The Value of Vaccines in Maintaining Health System Capacity in England
The Value of Vaccines in Maintaining Health System Capacity in England

Simon Brassel
Office of Health Economics, London

Margherita Neri
Office of Health Economics, London

Hannah Schirrmacher
Office of Health Economics, London

Lotte Steuten
Office of Health Economics, London

Please cite this report as:

Corresponding Author:
Simon Brassel
sbrassel@ohe.org

For further information please contact:

Professor Graham Cookson
Chief Executive, OHE
Honorary Visiting Professor in Economics at City, University of London

Tel +44 (0)207 747 1408
Email gcbookson@ohe.org
Many of the studies OHE Consulting performs are proprietary and the results are not released publicly. Studies of interest to a wide audience, however, may be made available, in whole or in part, with the client’s permission. They may be published by OHE alone, jointly with the client, or externally in scholarly publications. Publication is at the client’s discretion.

Studies published by OHE as OHE Consulting Reports are subject to internal quality assurance and undergo external review, usually by a member of OHE’s Editorial Panel. Any views expressed are those of the authors and do not necessarily reflect the views of OHE as an organisation.

Funding and Acknowledgements

This consulting report was commissioned and funded by The Association of the British Pharmaceutical Industry (ABPI).
Table of Contents

Executive Summary ............................................................................................................................ iv
1 Introduction ................................................................................................................................. 1
  1.1 Background to this work ...................................................................................................... 1
  1.2 An overview of excess demand in the NHS ..................................................................... 1
  1.3 Why opportunity costs matter more in a situation of excess demand for hospital beds .... 3

2 Measuring health system capacity value of vaccines ............................................................. 5
  2.1 Conceptual approach ......................................................................................................... 5
  2.2 Numerical example ............................................................................................................ 7

3 Empirical demonstration of the health system capacity value for selected vaccination programmes .......... 10
  3.1 Methods ............................................................................................................................ 10
  3.2 Results .............................................................................................................................. 11
    3.2.1 Base case analysis ..................................................................................................... 11
    3.2.2 Sensitivity analyses ................................................................................................. 12
    3.2.3 What if analysis 1: Value of COVID-19 vaccine ......................................................... 13

4 Discussion .................................................................................................................................. 14
5 Conclusion .................................................................................................................................. 17

6 References .................................................................................................................................. 18

Appendix 1 Adaptations from the approach and model from Sandmann et al. ............................ 20
Appendix 2 Estimation of vaccine preventable hospitalisations ................................................ 22
Appendix 3 Estimation of the opportunity costs ....................................................................... 24
Appendix 4 Aggregating all costs .............................................................................................. 24
Appendix 5 Model inputs ............................................................................................................ 25
Appendix 6 What if analysis 2: excess demand for elective hip replacement procedures ........... 28
Executive Summary

**The NHS faces unprecedented health system pressure**

The NHS has a long-standing history of excess demand for hospital treatments. Today, however, there is a record number of patients waiting for care. Moreover, their underlying condition may worsen due to exceptional long waits fuelled by the disruption to regular care from the COVID-19 pandemic. As a result, the NHS’s health system pressure was never as high as it is today.

**The opportunity costs of making choices**

In a situation of excess demand for healthcare, treating one patient means losing the opportunity to treat another. Therefore, each decision bears an opportunity cost. However, when assessing the value of health technologies, particularly where these impact on the need for hospital resources such as bed days, these opportunity costs are not always fully considered. The reason for this is mostly pragmatic, as the conventional utilises available accounting costs to value relevant resources.

In this paper, we adopted a novel approach of estimating the opportunity costs in a hospital setting to reassess the value of vaccination. This approach proxies the opportunity costs through the net monetary benefit foregone as scarce health care resources are used to treat a vaccine-preventable outcome instead of treating a patient from the waiting list. We apply this approach to cost the resource ‘hospital beds’ for three different scenarios of excess demand:

- Scenario 1: no excess demand
- Scenario 2: excess demand from patients with regular conditions
- Scenario 3: excess demand from patients suffering from illnesses with increased severity due to long waiting times.

**Under severe health system pressure, the value of vaccination may more than double**

Our paper consists of a conceptual and an empirical part. Most importantly, our concept demonstrates that the opportunity cost avoided through vaccination rises with the overall size of the waiting lists and the share of patients in the waiting lists whose condition is more severe due to delayed care.

Empirically, we estimate this value for four selected vaccination programmes from the national schedule in England. Our results show that by preventing a vaccine-preventable outcome to block a hospital bed, the opportunity costs avoided are twice the direct costs saved by avoiding vaccine-preventable hospitalisations.

Our approach is transferable to any health technology that significantly reduces or prevents the need for healthcare resources across various care sectors and for which today’s demand already exceeds the relevant capacity.
1 Introduction

1.1 Background to this work

The broader value of vaccines can be loosely defined as those value elements that capture a vaccine’s impact beyond improving the quality and length of life of the vaccinated individual and cost offsets to the healthcare system from preventing disease. Examples of broader value are the impact of vaccines on transmission patterns of the underlying disease or the productivity of patients and their carers. In the past decades, several health economists have called for considering the broader value of vaccines in value assessments despite the challenges in measuring those broader value elements (Jit et al., 2015; Bloom et al., 2017; Bloom, Fan and Sevilla, 2018; Annemans et al., 2021).

Our prior work on the broader value of vaccines contributed to this ongoing discussion. For example, we qualified critical gaps between future vaccines’ potential ‘broader’ value and English regulators’ ‘narrow’ value recognition (Brassel et al., 2021). We also estimated that about 75% of the total return on investment on vaccination from a governmental perspective resulted from the prevention of lost productivity, mainly outside the health care sector (Brassel and Steuten, 2020) and is therefore unrecognised by the current health technology assessment methods in the UK.

This report builds on a specific recommendation given in Brassel, Neri and Steuten (2021) that called for “improving methods to capture the value of vaccines that maintain health system capacity”. Such value can theoretically be captured as the cost-offsets to the health care system if the full opportunity costs of relevant resources are measured correctly.

Therefore, we aim to demonstrate that vaccines’ value increases with the demand for health care services when considering the limited hospital resources and the associated opportunity costs with their utilisation. This work is relevant to policymakers, as it assesses the health system capacity value of vaccination given different levels of excess demand for health care in the UK.

1.2 An overview of excess demand in the NHS

Excess demand exists when the level of demand for a particular service or resource exceeds the level of its supply. In the context of the NHS, excess demand exists when patients require more treatment services that providers can supply because resources are limited. As in other resource-constrained settings, healthcare decision-makers face the challenge of value maximising choices (Drummond, 2015).

The NHS has a long history of excess demand in the hospital setting, which manifests itself through a backlog of patients waiting for resources to become available to treat them. While this is a problem in both primary and secondary care, this analysis focuses on inpatient hospital care.

