sick days associated with an episode of cervical cancer were taken from Mehnert (2011).

Costs

The costs of £85.06 for a single dose of the vaccine currently applied within the NHS, were taken from the British National Formulary[5] (NICE, 2019a). To yield full protection, the administration of

[5] Please note that this is likely to be an overestimation due to undisclosed discounts from the manufacturer to the NHS.

two dosages is necessary (NHS, 2017), which increases the direct and indirect costs of the vaccination program.

Vaccine efficacy

In alignment with other authors (see Jit et al. (2014) or Chesson (2008)) we assumed a 100% efficacy of the current HPV vaccine in the National Immunisation Schedule against the main adverse outcome of cervical cancer in women. A coverage of 87% was multiplied with this efficacy rate based data from Public Health England (PHE, 2018).

2.3 Shingles vaccination program

Disease description, vaccination program and modelling

Herpes Zoster, better known as shingles, occurs from the reactivation of a latent Varicella Zoster Virus (VZV) infection. Although a shingles outbreak can occur at any given age, its incidence is known to increase with age (Public Health England, 2018) and more than two-thirds of all cases happen in patients over the age of 60 years (Lumb, 2010).

While the outbreak of shingles itself rarely leads to fatal cases, patients experience a painful rash for two to four weeks that lowers the quality of life and may require hospitalisation. Furthermore, an outbreak may lead to long term sequelae due to complications. The most common complication is the post-herpetic neuralgia (PHN), which is nerve-damage caused either by the virus itself or by an inflammatory response to it. PHN can last for a prolonged time (i.e. month or even years) and its frequency and severity increases with age (Lumb, 2010).

Shingles and PHN result in a significant human and economic burden (Gater et al., 2015). In the UK, the Joint Committee on Vaccination and Immunisation (JCVI) made a positive recommendation for a shingles vaccination program for adults aged 70 in 2010, after which the vaccine was routinely offered to adults aged 70 and to those aged 79 years as part of the catch-up campaign (Public Health England, 2018). Several modifications around the eligibility criteria concerning age and special rules for patients that missed the original vaccination rounds make the calculation of total coverage complex (Public Health England, 2018).

Today, adults become eligible on their 70th birthday for the initial routine vaccination and the catch-up programme on their 78th birthday. They remain eligible until their 80th birthday (Public Health England, 2018). Target age groups were chosen based on cost-effectiveness analysis considering the age-specific incidence of herpes zoster (HZ) and PHN and the decline in vaccine efficacy with age (Amirthalingam et al., 2018).

To reduce complexity, the model takes only one vaccination at the age of 70 into account. The model considers the GP and potential hospitalisation costs of a single episode of shingles infection and the associated costs with its most common complication PHN. Vaccine efficacy varies for HZ and PHN as there appears to be an additional protective effect from the vaccine against PHN that becomes statistically significant in the age groups 70+ (van Hoeck et al., 2009).

Vaccination costs are estimated for the available population at 70 years of age. Due to the vaccination age of 70 years and above and the relatively low participation of that age group in the active workforce, it is assumed that an outbreak of shingles does not lead to a loss of income and therefore a loss to the government due to forgone direct taxes or sick pay to employers. Furthermore, as the mortality rate from shingles is negligibly low, a shingles outbreak does not affect indirect tax contributions from individuals.

The model does capture however the loss in the provision of informal care by senior citizens that are between 70 and 80 years old and who experience a PHN episode, as this informal care provider will likely be replaced by active members of the workforce or social care.

Table 3: Main parameters for the shingles model.

Parameter	Value	Source
Vaccination age	70 and 78	(NHS, 2019a)
Duration of protection (after second vaccination)	7.6 years	(van Hoek et al., 2009)
Vaccine coverage	72%	(Amirthalingam et al., 2018)
Cost of vaccine per dose	£98.29	(NICE, 2019b)
Cost of administration	£10.06	(NHS England, 2019b)
GP cost of Herpes Zoster episode	£98.49	(van Hoek et al., 2009)
GP cost of PHN episode	£442.80	(van Hoek et al., 2009)
Daily rate of associated hospitalisations	£279.98	(van Hoek et al., 2009)
Proportion of patients with long-term sequelae from PHN	48%	(Kost and Straus, 1996)

Epidemiological data

The age-dependent incidence and hospitalisation rates for herpes zoster and the proportion of PHN cases that lasted longer than 90 days were taken from van Hoek et al. (2009) and are given in Table A13. Based on Kost and Strauss (1996), we modelled 48% of all PHN cases to become a chronic condition.

Costs

For shingles, GP costs are captured while for PHN, GP costs and hospitalisation costs are considered. As a result of chronic PHN cases, we assumed that each chronic PHN case leads to the loss of one year in informal care that is produced by the affected individuals.

The costs of associated GP and hospital visits and the costs of severe PHN episodes were taken from van Hoek (2009) and inflated to 2018 GBP. The costs of the vaccine itself were taken from the British National Formulary[6] (NICE, 2019b).

Vaccine efficacy

Vaccine efficacy of 62% against Herpes Zoster and 88% against PHN was based on data provided by (Amirthalingam et al., 2018) and an average protection period of 7.6 years was assumed (van Hoek et al., 2009). The coverage rate of 72% was multiplied with the individual vaccine efficacy rate.

[6] *Please note that this is likely to be an overestimation due to undisclosed discounts from the manufacturer to the NHS.*

2.4 Pneumococcal disease vaccination program

Disease description, vaccination program and modelling

Pneumococcal infections are caused by a bacterium called Streptococcus pneumoniae S.*pneumoniae* (pneumococcus) and are major causes of morbidity and mortality worldwide. Frequently it leads to serious but uncommon invasive diseases which are defined by the isolation of S. pneumoniae from a normally sterile site, such as blood, cerebrospinal fluid (CSF), pleural fluid, or synovial fluid. Meningitis (the inflammation of the brain and spinal cord), and bacteraemia (a form of blood poisoning) are examples for such an Invasive Pneumococcal Disease (PID) and both diseases are often life-threatening.

More commonly, it leads to non-invasive diseases such as non-bacteremic pneumonia and acute otitis media (Weycker et al., 2016). Pneumococcal pneumonia where the pneumococcus may be responsible for up to 60% of the total community-acquired pneumonia cases (Lim et al., 2009) and may lead to around 40,000 hospitalisations per year in the UK (VOX, 2019b).

There are over 90 different serotypes of the pneumococcus bacteria and in the UK two vaccines are available that are either given in the first year after the birth or to adults and those in clinical risk groups. In this model, we only focus on the vaccination program for infants. The infant vaccine protects against 13 serotypes of pneumococcal bacteria and is given at 12 weeks, followed by a booster at one-year-old (GOV.UK, 2020). While the long-term effects of the vaccination program are unclear, the base case considers life-long protection given a 1+1 schedule in infants.

The model considers cases and associated costs for all-cause pneumonia, meningitis, bacteraemia and acute otitis media triggered by a vaccine-preventable *S.pneumoniae* infection and that lead to hospitalisation. Most parameters were taken from Delgleize (2016) as it provided relevant information on most parameters and diseases of interest in one study.

As pneumonia, meningitis, bacteraemia is associated with an age-dependent mortality increase and significant sick days for parents and patients, the model captures foregone earnings in direct and indirect taxes, forgone value of informal care provided by senior citizens due to premature death, as well as pay-outs due to associated sick days.

Table 4: Main parameters of the pneumococcal disease model.

Parameter	Value	Source
Vaccination age	1	(NHS, 2019b)
Duration of protection (after second vaccination)	lifelong	Assumption but also lowered in sensitivity analysis
Vaccine efficacy against IPD	94.7 %	(Delgleize et al., 2016)
Vaccine efficacy against all-cause pneumonia	23.4 %	(Delgleize et al., 2016)
Vaccine efficacy against Acute Otitis Media	69.9%	(Delgleize et al., 2016)
Vaccine coverage	91 %	(Nuffield Trust, 2019)
Cost of vaccine per dose	£49.1	(NICE, 2019a)
Cost of administration	£10.06	(NHS England, 2019a)

Number of doses	2	(NHS, 2019b)
Hospitalisation costs of meningitis acute episode (children)	£8,377.83	(Delgleize et al., 2016)
Hospitalisation costs of meningitis acute episode (adults)	£7,707.35	(Delgleize et al., 2016)
Hospitalisation costs of bacteraemia acute episode (children)	£7,018.78	(Delgleize et al., 2016)
Hospitalisation costs of bacteraemia acute episode (adults)	£6,690.98	(Delgleize et al., 2016)
Hospitalisation costs of pneumonia acute episode (children)	£5,226.00	(Delgleize et al., 2016)
Hospitalisation costs of pneumonia acute episode (adults)	£4,981.00	(Delgleize et al., 2016)
Hospitalisation costs of Acute Otitis Media episode (children)	£1,215.00	(Delgleize et al., 2016)
Hospitalisation costs of Acute Otitis Media episode (adults)	£1,215.00	(Delgleize et al., 2016)
Average workdays lost per meningitis episode for parents and patients	18.20	(Delgleize et al., 2016)
Average workdays lost per bacteraemia episode for parents and patients	10.7	(Delgleize et al., 2016)
Average workdays lost per pneumonia episode for parents and patients	10.30	(Delgleize et al., 2016)

Epidemiological data

Data on age-dependent hospitalisations due to all-cause pneumonia and age-dependent incidence rates due to IPD that leads to either meningitis or bacteraemia before any vaccination against S.pneumoniae was introduced in 2006 and all related case fatality ratios were taken from Melegardo and Edmunds (2004) and are given in Table A14. Information from Delgeize el al. (2016) provided furthermore the number of associated sick days with pneumonia, meningitis and bacteraemia.

Costs

The associated medical costs for adverse medical outcomes associated with hospitalisations were taken from Delgeize (2016). For reasons of complexity, outpatient costs were ignored, which is an underestimation of the true value. A single dose price of £49.1 was based on information of the BNF[7] (NICE, 2019a) and a two-dose schedule was applied in the model.

Vaccine efficacy

The model considers a lifelong vaccine protection period, but the efficacy differs per adverse outcome. For serotypes that trigger IPD and hence may lead to meningitis and bacteraemia an efficacy of 94.7% per cent was applied, while for the cases of pneumonia that were triggered by an *S.pneumoniae* infection a vaccine efficacy of 23.4 % was considered (Delgleize et al., 2016). Overall coverage of 91% was taken from an analysis of the PHE data (Nuffield Trust, 2019) and multiplied with the efficacy values.