Between 2018 and 2021, nine treatment functions have consistently made up 80% of the NHS backlog for inpatient treatments: trauma and orthopaedics, ophthalmology, general surgery, ear, nose and throat, gynaecology, urology, gastroenterology, dermatology, and others. In the monthly data provided by the NHS, excess demand is represented by the incomplete pathways, which capture those patients waiting to start their treatment at the end of each month. Before April 2020, excess demand in the NHS was present, but relatively stable.
After April 2020, however, providers reallocated a lot of resources from non-COVID treatments to deal with the pandemic. Initially, the NHS managed to keep the total number of patients on incomplete pathways at around four million due to the drop in referrals from primary doctors (Gardner, Fraser and Peytrignet, 2020). However, the backlog’s size eventually grew by an unprecedented 26% between April 2020 and March 2021 to around 5 million (Figure 1).

As the backlog grows, there is increasing pressure on the health system to address patients waiting for treatment. The NHS aims for the waiting time for non-urgent, consultant-led treatments to be no more than 18 weeks. During the pandemic, the share of incomplete pathways delayed by more than 18 weeks, grew from 10% to 35%, and was greater than 50% during peak times (Figure 2).
Longer waiting times have been shown to be associated with patient dissatisfaction, delayed access to treatments, poorer clinical outcomes, increased costs, inequality, and patient anxiety (McIntyre and Chow, 2020).

Given the current state of the NHS backlog, two elements of opportunity cost are relevant to consider. First, there is a large amount of excess demand for elective surgeries, e.g., regular hip and knee replacements that have been paused during the pandemic. Hence, the queue for treatment is longer. Secondly, longer waiting times lead to a more severe case-mix of patients at admission. Particularly for patients with cancer or other chronic progressive diseases, longer waiting times can lead to a deteriorated condition at admission, associated with poorer health outcomes and higher costs of treatment. As such, on average, the queue consists of more patients with more severe conditions (Hanna et al., 2020).

In the remaining chapters, we refer to the first type of patient case-mix as ‘regular’ and the latter as ‘severe’. Each of these has different implications for the opportunity costs associated with a blocked hospital bed which may have been avoided by vaccination.

1.3 Why opportunity costs matter more in a situation of excess demand for hospital beds

In a situation of excess demand, shown by a waiting list of patients, choosing to treat one patient means losing the opportunity to treat another patient at that time. Therefore, each decision bears an opportunity cost. Adequately estimating the opportunity costs of resources, such as hospital bed-
days is vital to understanding the full value of healthcare interventions, including vaccination programmes where these help to avoid hospital admissions for vaccine-preventable diseases.

For pragmatic reasons, reference costs or average accounting expenditures of the chosen alternative are often conventionally used in economic evaluations to approximate the opportunity cost of a bed-day. As such, explicit consideration of the second-best option is often dropped, which would only be adequate in the unlikely circumstance of perfect competition and the absence of any excess demand for bed-days. However, hospital bed-days are considered a prime example of a resource whose opportunity costs may diverge from the values calculated using conventional methods given the pervasive market failure in health care settings (Drummond, 2015, pp.223–224) and an omnipresent excess demand for services mentioned above.

To overcome this common flaw, Sandmann et al. (2018a) have developed a novel approach for estimating the opportunity cost of bed-days in terms of health forgone for the second-best patient, expressed in monetary terms. Their approach involves calculating the opportunity cost during excess demand depending on the chosen alternative. If the bed is used to treat the optimal patient (i.e., with the highest achievable net monetary benefit (NMB)), the opportunity cost of this choice equals the NMB of the forgone second-best alternative. However, if decision-makers do not use the bed-day for the optimal patient, Sandmann et al. (2018a) propose to proxy the opportunity cost of this bed-day as the sum of the highest NMB forgone plus the expenditure incurred.

Our work will assume that, on average, treating an acute, vaccine-preventable outcome is a suboptimal choice compared to the average elective treatment (see section 2.1 for details). Hence, the opportunity cost for the hospital bed-day when treating patient i (and having patient j as the next best alternative to patient i) is

\[ OC_i = LOS_i \times \left( \frac{C_i}{LOS_i} + \frac{B_j + \lambda - C_j}{LOS_j} \right) \]

where \( C_i \) is the cost incurred for the alternative chosen, \( B_j + \lambda - C_j \) is the net monetary benefit of the next best alternative based on the (health) benefit gained per second-best patient \( B_j \), the monetary value assigned to QALYs in local cost-effectiveness thresholds \( \lambda \) and the expenditure incurred per second-best patient \( C_j \). LOS is the length of stay of patient i or j, respectively.

Considering the continuous excess demand for hospital bed-days of patients with different needs and complexity in the NHS, this report demonstrates conceptually how using this novel method leads to a different estimate of the value of vaccines from the payer’s perspective in avoiding vaccine-preventable hospitalisations (chapter 2), before quantifying this value through empirical analysis (chapter 3).
2 Measuring health system capacity value of vaccines

2.1 Conceptual approach

In this section, we present the conceptual approach for measuring the value of vaccines that includes the value derived from maintaining the availability of health system capacity. This builds on the method of Sandmann et al. (2018a) for estimating the opportunity cost of bed days, as introduced in section 1.3. Their approach focuses on the hospital setting and assumes that beds are the key resource that facilitates access to hospital treatment, subject to excess demand. We expand this approach to show how the opportunity cost of hospital beds varies further depending on the type of patient, distinguishing between a ‘regular’ (waiting time for treatment <18 weeks) vs ‘severe’ (waiting time for treatment > 18 weeks) patient waiting for treatment.

To illustrate how the opportunity cost of this bed changes depending on the presence and the severity of patients waiting for treatment, we look at three scenarios of excess demand for hospital beds as illustrated in the middle section of Figure 3:

1. **No excess demand** (i.e., spare hospital bed capacity is available). This is a rather unrealistic scenario, as there is always some excess demand and alternative uses for the healthcare system resources like hospital beds.

2. **Excess demand for elective hospitalisations of ‘regular’ patients.** Elective patients are ‘regular’ in the sense that the severity of their condition is unaffected by the waiting period because their procedures are generally performed within the recommended waiting period. This scenario proxies a situation like the pre-COVID period when excess demand was present but waiting times targets for elective procedures were met¹.

3. **Excess demand for elective hospitalisations of ‘severe’ and ‘regular’ patients.** In this scenario, we assume that a large share of patients waits longer than 18 weeks for their treatment and whose severity of their underlying condition has therefore worsened. This scenario proxies a situation like the (post-)COVID period when a substantial number of patients in the NHS are waiting longer than the recommended target treatment timelines of 18-weeks.

¹ In fact the operational standard of treating 92% of all patients waiting for elective care within 18-weeks was last met in February 2016 (Thorby, Gardner and Turton, 2019), suggesting that scenario three has become the status quo well before the COVID-19 pandemic.
For each scenario, we measure the opportunity cost of the hospital bed from the payer’s perspective. Treating a patient suffering from a vaccine-preventable outcome generates opportunity costs in the form of forgone NMBs as long as regular and severe patients elective demand treatments that cannot be supplied due to the constrained resource of interest (hospital bed). We assume that these opportunity costs drop to zero as soon as the backlog with the respective patients is resolved.

**Scenario 1: No excess demand**

Under a no excess demand scenario (left column of Figure 3), the bed occupied by a patient with a vaccine-preventable disease carries no opportunity cost because spare bed capacity is available, and there is no alternative, immediate use of the same bed.