[7] *Please note that a discount of 20% on the respective vaccine price may be an underestimation of the true discount resulting from bulk buying contracts of vaccines in England. This would, in return, underestimate the estimated ROI.*

2.5 Sensitivity Analysis

A one-way sensitivity analysis was carried out for selected parameters. Their ranges are given in given in Table 5. The discount rate of effects as well as the overall coverage rates was not included as those parameters do not affect the overall ROI of a static model.

Table 5: One-way sensitivity analysis - input parameters

Parameter	Base case	Lower Value	Higher Value
Vaccine price[8]	List prices from BNF	-20% discount	n/a
Discount rate of costs	3.5%	1.5%[9]	n/a
Long term inflation	2%	0%	4%
Duration of Protection (for Pneumococcal Disease only)	Lifelong	65 years	n/a

[8] Please note that the 20% discount rate have been assumed based on the standard practice in cost-effectiveness/cost-utility modelling and do not represent any bulk discount rate that may have been agreed between the vaccine manufacturer and Public Health England. A higher price than the list price published on the BNF is not realistic and is therefore not considered.

[9] A cost discount rate of 1.5% is the recommended lower bound for sensitivity analyses as per the reference case for Technology Appraisals by NICE; it is also the discount rate recommended in the NICE methods for public health guidance.

3 Results

Our model-based analyses of three selected vaccination programs targeting either new-borns, children or senior citizens in the UK and their impact on relevant medical costs, direct and indirect taxes and sick day pay-outs, suggest an average ROI of £2.18 for every pound spent when the 3.5% discounted rates of the NICE reference case are applied. However, as Figure 2 shows, there is a large difference between the discounted and undiscounted results for each vaccination program that reflects the impact of discounting over the individual model lifetime. There is also a clear difference between the programs that are discussed in the sections below.

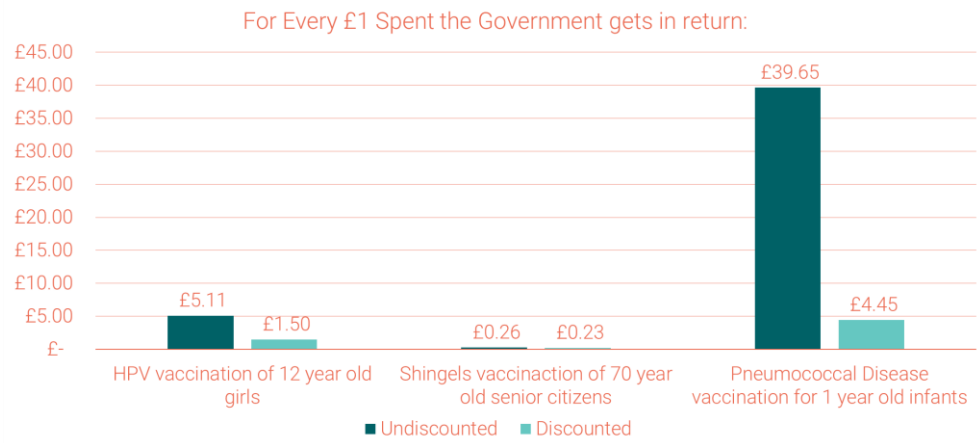

Figure 2: ROI per £1 spent from governmental per vaccination programs in the UK.
All monetary value given at 2018 GBP prices.

The model also estimates the number of lives saved which are given in Table 6.

Table 6: Lives saved by HPV and Pneumococcal Disease Vaccination Programs over for the respective birth cohorts.

	HPV vaccination program	Pneumococcal Disease Vaccination Program
Number of lives saved (undiscounted)	723	3769
Number of lives saved (discounted at 3.5%)	140	296

3.1 Results of the HPV vaccination program

The ROI for the HPV vaccination program is 50%. Much of the broader value for the government (60%) is driven by preserving the indirect taxes that would have been lost if the individual had died prematurely. The preserved direct tax to the government is of a lower magnitude due to capped time of an individual's active participation in the workforce.

Table 7: Results of the HPV model (discounted at 3.5%) for a cohort size of 384,526 12-year-old girls. All monetary values are given GBP at 2018 prices.

	Difference between non-vaccinated and vaccinated groups (% of the total)
Total Vaccination costs	£63,527,142
Direct Medical Costs of preventable disease	-£18,868,836 (19.8%)
Forgone Income Tax	-£15,776,666 (16.6%)
Forgone Indirect Taxes	-£56,849,310 (59.7%)
Sick day pay-outs	-£2,366,240 (2.5%)
Forgone value of informal care	- £1,298,633 (1.4%)
ROI	50%
Every 1 £ spend yields returns of	£1.50

3.2 Results of the shingles vaccination program

For the shingles vaccination, every £1 spent by the government would return £0.23. As can be seen in Table 8, over 50% of the actual value potential is generated by preserving an elderly's ability to provide informal care, which would otherwise have been lost due to long-lasting PHN. As the model considers no mortality from shingles, there is no impact on direct or indirect taxes or NI pay-outs.

Table 8: Results of the shingles model (discounted at 3.5%) for a cohort of 716,904 men and women aged 70. All monetary values are given GBP at 2018 prices.

	Difference between non-vaccinated and vaccinated groups (% of the total)
Total Vaccination costs	£27,920,439
GP Costs of HZ	-£1,017,017 (15.9%)
GP costs PHN	-£1,091,054 (17.1%)
Direct Hospitalisation Costs	-£626,781 (9.8%)
Forgone value of informal care	-£1,091,054 (57.2%)
ROI	-77%
Every 1 £ spend yields returns of	£0.23

3.3 Results of the pneumococcal disease vaccination program

The largest ROI of all the vaccination programs in all three models is estimated to come from the pneumococcal vaccine programs for newly born babies. The discounted ROI is £4.45 on every £1 the government spends on the program. Here, indirect tax contributions that would be lost without vaccination are again the main driver of the ROI (55%) and 23% of the value are delivered through a reduction in direct medical costs due to hospitalisation triggered by an associated outcome.

Table 9: Results of pneumococcal disease model (discounted at 3.5%) for 752,862 new-borns. All monetary values are given GBP at 2018 prices.

	Difference between non-vaccinated and vaccinated groups (% of the total)
Total Vaccination costs	£37,424,433
Hospitalisation Costs Pneumonia	-£17,145,037 (10.3%)
Hospitalisation Costs of Meningitis	-£479,715 (0.3%)
Hospitalisation Costs of Bacteraemia	-£7,286,509 (4.4%)
Hospitalisation Costs of AOM	-£13,576,803 (8.1%)
Forgone Income Tax	-£26,702,708 (16.0%)
Forgone Indirect Taxes	-£92,364,096 (55.4%)
Sick day pay-outs	-£363,726 (0.2%)
Forgone value of informal care	-£8,765,510 (5.3%)
ROI	345%
Every 1 £ spend yields returns of	£4.45

3.4 Sensitivity analysis

The results of the one-way sensitivity analysis of three selected parameters for each vaccination program are given in Figure 3, Figure 4 and Figure 5. The latter also includes a lower range of assumed duration of protection for the pneumococcal disease program. The variation of the discount rate of costs and long-term inflation has a strong impact on those programs that target younger populations.

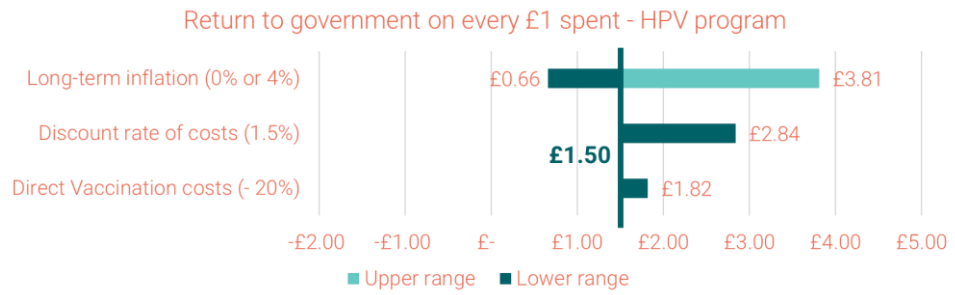

Figure 3: One-way sensitivity analysis for selected parameters of the HPV program.

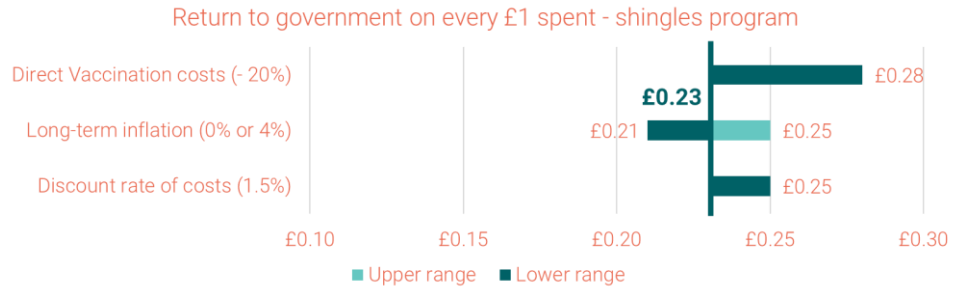

Figure 4: One-way sensitivity analysis for selected parameters of the shingles program

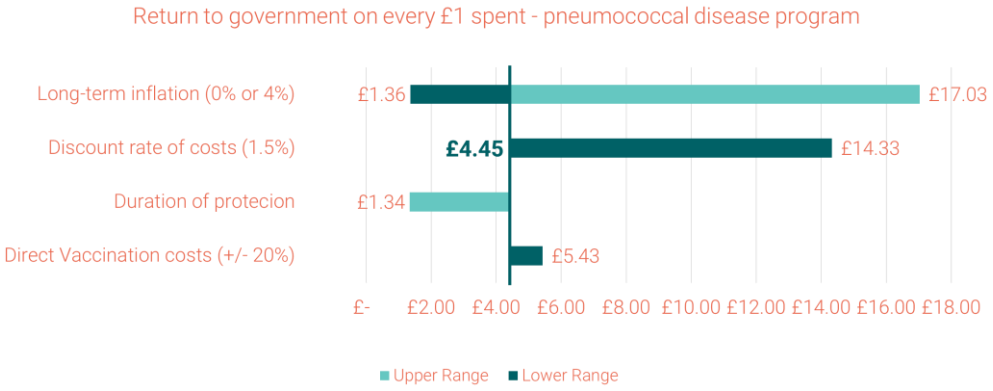

Figure 5: One-way sensitivity analysis for selected parameters of the pneumococcal disease program

4 Discussion

The model estimated the impact of three vaccination programs to the UK vaccination schedule compared to a no-vaccination scenario. On average, the return on investment to the government is £2.18 per £1 invested.