From a payer’s perspective, the value of vaccines is simply the avoidable economic costs to hospitalise and treat a patient due to a vaccine-preventable disease. This is equal to the value of vaccines when resources are valued according to the traditional reference cost method.

**Scenario 2: Excess demand for elective hospitalisations of regular patients**

With excess demand for elective hospitalisations of regular patients (middle column of Figure 3), there are alternative uses of the bed in addition to admitting a patient with a vaccine-preventable disease. Therefore, in this case, we must consider the opportunity cost associated with using the bed.

We assume that vaccine-preventable diseases lead to acute hospitalisations, which, due to their urgency, take priority over elective ones. Another assumed consequence of the urgency of acute hospitalisations is that, on average, they are more costly than elective ones. Therefore, blocking a bed with a vaccine-preventable disease represents a suboptimal choice when valuing resources according to the opportunity cost approach (i.e., lower NMB than elective hospitalisations).
Following Sandmann et al. (2018a), the opportunity cost of a bed blocked by a vaccine-preventable disease in scenario 2 is, therefore, the sum of the acute hospitalisation cost and the NMB forgone from an elective hospitalisation. This sum provides the value of vaccines from the payer’s perspective in preventing a vaccine-preventable hospitalisation.

At the margin where the associated excess demand is resolved, no further opportunity costs are generated.

**Scenario 3: Excess demand for elective hospitalisations of severe patients and regular patients**

In scenario 3 (right column of Figure 3), the opportunity cost of the bed blocked due to a vaccine-preventable disease can again be obtained as the sum of the acute hospitalisation cost and the NMB forgone from the next-best alternative use of the bed, as we do not use the bed for the best alternative.

In this case, the waiting list for elective treatments includes both regular and severe patients. According to the urgency of treatment principle, the admission of severe patients would take priority over regular elective patients and therefore represent the next-best alternative use of the bed occupied by a vaccine-preventable disease. When elective treatments are delayed for too long, this will negatively affect patient outcomes and potentially increase costs for many conditions. For example, there is ample evidence in the field of cancer that each month delay leads to a higher risk of mortality (Hanna et al., 2020) and larger costs (Ray et al., 2015). As a result, the forgone NMB will likely be lower than that in scenario 2.

Assuming that patients waiting for elective treatment do not get better without treatment, their excess demand does not resolve itself. Hence, the treatment of patients on the waiting list will resume as soon as vaccine-preventable hospitalisations are resolved. At this point, the hospitalisation of severe patients will have priority. Hence, their treatment carries an additional opportunity cost in terms of the forgone NMB from the elective hospitalisation of regular patients, which represents the next-best use of the same hospital bed.

In scenario 3, the value of vaccines in preventing that a vaccine-preventable disease blocks a bed is the sum of three components: the acute hospitalisation cost, the forgone NMB forgone from an elective hospitalisation of a severe patient, and the forgone NMB forgone from an elective hospitalisation of a regular patient.

### 2.2 Numerical example

This section provides a numerical example of the above conceptual development using hypothetical assumptions around the costs, health gains, and resulting NMBs of different hospitalisation types, as illustrated in Table 1.
TABLE 1 COST, HEALTH GAIN AND NMB BY HOSPITALISATION TYPE

<table>
<thead>
<tr>
<th>Hospitalisation type</th>
<th>Cost</th>
<th>Health gain</th>
<th>NMB</th>
<th>Hospitalisation priority (based on urgency)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acute hospitalisation, due to vaccine preventable disease</td>
<td>£5,000</td>
<td>0.5</td>
<td>£5,000</td>
<td>1st</td>
</tr>
<tr>
<td>Elective hospitalisation of regular patient</td>
<td>£1,000</td>
<td>0.5</td>
<td>£9,000</td>
<td>3rd</td>
</tr>
<tr>
<td>Elective hospitalisation of severe patient</td>
<td>£4,000</td>
<td>0.5</td>
<td>£6,000</td>
<td>2nd</td>
</tr>
</tbody>
</table>

Note: The assumed cost-effectiveness threshold is £20,000 per QALY.

Table 1 shows three types of patients that require hospitalisation. For simplicity, we assume that the health gained by each patient is the same. Acute hospitalisations resulting from a vaccine-preventable disease are associated with the highest costs due to the high urgency of treatment. The cost difference between elective hospitalisations of regular and severe patients reflects the idea that the same hospital treatment will be more expensive to perform in case of a worse prognosis.

Prioritisation decisions for hospital admission are made according to the order shown in the right-most column of Table 1, which reflects the urgency for treatment. To exemplify the idea of consecutive uses of the same bed, we consider the economic costs of a hospital bed in two successive time periods: T and T+1.

Table 2 depicts treatments, costs, and value of vaccination in periods T and T+1 for the three scenarios discussed in the previous section.

TABLE 2 VACCINATION VALUE BASED ON OPPORTUNITY COST (OC.) APPROACH FOR EACH SCENARIO

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Time period: treatment choice</th>
<th>Incurred cost</th>
<th>NMB forgone for the next best use</th>
<th>Vaccine value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. No excess demand</td>
<td>T: Acute hospitalisation due to vaccine-preventable outcome</td>
<td>£5,000</td>
<td>£0</td>
<td>£5,000</td>
</tr>
<tr>
<td></td>
<td>T+1: No treatment</td>
<td>£0</td>
<td>£0</td>
<td></td>
</tr>
<tr>
<td>2. Excess demand for elective hospitalisations of regular patients</td>
<td>T: Acute hospitalisation due to vaccine-preventable outcome</td>
<td>£5,000</td>
<td>£9,000</td>
<td>£14,000</td>
</tr>
<tr>
<td></td>
<td>T+1: Elective hospitalisation of regular patient</td>
<td>£1,000</td>
<td>£0</td>
<td></td>
</tr>
<tr>
<td>3. Excess demand for elective hospitalisations of severe patients and regular patients</td>
<td>T: Acute hospitalisation due to vaccine-preventable outcome</td>
<td>£5,000</td>
<td>£6,000</td>
<td>£20,000</td>
</tr>
<tr>
<td></td>
<td>T+1: Elective hospitalisation of severe patient</td>
<td>£4,000</td>
<td>£9,000</td>
<td></td>
</tr>
</tbody>
</table>

Scenario 1: No excess demand

In period T of scenario 1, the payer incurs a cost of £5,000 to hospitalise a patient affected by a vaccine-preventable disease. The forgone NMB of this choice is £0 because there is no excess demand for the hospital bed, neither at period T nor at period T+1.
The value of vaccination in scenario 1 corresponds to the avoidable costs of £5,000 associated with treating the vaccine-preventable outcome.

**Scenario 2: Excess demand for elective hospitalisations of regular patients**

In period T of scenario 2, the payer incurs the costs of £5,000 to treat a patient affected by a vaccine-preventable disease. However, in this case, the payer foregoes an NMB worth £9,000 from the elective hospitalisation of a regular patient in period T. The hospital must wait until period T+1 to carry out the elective procedure, which costs £1,000. At T+1, the forgone NMB is £0 because the hospital admission of the marginal regular patient means that the excess demand for elective hospitalisations is resolved.