This number was estimated by modelling major associated medical costs with the vaccine-preventable disease (mostly hospitalisation costs) and the impact on the governments monetary in-flows in terms of direct and indirect taxes and out-flows in terms of sick day payments. Also, the model assessed the effect of vaccination on the provision of informal care by parents and spouses as, in case of premature death or disability due to a vaccine-preventable disease, we assume that those activities would be replaced by an active member of the workforce or by formal social care providers, either way incurring costs to the government.

As expected, the results are highly dependent on the discount rate and the long-term inflation rate, the costs of the vaccination programs and, in case of the pneumococcal disease vaccination program, the duration of protection provided the vaccine.

The approach used was similar to that of the Supporting Active Ageing Through Immunisation (SAATI) Partnership (SAATI, 2013). They report that every €1 invested in adult vaccination commencing at the age of 50 years would yield €4.02 of future economic revenue for the government over the lifetime of the (Dutch) cohort model. Our results are more conservative and may ultimately have underestimated the true ROI for several reasons discussed below.

The effect of discounting on the benefits of vaccination has been strongly debated in the literature (Jit and Mibei, 2015). The models' time horizon, up to 100 years of age, in combination with the discount rate of 3.5% of the NICE reference case, diminish most of the returns generated from tax income, which is especially visible in the pneumococcal disease results that fall from £39.65 per pound spent if no discounting is applied, to £14.33 per pound spent if costs are discounted at a rate of 1.5%, and to £4.45 per pound spent if the base case scenario discount rate of 3.5% is applied.

Other model assumptions impact results in the opposite direction. The long-term inflation rate for example, if set to 0% instead of 2%, would reduce the average discounted ROI of all three programmes from £2.18 to £0.76 spent which would represent a loss to the government while the break-even point would be reached at a long-term inflation rate of 0.56%. It is, however, implausible to assume such a low inflation rate, let alone no inflation.

The prices of the vaccines itself have a large impact on the overall results. As the base case prices are those listed in the British National Formulary, they do not reflect a possible bulk discount. If a conservative discount of 20% for every vaccine price is assumed, the average discounted ROI per pound spent on vaccination for all three programs increases by 20%, from £2.18 to £2.62. The true non-disclosed bulk discounts that are negotiated by the Department of Health and Social Care may lead an even higher RO: A priced discount of 30% leads to an ROI of £2.82 per £1 spent and to £3.29 per £1 spent in case of 40%.

The return on investment from a governmental perspective is furthermore strongly dependent on the underlying targeted population. The HPV vaccine is estimated to provide a positive return to the government even though cervical cancer is the only adverse outcome modelled. As most childhood or adolescent vaccination programs that prevent mortality, the HPV vaccination creates most of its ROI at later stages in life through accumulated taxes and informal care.

Concerning the shingles vaccine, the relatively lower ROI from a governmental perspective was expected a priori as no participation in the active working force of the targeted population was assumed. However, as the quality of life losses due to (long term) pain caused by herpes zoster infection is relatively large, the shingles vaccination program is cost-effective in the UK (van Hoek et al., 2009). This finding also demonstrates the complementary nature and information provided by the different modelling approach (i.e. fiscal health modelling and cost-effectiveness modelling).

The pneumococcal disease vaccination program generates a relatively high ROI due to its younger vaccination age and the prevention of fatal pneumococcal disease cases. While it is the only program that would potentially generate a positive ROI in case of zero long-term inflation even this model likely underestimates the true value as not all adverse outcomes such as long-term sequelae, and associated outpatient costs are captured by the model.

4.1 Strengths of this study

This study is one of the few attempting to quantify the return on investment of vaccination from a governmental perspective based on a quantification of the losses and gains in taxes and informal care. It considers three UK vaccination programs that differ significantly in their targeted population. Such models may, therefore, inform decision makers and budget holders, both in- and outside the healthcare system, in addition to cost-effectiveness analyses undertaken from a health system's perspective.

4.2 Weaknesses of this study

This study has several limitations that, all else equal, may have led to an over- or underestimation of the ROI of these programmes from a government perspective.

First, payments from the public budget to the individual (such as for education or pension payments) are not considered, which ignores potentially significant outflows from the public budget. Also, the assumption of a 2% inflation rate is likely to overestimate the productivity increase of medical services over time. These two limitations may have led to our ROI estimates being overestimated.

Second, vaccines costs are likely to be overestimated, due to non-disclosed discount agreements between the manufacturer and the Department of Health and Social Care. On the other hand, the model does not include potential carer costs associated with getting the vaccination. Whether this leads to an over- or underestimation of the modelled ROI is unclear as the size of the discount is unknown.

Third, vaccination programs can generate "substantial externalities (indirect effects on third parties via herd immunity) that are not necessarily observed with other types of medical interventions" (Mauskopf et al., 2018). Our model ignores herd-immunity for the HPV and pneumococcal disease program, both within and between generations. Therefore, it underestimates the broader value of these programs as more people benefit from vaccination without incurring the costs of it.

5 Conclusion

The three selected vaccination programs (pneumococcal disease, HPV and shingles) combined are estimated to generate a positive ROI to the government. As expected, vaccination programs that target a young population and prevent fatal events generate a relatively high ROI from a government perspective compared to programs targeting the elderly. Most of the financial returns generated are not captured within the healthcare system but accrue as tax income (which could be redistributed to any department). Tax contributions and the preservation of informal care provided *by* the elderly, are key drivers of the broader value of vaccination.

Because cost and benefits accrue over many years up to the expected lifetime of a vaccinated cohort, discounting and inflation rates have a large impact on the results and warrant careful consideration when set by the relevant stakeholders.

This study adds to work by others that recommend using fiscal health (and other types of modelling) to complement the more common cost-effectiveness analyses which use a narrower health system's perspective. The results of this analysis indeed demonstrated that for two of the assessed vaccination programs, the main monetary value is generated outside the healthcare system. The shingles vaccination program, with its focus on a population of senior citizens, does not generate comparable amounts of monetary value beyond its direct health impacts but has been found cost-effective in other analyses because it prevents long and painful sequel and therefore promotes healthy ageing.

Our recommendation is therefore that policymakers should carefully base their investment decisions for future vaccination programs first based on cost-utility evaluations as investments in health care are justified by the health gains produced alone. If, however, the concern is mainly a financial one and when there is evidence that a relatively large proportion of value is outside the healthcare system, complementary fiscal analyses provide this additional information.

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Appendix

Table A10: Average unemployment rates per age group 2018.
Source ONS (2019a).

AGE GROUP	AVERAGE 2018 [% OF TOTAL POPULATION]
Aged 16 and over	4.1
Aged 16-64	16.7
Aged 16-17	23.6
Aged 18-24	10.2
Aged 25-34	3.7
Aged 35-49	2.7

Table A11 Direct and Indirect Taxes for females.
Income and direct tax data are taken from GOV.UK (2019a), the share of indirect taxes of disposable income is taken from ONS (2017), unemployment data from ONS (2019b) and the consumer price index for price adjustment.

Direct and Indirect Taxes for females								
	Mean Income after tax	Share of Disposable Income spend on Indirect Tax	Mean indirect tax	Mean Direct Tax inflated to 2018	Mean Indirect Tax inflated to 2018	Un-employment rate 2018	Mean Direct Tax inflated to 2018 adjusted for un-employment	Mean Indirect Tax inflated to 2018 adjusted for un-employment
Under 20	14,818	18%	2,667	1,031	2,799	23.6%	788	2,140
20-24	16,840		3,031	1,427	3,181	10.2%	1,282	2,857
25-29	21,500		3,870	2,729	4,062	3.7%	2,628	3,912
30-34	24,680		4,442	3,904	4,662	2.7%	3,799	4,536
35-39	26,660		4,799	4,765	5,036	0.0%	4,765	5,036
40-44	27,560		4,961	5,290	5,206	0.0%	5,290	5,206
45-49	27,350		4,923	5,195	5,167	0.0%	5,195	5,167
50-54	26,280		4,730	4,744	4,965	3.0%	4,604	4,818
55-59	25,400		4,572	4,303	4,798	3.0%	4,176	4,657
60-64	22,970		4,135	3,390	4,339	1.4%	3,341	4,277
65-69	21,050		3,789	2,781	3,977	1.4%	2,741	3,919
70-74	19,820		3,568	2,393	3,744	1.4%	2,358	3,690

75 and over	18,990		3,418	2,214	3,587	1.4%	2,182	3,536

Table A12: Incidence and Mortality rates for cervical cancer.
Source (2014).

Age	Incidence rate	Mortality rate	Age	Incidence rate	Mortality rate	Age	Incidence rate	Mortality rate
0	0	0	**37**	0.000106	0.00001	**74**	0.000077	0.000069
1	0	0	**38**	0.000106	0.00001	**75**	0.000093	0.000104
2	0	0	**39**	0.000106	0.00001	**76**	0.000093	0.000104
3	0	0	**40**	0.000153	0.000026	**77**	0.000093	0.000104
4	0	0	**41**	0.000153	0.000026	**78**	0.000093	0.000104
5	0	0	**42**	0.000153	0.000026	**79**	0.000093	0.000104
6	0	0	**43**	0.000153	0.000026	**80**	0.000093	0.000104
7	0	0	**44**	0.000153	0.000026	**81**	0.000093	0.000104
8	0	0	**45**	0.00012	0.000029	**82**	0.000093	0.000104
9	0	0	**46**	0.00012	0.000029	**83**	0.000093	0.000104
10	0	0	**47**	0.00012	0.000029	**84**	0.000093	0.000104
11	0	0	**48**	0.00012	0.000029	**85**	0.000093	0.000104
12	0	0	**49**	0.00012	0.000029	**86**	0.000093	0.000104
13	0	0	**50**	0.000086	0.000036	**87**	0.000093	0.000104
14	0	0	**51**	0.000086	0.000036	**88**	0.000093	0.000104
15	0.000106	0.00001	**52**	0.000086	0.000036	**89**	0.000093	0.000104
16	0.000106	0.00001	**53**	0.000086	0.000036	**90**	0.000093	0.000104
17	0.000106	0.00001	**54**	0.000086	0.000036	**91**	0.000093	0.000104
18	0.000106	0.00001	**55**	0.000076	0.000043	**92**	0.000093	0.000104
19	0.000106	0.00001	**56**	0.000076	0.000043	**93**	0.000093	0.000104
20	0.000106	0.00001	**57**	0.000076	0.000043	**94**	0.000093	0.000104
21	0.000106	0.00001	**58**	0.000076	0.000043	**95**	0.000093	0.000104
22	0.000106	0.00001	**59**	0.000076	0.000043	**96**	0.000093	0.000104
23	0.000106	0.00001	**60**	0.000073	0.00005	**97**	0.000093	0.000104
24	0.000106	0.00001	**61**	0.000073	0.00005	**98**	0.000093	0.000104
25	0.000106	0.00001	**62**	0.000073	0.00005	**99**	0.000093	0.000104
26	0.000106	0.00001	**63**	0.000073	0.00005	**100**	0.000093	0.000104
27	0.000106	0.00001	**64**	0.000073	0.00005			
28	0.000106	0.00001	**65**	0.000074	0.000057			
29	0.000106	0.00001	**66**	0.000074	0.000057			
30	0.000106	0.00001	**67**	0.000074	0.000057			
31	0.000106	0.00001	**68**	0.000074	0.000057			
32	0.000106	0.00001	**69**	0.000074	0.000057			
33	0.000106	0.00001	**70**	0.000077	0.000069			
34	0.000106	0.00001	**71**	0.000077	0.000069			
35	0.000106	0.00001	**72**	0.000077	0.000069			