From the payer perspective, the value of vaccination in scenario 2 is, therefore, £14,000. This corresponds to the sum of the hospitalisation costs due to the vaccine-preventable disease in period T (£5,000) and the forgone NMB of the elective hospitalisation in period T (£9,000). The hospitalisation cost of £1,000 incurred in period T+1 is not considered in the vaccination value because it is independent of the vaccination programme implementation (i.e., the hospital would incur these costs also when no vaccine-preventable outcome does not block the bed).

**Scenario 3: Excess demand for elective hospitalisations of severe patients and regular patients**

As for the previous scenarios, period T of scenario 3 is characterised by £5,000 incurred in hospitalisation cost of a patient affected by a vaccine-preventable disease. The payer forgoes a NMB worth £6,000 because the next-best use of the hospital bed in period T is the elective hospitalisation of a severe patient. In period T+1, the hospital bed can now be used by a severe patient, which costs £4,000. However, the payer is also forgoing an additional NMB of £9,000 in T+1. This is due to the persisting excess demand for elective hospitalisation of a regular patient, which in this case represents the next-best use of the hospital bed.

The value of vaccination in scenario 3 to the payer is, therefore, £20,000. This valuation results from the sum of the cost incurred to treat the vaccine-preventable outcome (£5,000), the forgone NMB of the elective hospitalisation of the severe patient in period T (£6,000) and the forgone NMB of the elective hospitalisation of the regular patient in period T+1 (£9,000). Like in scenario 2, the hospitalisation costs of £4,000 do not have to be considered as the payer would also incur these costs when no vaccination is present.
3 Empirical demonstration of the health system capacity value for selected vaccination programmes

3.1 Methods

Our empirical approach is motivated by prior work by Sandmann et al. (2018b). They estimated the hospital burden of norovirus-associated gastroenteritis in England, thereby implementing their novel idea on how to calculate the opportunity costs of hospital bed days in terms of health forgone for the second-best patient, but expressed monetarily (Sandmann et al., 2018a).

We adapted this approach to estimate the value of vaccination including, in part, its health system capacity value as it accrues from maintaining the availability of hospital beds that would otherwise be blocked due to vaccine-preventable hospital admissions. In contrast to common approaches in cost-effectiveness evaluation, we value our primary resource of interests (hospital bed days) based on their opportunity costs which include the NMB forgone associated with the next best alternative use of these bed days.

We do this for two scenarios of excess demand for the blocked hospital bed; the first reflecting excess demand for elective treatment, and the second reflecting the COVID backlog from pent-up demand of delayed elective treatments. The approach assumes that the hospital has no choice other than to treat the vaccine-preventable outcome first, a severe patient from the backlog second and regular backlog patient last. The opportunity costs then equal the sum of the incurred expenditure to treat the vaccine-preventable outcome and the forgone NMB approximate opportunity costs.

We created an Excel-based model that uses data from various public sources to estimate the health system capacity value for selected vaccination programmes that consider the opportunity costs of a blocked hospital bed. In the following paragraphs, we give an outline of the model structure. Appendix A provides more details on the model, including the input data and calculations.

We include four immunisation programmes from the English immunisation schedule in our analyses. These are the annual flu vaccination and vaccination against Meningococcal type B disease, Rotavirus and Pneumococcal Disease.

First, the model estimates the hospitalisations prevented by four vaccination programmes within specific age groups in the financial year 2018/2019 (pre-COVID period). We calculate the number of freed-up hospital bed days (prevented hospitalisations due to vaccine) and the related direct costs saved based on activity-weighted mean reference costs for the total activity within HRG codes relevant to the outcome prevented by the immunisation programme of interest. Appendix 5 outlines the values used for the input parameters of the model.

Second, we calculate the opportunity costs of a blocked hospital bed day. For the opportunity costing, we followed the approach by Sandmann et al. (2018b) for scenario 2 (regular excess demand) and adapted their values for scenario 2 (severe excess demand). They provided a base case estimate of the health gain from a regular admitted patient in England to proxy the health gain of the next-best alternative treatment. Together with the corresponding activity-weighted mean reference costs for elective, non-elective, non-elective short stay and day cases of the related HRG
and the cost-effectiveness threshold (£20,000), this allows computing the NMB of an average hospital treatment\(^2\), thus providing an estimate of the opportunity cost of a blocked hospital bed. To proxy the reduction in NMB forgone due to increased complexity of the underlying disease following a longer wait (scenario 2), we added a cost-premium based on the average monetary increase per complexity score\(^3\). The associated methods and values are laid out in more detail in appendix 5.

In the third and final step, we aggregate the results of steps one and two to estimate the savings stemming from avoiding vaccine-preventable hospitalisations and savings on opportunity costs of a blocked hospital bed. We estimate this value in three different base case scenarios, corresponding with three different levels of health system pressure, as described in chapter 2.

In summary, the model estimates the health system capacity value of selected vaccination programmes based on prevented hospitalisations in 2018/2019, given today’s backlog composition of excess demand for regular treatments plus the demand for treatments from patients with increased severity due to long delays.

**Sensitivity analyses**

We carry out a sensitivity analysis by varying the level of the NMB forgone associated with regular and severe patients. We use the upper and lower boundaries of the estimates of the NMB forgone provided by Sandmann et al. (2018b) to obtain the upper and lower values of the full economic costs saved by the four vaccination programmes when conserving hospital beds.

**Additional what-if analyses**

In addition to the base case analyses, we carry out two what-if analyses.

The first what-if analysis considers the health system capacity value of Public Health England’s estimate for the prevention of hospitalisation due to COVID vaccines until May 2021 (PHE, 2021a).

The second what-if analysis assumes that the total freed-up bed capacity by the four vaccination programmes is utilised to clear the large backlog associated with hip replacements. The increment in QALYs associated with hip replacements is larger than the upper boundaries for the average QALY gain provided by Sandmann et al. (2018a). The demand for hip surgeries is greater than the capacity-freed up by the immunisation programmes. Hence, we can safely assume that we do not overestimate the amounts of hip surgeries that the hospital could (in theory) perform using the freed-up bed capacity.

We report all monetary values in 2020 GBP.

### 3.2 Results

#### 3.2.1 Base case analysis

Figure 3 shows the value of four vaccination programmes regarding the economic costs saved under three excess demand scenarios.

---

\(^2\) Please see the appendix for simplifications of our approach in comparison to (Sandmann et al., 2018b).

\(^3\) Please note that a reduction in the achievable NMB is also likely stemming from the loss in QALYs from long waiting times (Krelle, Barclay and Tallack, 2021), that can not be fully gained back through elective care. However, for reasons of data availability we decided to proxy the reduction in NMBs forgone for severe patients through an increase in associated treatment costs.
The components of prevented economic cost are £71 million in savings from vaccine-preventable hospitalisations, £64 million from the elective hospitalisations of regular patients and £45 million from the elective hospitalisations of severe patients.

The total value of vaccination increases across the three scenarios, together with increasing pressure on the health care system. As soon as there is excess demand for elective treatments from regular patients, the value of vaccines increases from £71 million to £135 million (+90%).