Age	Incidence rate	Mortality rate	Age	Incidence rate	Mortality rate	Age	Incidence rate	Mortality rate
36	0.000106	0.00001	**73**	0.000077	0.000069			

Table A13: Incidence and Hospitalisation rate for Herpes Zoster and related sequelae.
Source van Hoeck (2009, 2012).

Age	Incidence rate (Herpes zoster)	Hospitalisation rate due to HZ	Hospitalisation days per stay due to HZ	Proportion of developing PHN (Postherpetic neuralgia)
0-69	0	0	0	0
70	0.008760	1.5%	11.000000	15%
71	0.008760	1.5%	11.000000	15%
72	0.008760	1.5%	11.000000	15%
73	0.008760	1.5%	11.000000	15%
74	0.008760	1.5%	11.000000	15%
75	0.009610	2.2%	14.000000	20%
76	0.009610	2.2%	14.000000	20%
77	0.009610	2.2%	14.000000	20%
78	0.009610	2.2%	14.000000	20%
79	0.009610	2.2%	14.000000	20%
80	0.010460	3.0%	17.000000	27%
81	0.010460	3.0%	17.000000	27%
82	0.010460	3.0%	17.000000	27%
83	0.010460	3.0%	17.000000	27%
84	0.010460	3.0%	17.000000	27%
85	0.012160	4.4%	22.000000	52%
86	0.012160	4.4%	22.000000	52%
87	0.012160	4.4%	22.000000	52%
88	0.012160	4.4%	22.000000	52%
89	0.012160	4.4%	22.000000	52%
90	0.012160	4.4%	22.000000	52%
91	0.012160	4.4%	22.000000	52%
92	0.012160	4.4%	22.000000	52%
93	0.012160	4.4%	22.000000	52%
94	0.012160	4.4%	22.000000	52%
95	0.012160	4.4%	22.000000	52%
96	0.012160	4.4%	22.000000	52%
97	0.012160	4.4%	22.000000	52%
98	0.012160	4.4%	22.000000	52%
99	0.012160	4.4%	22.000000	52%
100	0.012160	4.4%	22.000000	52%

Table A14: Hospitalisation rates for adverse effects triggered by S. Streptococcus based on data taken from Melegardo and Edmunds (2004).

Age	Hospitalisation rate of all-cause pneumonia	Incidence rate of Invasive Meningitis	Incidence of Bacteraemia	Case Fatality Ratio of Pneumonia	Case Fatality Ratio of Meningitis	Case Fatality Ratio of Bacteraemia
0	0.002212	0.000095	0.000273	1%	9.2%	2.6%
1	0.001312	0.000040	0.000106	0%	13%	2%
2	0.001312	0.000006	0.000106	0%	17%	3%
3	0.001312	0.000006	0.000106	0%	17%	3%
4	0.001312	0.000006	0.000106	0%	17%	3%
5	0.000417	0.000003	0.000019	1%	5%	0%
6	0.000417	0.000003	0.000019	1%	5%	0%
7	0.000417	0.000003	0.000019	1%	5%	0%
8	0.000417	0.000003	0.000019	1%	5%	0%
9	0.000417	0.000003	0.000019	1%	5%	0%
10	0.000172	0.000001	0.000007	2%	5%	0%
11	0.000172	0.000001	0.000007	2%	5%	0%
12	0.000172	0.000001	0.000007	2%	5%	0%
13	0.000172	0.000001	0.000007	2%	5%	0%
14	0.000172	0.000001	0.000007	2%	5%	0%
15	0.000163	0.000002	0.000012	2%	12%	0%
16	0.000163	0.000002	0.000012	2%	12%	0%
17	0.000163	0.000002	0.000012	2%	12%	0%
18	0.000163	0.000002	0.000012	2%	12%	0%
19	0.000163	0.000002	0.000012	2%	12%	0%
20	0.000181	0.000002	0.000018	3%	12%	8%
21	0.000181	0.000002	0.000018	3%	12%	8%
22	0.000181	0.000002	0.000018	3%	12%	8%
23	0.000181	0.000002	0.000018	3%	12%	8%
24	0.000181	0.000002	0.000018	3%	12%	8%
25	0.000260	0.000002	0.000031	3%	12%	20%
26	0.000260	0.000002	0.000031	3%	12%	20%
27	0.000260	0.000002	0.000031	3%	12%	20%
28	0.000260	0.000002	0.000031	3%	12%	20%
29	0.000260	0.000002	0.000031	3%	12%	20%

Age	Hospitalisation rate of all-cause pneumonia	Incidence rate of Invasive Meningitis	Incidence of Bacteraemia	Case Fatality Ratio of Pneumonia	Case Fatality Ratio of Meningitis	Case Fatality Ratio of Bacteraemia
30	0.000260	0.000002	0.000031	3%	12%	20%
31	0.000260	0.000002	0.000031	3%	12%	20%
32	0.000260	0.000002	0.000031	3%	12%	20%
33	0.000260	0.000002	0.000031	3%	12%	20%
34	0.000260	0.000002	0.000031	3%	12%	20%
35	0.000260	0.000002	0.000031	3%	12%	20%
36	0.000260	0.000002	0.000031	3%	12%	20%
37	0.000260	0.000002	0.000031	3%	12%	20%
38	0.000260	0.000002	0.000031	3%	12%	20%
39	0.000260	0.000002	0.000031	3%	12%	20%
40	0.000260	0.000002	0.000031	3%	12%	20%
41	0.000260	0.000002	0.000031	3%	12%	20%
42	0.000260	0.000002	0.000031	3%	12%	20%
43	0.000260	0.000002	0.000031	3%	12%	20%
44	0.000260	0.000002	0.000031	3%	12%	20%
45	0.000554	0.000004	0.000065	14%	16%	26%
46	0.000554	0.000004	0.000065	14%	16%	26%
47	0.000554	0.000004	0.000065	14%	16%	26%
48	0.000554	0.000004	0.000065	14%	16%	26%
49	0.000554	0.000004	0.000065	14%	16%	26%
50	0.000554	0.000004	0.000065	14%	16%	26%
51	0.000554	0.000004	0.000065	14%	16%	26%
52	0.000554	0.000004	0.000065	14%	16%	26%
53	0.000554	0.000004	0.000065	14%	16%	26%
54	0.000554	0.000004	0.000065	14%	16%	26%
55	0.000554	0.000004	0.000065	14%	16%	26%
56	0.000554	0.000004	0.000065	14%	16%	26%
57	0.000554	0.000004	0.000065	14%	16%	26%
58	0.000554	0.000004	0.000065	14%	16%	26%
59	0.000554	0.000004	0.000065	14%	16%	26%
60	0.000554	0.000005	0.000065	14%	16%	27%
61	0.000554	0.000009	0.000065	14%	16%	27%
62	0.000554	0.000009	0.000065	14%	16%	27%
63	0.000554	0.000009	0.000065	14%	16%	27%
64	0.000554	0.000009	0.000065	14%	16%	27%

Age	Hospitalisation rate of all-cause pneumonia	Incidence rate of Invasive Meningitis	Incidence of Bacteraemia	Case Fatality Ratio of Pneumonia	Case Fatality Ratio of Meningitis	Case Fatality Ratio of Bacteraemia
65	0.001936	0.000009	0.000187	29%	30%	27%
66	0.001936	0.000007	0.000187	29%	30%	27%
67	0.001936	0.000007	0.000187	29%	30%	27%
68	0.001936	0.000007	0.000187	29%	30%	27%
69	0.001936	0.000007	0.000187	29%	30%	27%
70	0.001936	0.000008	0.000187	29%	30%	27%
71	0.001936	0.000008	0.000187	29%	30%	27%
72	0.001936	0.000008	0.000187	29%	30%	27%
73	0.001936	0.000008	0.000187	29%	30%	27%
74	0.001936	0.000008	0.000187	29%	30%	27%
75	0.006977	0.000005	0.000425	46%	30%	40%
76	0.006977	0.000005	0.000425	46%	30%	40%
77	0.006977	0.000005	0.000425	46%	30%	40%
78	0.006977	0.000005	0.000425	46%	30%	40%
79	0.006977	0.000005	0.000425	46%	30%	40%
80	0.006977	0.000001	0.000425	46%	30%	40%
81	0.006977	0.000001	0.000425	46%	30%	40%
82	0.006977	0.000001	0.000425	46%	30%	40%
83	0.006977	0.000001	0.000425	46%	30%	40%
84	0.006977	0.000001	0.000425	46%	30%	40%
85	0.006977	0.000003	0.000425	46%	30%	40%
86	0.006977	0.000003	0.000425	46%	30%	40%
87	0.006977	0.000003	0.000425	46%	30%	40%
88	0.006977	0.000003	0.000425	46%	30%	40%
89	0.006977	0.000003	0.000425	46%	30%	40%
90	0.006977	0.000005	0.000425	46%	30%	40%
91	0.006977	0.000005	0.000425	46%	30%	40%
92	0.006977	0.000005	0.000425	46%	30%	40%
93	0.006977	0.000005	0.000425	46%	30%	40%
94	0.006977	0.000005	0.000425	46%	30%	40%
95	0.006977	0.000005	0.000425	46%	30%	40%
96	0.006977	0.000005	0.000425	46%	30%	40%
97	0.006977	0.000005	0.000425	46%	30%	40%
98	0.006977	0.000005	0.000425	46%	30%	40%
99	0.006977	0.000005	0.000425	46%	30%	40%

Age	Hospitalisation rate of all-cause pneumonia	Incidence rate of Invasive Meningitis	Incidence of Bacteraemia	Case Fatality Ratio of Pneumonia	Case Fatality Ratio of Meningitis	Case Fatality Ratio of Bacteraemia
100	0.006977	0.000005	0.000425	46%	30%	40%

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