With excess demand for elective procedures of both severe and regular patients, the value of vaccination further increases by 34% to £180 million. The value of vaccines in scenario 3 (excess demand for regular and severe patients) is approximately 2.5 times larger than in scenario 1 (no excess demand).

![Economic Costs Saved](image)

**FIGURE 4 ECONOMIC COSTS SAVED BY FOUR VACCINATION PROGRAMMES UNDER THREE EXCESS DEMAND SCENARIOS**

### 3.2.2 Sensitivity analyses

Figure 5 shows the economic costs saved by four vaccination programmes under the three excess demand scenarios with lower and upper bound values of forgone NMB of elective procedures. These are obtained by considering a range of different values for QALYs gained through elective procedures, which affect the NMB through changes in the (gross) monetary benefit generated by vaccination. We note that the results for the no excess scenario remain the same as there is no NMB forgone in this situation.

At the lower bound of the sensitivity analysis, the economic costs saved by the four vaccination programmes increases from £71 million to £91 million during excess demand from regular patients and further to £93 million when excess demand from severe patients is considered in addition. The latter is £45 million lower compared to the base case analysis in section 3.2.1.

At the upper bound of the sensitivity analysis, the economic costs saved are estimated at £144 million and £199 million in the scenarios of excess demand for regular elective patients and for both regular and elective patients, respectively. The latter represents an increase of £9 million compared to the base case analysis.
3.2.3 What-if analysis I: Value of COVID-19 vaccine

We present separately the economic costs saved when limiting the scope of analysis to the hospitalisations avoided by COVID-19 vaccines up to May 2021 (Figure 6). The actual number of freed-up bed days by the COVID vaccine until May 2021 is in close range to the combined annual freed-up bed days of the four other vaccination programmes. However, on average, COVID hospitalisation is more costly and requires a longer hospital stay. Hence, in the five months since the start of the COVID-19 vaccination programme, we estimate that the prevented economic costs amount to £370.15 million and £488.56 million in the scenarios of excess demand for regular patients and both regular and severe patients, respectively.
4 Discussion

This research illustrates a novel conceptual approach to estimate the value of vaccines from the payer’s perspective in maintaining the availability of health system capacity under various scenarios of excess demand. A complementary empirical model estimates this value for a selection of four vaccination programmes in England.

The findings add to the understanding of the broader value of vaccines and support the argument made by various health economists, including ourselves, that immunisation technology may be systematically undervalued (Jit et al., 2015; Bloom et al., 2017; Bloom, Fan and Sevilla, 2018; Bell, Neri and Steuten, 2020; Brassel and Steuten, 2020; Annemans et al., 2021; Brassel, Neri and Steuten, 2021; Brassel et al., 2021).

Traditional value assessment methods consider vaccines (and any other preventative treatments) as if there was no excess demand for the resources in a health care system (our “scenario 1”). There is, however, a long-standing history of excess demand for hospital bed days within the NHS, and the assumption of no excess demand is therefore unrealistic. Hence, the current approach does not appropriately consider the opportunity costs stemming from patients who miss out on their treatment when a patient with a vaccine-preventable outcome blocks a hospital bed. This usually ignored component of vaccines’ value can be seen as the value of vaccines in maintaining the availability of hospital capacity as long as there is excess demand for treatments.

The results of the empirical model illustrate the magnitude of the issue. We considered four vaccination programmes in England that prevent large numbers of annual hospitalisations. From the national payer’s perspective, the four vaccine programmes save approximately £70 million per year in direct hospitalisation costs associated with the vaccine-preventable outcome.

In addition, vaccines generate about £64 million (£20 million to £73 million) by preventing the opportunity costs stemming from the NMB forgone of regular patients waiting for elective hospital treatment. Their value grows by over £108 million (£22 million to £127 million) when the waiting list for elective hospital treatments also includes severe patients in whom prolonged treatment delays have led to poorer outcomes and/or higher costs of care. Therefore, our average estimates show that the value of these four vaccine programmes more than doubles when considering their contribution to maintaining health system capacity.

As we show through sensitivity analyses, the estimated magnitude of the four vaccines’ health system capacity value is strongly dependent on the model assumptions around the average NMB from hospital treatment. Compared to the base case analysis, accounting for the full opportunity costs using the lower bound for the NMBs forgone increases the vaccination value under regular pressure by only £20 million (28%) and £22 million (31%) under severe pressure, respectively. However, considering the upper bound for the average NMB from hospital treatment increases the value of vaccination by £73 million (100%) under regular pressure and by almost £200 million (180%) in case of severe pressure.

We must note that using the upper bound might still mask the true scale of the underestimation of vaccines’ current health system capacity value. For example, the NHS waiting list as of today

---

4 We should note that if one takes a hospital perspective, our estimates should be adjusted to capture only the variable cost component of all savings in the short run. In such case, only the variable cost proportion of the total tariff reimbursed to hospitals will lead to directly incurred cost-savings in the short term. Based on Plowman (2001) the variable cost proportion is around 15% of the total tariff.
contains more demand for bed days to perform hip replacements (a very high-value treatment) than the four vaccination programmes can free up. Therefore, the four vaccination programmes would enable a hypothetical hospital to use all of the freed-up capacity to perform hip replacements and, thus generating NMBs in the range £1.2 billion (as shown in Appendix 6). Given that a hospital does not focus solely on a single treatment, this must be considered a purely hypothetical case. However, it might be interesting for the health maximising decision-maker as it demonstrates the magnitude of NMBs that could potentially be at risk.

One of the most important findings of our work is that the underestimation of vaccines’ value is generally more considerable with increasing “pressure” on the health care system. The current NHS backlog for hospital treatments caused by the COVID-19 pandemic includes high excess demand for regular and severe patients. In addition, the drop in consultations during the pandemic resulted in a ‘missing’ incidence of over seven million patients, of whom 65-80% are expected to return to access NHS care over the next year (Office of National Statistics and Department of Health And Social Care, 2021). Hence, the potential economic value generated by vaccines was never as high as today and is likely to be growing.

In addition to those efficiency gains, our results are also relevant for health equity. Long waits for surgical procedures from patients of lower socioeconomic backgrounds have reported worse outcomes in quality of life (Office of National Statistics and Department of Health And Social Care, 2021). Hence, any preventative treatment that contributes to avoiding long waits beyond the 18-week target promote, on average, health equity.

Therefore, this result carries important implications for future allocation decisions to the preventative budget in the UK. Based on the base case of our empirical example, under traditional evaluation methods, a budget allocation decision leading to an increased vaccination coverage and a 5% decrease in hospitalisations would estimate a value gain of approximately £3.5 million by saving on direct hospitalisation costs. However, when we account for the opportunity cost of hospital beds blocked by vaccine-preventable outcomes, the estimated value gain is closer to £10 million. By the reverse logic, society would lose the same value when coverage rates of vaccines are decreased to a level that leads to a 5% increase in vaccine-preventable hospitalisations.

Our conceptual approach for estimating the value of maintaining health system capacity is transferable to any technology preventing excess demand and across different types of resources needed to deliver primary and secondary care. It is based on the assumption that the opportunity costs of imperfectly-marketable resources (such as hospital beds) may diverge from the cost derived through conventional costing methods (Sandmann et al., 2018a). Therefore, in a resource-constrained setting with excess demand for care, any treatment that avoids future demand for care would be undervalued. That includes, for example, interventional procedures and technologies if they reduce the future need for revisions. However, due to the very nature of preventative health technologies, this undervaluation is likely to be more significant for technologies like vaccines, public health campaigns or screening programmes.

Our conceptual and empirical models rely on several simplifying assumptions. First, we assume that the increasing severity of patients waiting for elective treatment reduces the forgone NMB. We model this decrement through higher hospitalisation costs while maintaining health gains and length of hospital stay per elective treatment constant. The data of our empirical model support the first part of our assumption, as the average HRG values for elective procedures increase with the complication and comorbidity (CC) score. Nonetheless, evidence in the literature suggests that delays in treatment may lead to poorer outcomes and a higher risk of mortality (Hanna et al., 2020; Elkomy and Cookson, 2020). In this case, the forgone NMB per elective patient would be lower than we estimated.
Second, our model assumes that the length of hospital stay is unaffected by the severity of the disease, which might be unrealistic. Relaxing this assumption and, consequently, assuming that increased severity also increases the length of stay, the total forgone NMB would be higher as even fewer patients from the backlog get access to treatment. Despite these caveats, the current lack of generalisable estimates of the impact of severity on health outcomes and length of stay, which are likely to differ across conditions, motivates our choice.

Third, we impose that the urgency for treatment is the main determinant of prioritising patients in the hospital. However, the usual medical triage and priority setting may not apply in times of severe health system pressure (Flaatten et al., 2020). In times of extreme stress on the health system, when resources are at risk of rationing, different rules may drive admission to hospital (e.g. based on need and ability to benefit, to maximise the number of lives saved) (Kirkpatrick et al., 2020). A discussion of how principles of triaging are adapted under hospital pressure conditions would, however, involve critical ethical considerations which are well beyond the scope of our work. As such, we do not consider them in our model.

Fourth, based on the above triaging principle, in ‘scenario 3’, we argue that all hospital beds freed-up by vaccination are allocated to treat severe elective patients, thus generating opportunity cost through forgone NMB of regular elective patients. To support this logic, the demand for bed days from severe patients in the backlog must be, at least, as high as the bed days freed up by the considered vaccines. Suppose we attribute increased severity to waiting for elective treatment beyond the recommended NHS threshold of 18 weeks. In that case, NHS England data on the number of incomplete pathways delayed by over 18 weeks at the end of the 2020-21 financial year (NHS England, 2021) confirms the plausibility of our approach in scenario 3, even if we account for the large number of day cases in the waiting list.

Finally, we used hospital beds as the key resource ensuring hospital admission and encapsulating a broader combination of resources that enable treatment (e.g. staff, medicines, equipment). While, in our model, hospital beds are perfectly transferable across hospital departments and treatments, in reality, this is not the case. For example, hospitals beds in emergency care or maternity wards are generally non-interchangeable with beds in other wards. We believe that this simplification does not affect the main conclusion of this paper, i.e., that the value of vaccines is greater under scenarios of excess demand for hospital beds.

Further work to quantify this value component for specific vaccines should detail hospital beds’ alternative uses and NMBs. For example, significant parts of the health system capacity value of the annual flu vaccination (and COVID-19) programme are likely to accrue in emergency care wards during the winter season. An assessment of the value of vaccination in reducing the negative externality of flu infections would require a narrower perspective of analysis capturing the impact on the supply of emergency hospital care.
5 Conclusion

Understanding and considering opportunity costs is crucial to capture the value of any preventative treatment in freeing up relevant resources during excess demand for health care services. Our work presented a novel approach to conceptualise vaccines’ health system capacity value when considering opportunity costs and quantified this value using an empirical approach.

The current level and composition of patients that demand health care are unprecedented. Therefore, policymakers should be aware that in addition to preventing the outcome of interest, vaccines deliver value in maintaining regular health care services and clearing the pent-up demand from the pandemic.

Therefore, vaccines’ health system capacity value should be a key-value element to consider when assessing vaccines’ value. Existing and potential future vaccination programmes deliver more value than hitherto quantified.
6 References


Appendix 1 Adaptations from the approach and model from Sandmann et al.

We compute the economic costs (expenditure incurred plus opportunity costs) to the NHS under the three scenarios (and two extra scenarios) as summarised in Table A. The health system capacity value equals NMB that would have been forgone under the two different scenarios of excess demand.
### TABLE A1: SCENARIOS AND ESTIMATES OF BASE CASE AND SENSITIVITY ANALYSES

<table>
<thead>
<tr>
<th>Scenario</th>
<th>No health system pressure</th>
<th>Excess demand for elective hospitalisations of ‘regular’ patients</th>
<th>Excess demand for elective hospitalisations of ‘severe’ and ‘regular’ patients</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lower Bound</strong></td>
<td>Hospitalisation costs of vaccine preventable outcome</td>
<td>Hospitalisation costs of vaccine preventable outcome</td>
<td>Hospitalisation costs of vaccine preventable outcome + lower bound of NMB forgone associated with a severely delayed elective treatment in T1 + lower bound of NMB forgone associated with a regular elective treatment in T2</td>
</tr>
<tr>
<td><strong>Base case</strong></td>
<td>Hospitalisation costs of vaccine preventable outcome</td>
<td>Hospitalisation costs of vaccine preventable outcome + mean of NMB forgone associated with a regular elective treatment</td>
<td>Hospitalisation costs of vaccine preventable outcome + mean of NMB forgone associated with a severely delayed elective treatment in T1 + mean of NMB forgone associated with a regular elective treatment in T2</td>
</tr>
<tr>
<td><strong>Upper Bound</strong></td>
<td>Hospitalisation costs of vaccine preventable outcome</td>
<td>Hospitalisation costs of vaccine preventable outcome + upper bound of NMB forgone associated with a regular elective treatment</td>
<td>Hospitalisation costs of vaccine preventable outcome + upper bound of NMB forgone associated with a severely delayed elective treatment in T1 + upper bound of NMB forgone associated with a regular elective treatment in T2</td>
</tr>
<tr>
<td><strong>What if 1 COVID 19</strong></td>
<td>Costs of COVID hospitalisations</td>
<td>Costs of COVID hospitalisations + lower bound of NMB forgone associated with a regular elective treatment</td>
<td>Costs of COVID hospitalisations + lower bound of NMB forgone associated with a severely delayed elective treatment in T1 + lower bound of NMB forgone associated with a regular elective treatment in T2</td>
</tr>
<tr>
<td><strong>What if 2 Hip Surgeries</strong></td>
<td>Hospitalisation costs of vaccine preventable outcome</td>
<td>Hospitalisation costs of vaccine preventable outcome + mean of NMB forgone associated with a regular hip replacement</td>
<td>Hospitalisation costs of vaccine preventable outcome + mean of NMB forgone associated with a severely delayed hip replacement in T1 + mean of NMB forgone associated with a regular hip replacement in T2</td>
</tr>
</tbody>
</table>
Appendix 2 Estimation of vaccine preventable hospitalisations

We chose five vaccination programmes known to prevent a significant number of hospitalisations in England per year.

We retrieved the pre-pandemic coverage and efficiency rates per age bracket (defined by age brackets within the Hospital Episode statistics) for each programme, the relevant ICD-10 diagnosis codes known to lead to hospitalisation, related finished consultant episodes (FCEs) in the age bracket and the median length of stay per ICD code. If necessary, we only considered a share of hospitalisations attributable to the vaccine-preventable outcome. We summarise the assumptions in Table A2.

For each ICD code we then retrieved the relevant health care resource group (HRG) from the HRG4+ 2018/19 Local Payment Grouper. We calculated a weighted average HRG value for each vaccination programme based on the FCE in the hospital. Similarly, we calculated an FCE-weighted average of the median length of stay. No imputation of data was carried out.

We estimated the impact of the vaccine based on effectiveness and coverage. We then calculated the expected number of prevented hospitalisations by dividing the observed hospitalisations from the Hospital Episode Statistics 2019/2019 by the impact of the vaccine.

Finally, by multiplying our estimate for the average length of stay associated with the grouped vaccine-preventable outcomes per vaccination programme, we obtained the freed-up bed days per vaccination programme in 2018/2019.
### TABLE A2: INFORMATION ON VACCINATION PROGRAMMES CONSIDERED

<table>
<thead>
<tr>
<th>Vaccination programme</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Seasonal Influenza</strong></td>
<td>We consider seasonal influenza vaccination in children under the age of nine and adults aged 65 and older. Age-related coverage and effectiveness rates are based on data from Public Health England (2019b) for the winter season 2018/2019. We extracted all influenza-related admission from the Hospital Episodes Statics 2018/2019 based on a primary diagnosis of relevant ICD-10 codes (J10.0, J10.1, J10.8, J11.0, J11.8).</td>
</tr>
<tr>
<td><strong>Meningococcal B Disease</strong></td>
<td>We consider relevant-vaccine preventable outcomes (ICD-10 code A39.x) only for the 0-4 year-olds as the programme was implemented in 2015. Age-related coverage rates are taken from Childhood Vaccination Coverage Statistics, England (2019-20) and efficacy was based on Christensen (2014). We assumed that 55% of hospital admission for the relevant ICD-10 codes are due to vaccine preventable disease (PHE, 2019).</td>
</tr>
<tr>
<td><strong>Rotavirus</strong></td>
<td>We consider a range of ICD-10 diagnosis codes (K52.8, K52.9, A00-A09) in children under five years and assume that 25% of the related hospitalisation are associated with the vaccine preventable outcome (Harris et al., 2007). Age-related coverage rates are taken from Childhood Vaccination Coverage Statistics, England (2019-20) and efficacy was based on (Jit and Edmunds, 2007).</td>
</tr>
<tr>
<td><strong>Pneumococcal Disease</strong></td>
<td>As vaccine preventable outcomes, we consider Pneumococcal Meningitis (ICD-10 code G00.1), Sepsis due to Streptococcus pneumoniae (A40.3) and Pneumonia due to Streptococcus pneumoniae (J13.X). We consider vaccination with the respective childhood or adult vaccine amongst everybody under the age of 10 and everybody aged 65 or older. The total coverage for adults was assumed to be 69% up to the end of March 2020 and the childhood coverage is based on data from the Childhood Vaccination Coverage Statistics, England (2019-20). The childhood vaccine efficacy were based on Delgleize et al. (2016) and the adult vaccine efficacy on Djennad et al. (2018).</td>
</tr>
<tr>
<td><strong>Additional What-if analysis COVID-19</strong></td>
<td>We added a simplified scenario for the prevented COVID hospitalisations by the increasing general population’s vaccination rates. Public Health England estimated that up to the end of May 2022, COVID vaccines prevented 42,000 hospitalisations in England (PHE, 2021b). The median length of stay was based on an analysis by the Nuffield Trust (Scobie and Keeble, 2021), and the average HRG level for a COVID-related hospitalisation was taken from Thom et al. (2021).</td>
</tr>
</tbody>
</table>

---

5 Please note that the Influenza vaccination program has been expanded since. The current eligibility criteria are available at National flu immunisation programme 2021 to 2022 letter - GOV.UK (www.gov.uk).
Appendix 3 Estimation of the opportunity costs

We calculate the NMBs forgone as follows. The first approach takes the average health gain from a hospital treatment directly from Sandman et al. (2018b). Each value is multiplied by the cost-effectiveness threshold (here assumed £20,000) to yield an estimate of the monetised benefits. Finally, the average HRG level from hospital treatment, taken from the same paper and inflated to 2020 GBP levels using CPI inflation data, is subtracted to yield the NMBs forgone.

We refer to the appendix of Sandman et al. (2018b) for details on the methodology to calculate the estimates for the average NMB forgone for the base case estimate end the estimates for the upper and lower bound. However, due to the specific research question in the Sandmann paper, the estimates for the NMB forgone exclude patients with gastroenteritis and include all health gains and costs associated with the vaccine-preventable outcomes of interest in our model. Therefore, our approach is an apparent simplification of the original as each next best alternative should only exclude the health gains and costs associated with the vaccine-preventable outcome of the specific vaccination programme but should include patients with gastroenteritis. However, we consider the estimates a ‘good-enough proxy for an empirical demonstration of our conceptual thinking given that finished consultant episodes relevant to gastroenteritis were only 0.138% of the total.

The second approach calculates the NMB forgone exclusively based on the health gain costs associated with hip replacements. We utilise this approach in one of the what-if analyses. The estimate is proxied using the (discounted) QALY’s gained from hip replacement (vs no hip replacement) over 15 years. The estimate is taken from Appleby et al. (2013) and assumes degradation in health after the operation taken. The corresponding HRGs are based on the National Schedule of NHS Costs Year in 2019-20.

For both approaches, we calculated the reduced NMB forgone for the severe pressure scenario. While we are aware that a reduction in the achievable NMB is likely due to the QALY loss from long waiting times (Krelle, Barclay and Tallack, 2021), for pragmatic reasons, we decided to proxy the overall reduction in NBM through an increase in costs. Hence, we increased the average unit cost for the relevant outcome by the average increase in unit costs when increasing the complexity (CC) score. For the first approach, the average increase is calculated across all suitable HRGs and CC scores. In contrast, for the second approach, we only considered the average increase of the CC score for hip-related HRGs.

Appendix 4 Aggregating all costs

Finally, all cost components (the expenditure to treat vaccine-preventable outcomes and the opportunity costs are aggregated according to the three different scenarios and for the upper, mean and lower values of the net monetary benefit forgone. All costs are reported in 2020 GBP and, where necessary, inflated using CPI data.
### TABLE A5: VALUES FOR THE MODEL INPUT PARAMETERS

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value (sensitivity analysis)</th>
<th>Unit</th>
<th>Description and sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of stay</td>
<td>5.01</td>
<td>Days</td>
<td>Mean hospital LOS of all non-gastroenteritis cases in England (HES, 2015/16). Sensitivity analysis: Lowest and highest mean LOS per non-gastroenteritis sub-group (local hospital sample). Taken from Sandmann et al. (2018).</td>
</tr>
<tr>
<td></td>
<td>8.4</td>
<td>Days</td>
<td>Average mean hospital LOS of patients treated for hip replacement surgeries (OPCS codes: W37.0 -W37.4, W37.8, W37.9, W38.0-W38.4, W38.8, W38.9, W39.0-W39.6, W39.8, W39.9, W93.1-W93.3, W94.1-W94.3, W94.8, W94.9, W95.1-W95.4, W95.8, W95.9). Taken from HES 2018/19.</td>
</tr>
<tr>
<td></td>
<td>3.51</td>
<td>Days</td>
<td>Median LOS of patients treated for vaccine preventable outcomes related to influenza, weighted by FCEs (the ICD codes for preventable outcomes are: J10.0, J10.1, J10.8, J11.0, J11.1, J11.8). The ICD codes were taken from Frankling and Hochlaf (2018) and the FCE and median LOS data from HES 2018/19.</td>
</tr>
<tr>
<td></td>
<td>4.14</td>
<td>Days</td>
<td>Median LOS of patients treated for vaccine preventable outcomes related to meningococcal disease, weighted by FCEs (the ICD codes for preventable outcomes are: A39.0, A39.2, A39.3, A39.4, A39.8, A39.9). The ICD codes were taken from Christensen et al. (2013) and the FCE and median LOS data from HES 2018/19.</td>
</tr>
<tr>
<td></td>
<td>1.12</td>
<td>Days</td>
<td>Median LOS of patients treated for vaccine preventable outcomes related to rotavirus, weighted by FCEs (the ICD codes for preventable outcomes are: K52.8, K52.9, A00.0, A00.9, A01.0-A01.4, A02.0-A02.2, A02.8, A02.9, A03.0-A03.3, A03.8, A03.9, A04.0-A04.9, A05.1-A05.4, A05.8, A05.9, A06.0, A06.1, A06.4-A06.6, A06.8, A06.9, A07.1-A07.3, A07.8, A08.0-A08.5, A09.0, A09.9). The ICD codes were taken from Jit and Edmunds (2007) and the FCE and median LOS data from HES 2018/19.</td>
</tr>
<tr>
<td></td>
<td>7.3</td>
<td>Days</td>
<td>Median LOS of patients treated for vaccine preventable outcomes related to pneumococcal disease, weighted by FCEs (the ICD codes for preventable outcomes are: G00.1, A40.3, J13.X). The ICD codes were taken from Delgleize et al. (2016) and the FCE and median LOS data from HES 2018/19.</td>
</tr>
<tr>
<td></td>
<td>7.0</td>
<td>Days</td>
<td>Median LOS of patients treated for vaccine preventable outcomes related to COVID-19 (Scobie and Keeble, 2021)</td>
</tr>
<tr>
<td>FCE adjustments</td>
<td>25%</td>
<td>Of all relevant FCEs</td>
<td>Share of hospitalisations retrieved that are attributable to Rotavirus. Taken from (Harris et al., 2007)</td>
</tr>
<tr>
<td>Parameter</td>
<td>Value (sensitivity analysis)</td>
<td>Unit</td>
<td>Description and sources</td>
</tr>
<tr>
<td>--------------------</td>
<td>------------------------------</td>
<td>------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>55%</td>
<td>Of all relevant FCEs</td>
<td></td>
<td>Share of hospitalisation retrieved that are attributable to Meningococcal disease group B. Taken from (PHE, 2019)</td>
</tr>
<tr>
<td><strong>Unit costs</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>£1,491</td>
<td>per patient</td>
<td></td>
<td>Mean NHS reference costs of non-gastroenteritis cases in England in 2015/16 (activity-weighted, excluding HRGs FZ36 and PF21+) and inflated to 2020 using the CPI. Taken from Sandmann et al. (2018).</td>
</tr>
<tr>
<td>£1506.65</td>
<td>per patient</td>
<td></td>
<td>Activity weighted average cost for vaccine preventable outcomes related to influenza, across all CC scores, weighted by FCEs (using the following HRGs: DZ11 and WJ03), taken from the national schedule of NHS costs 2019/20.</td>
</tr>
<tr>
<td>£5752.23</td>
<td>per patient</td>
<td></td>
<td>Activity weighted average cost for vaccine preventable outcomes related to meningococcal disease, across all CC scores, weighted by FCEs (using the following HRGs: AA22, WJ06, AA53 and AA54), taken from the national schedule of NHS costs 2019/20.</td>
</tr>
<tr>
<td>£1356.72</td>
<td>per patient</td>
<td></td>
<td>Activity weighted average cost for vaccine preventable outcomes related to rotavirus, across all CC scores, weighted by FCEs (using the following HRGs: FD02 and FD01), taken from the national schedule of NHS costs 2019/20.</td>
</tr>
<tr>
<td>£2052.20</td>
<td>per patient</td>
<td></td>
<td>Activity weighted average cost for vaccine preventable outcomes related to pneumococcal disease, across all CC scores, weighted by FCEs (using the following HRGs: AA22, WJ06 and DZ11), taken from the national schedule of NHS costs 2019/20.</td>
</tr>
<tr>
<td>£4847.00</td>
<td>per patient</td>
<td></td>
<td>Average cost of a hospital stay for a COVID-19 infection, weighted by HRG (Thom et al. (2021)).</td>
</tr>
<tr>
<td><strong>QALY gain</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.239 (0.142, 0.260)</td>
<td>per patient</td>
<td></td>
<td>Mean (discounted) QALYs gained from hospital treatment for non-gastroenteritis cases with chronic conditions (local hospital sample, n=871). Sensitivity analysis: Mean (discounted) QALYs gained of all patients without gastroenteritis (n=2,465) and with acute life-threatening conditions (n=537), respectively. Acute life-threatening conditions were included as extreme scenario only as it seemed unrealistic to assume forgoing them constantly. Taken from Sandmann et al. (2018).</td>
</tr>
<tr>
<td>2.77</td>
<td>per patient</td>
<td></td>
<td>Lifetime (15 years) discounted arithmetic mean QALY gain for hip replacement vs no hip replacement for NHS hospitals, assuming degradation in health after the operation (Appleby et al. (2013)).</td>
</tr>
<tr>
<td>Parameter</td>
<td>Value (sensitivity analysis)</td>
<td>Unit</td>
<td>Description and sources</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>------------------------------</td>
<td>------------</td>
<td>------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>HRG severity premium</td>
<td>821</td>
<td></td>
<td>Average increase in cost as the severity of the activity increases. Calculated for all elective procedures, using 2019/20 HRG data.</td>
</tr>
</tbody>
</table>

Appendix 6 What-if analysis 2: excess demand for elective hip replacement procedures

Elective procedures for hip replacement represent high value thanks to the relatively large QALY gains for patients. This what-if analysis shows the results of a hypothetical scenario where all beds freed up by the four vaccination programmes are used to hospitalise patients for elective hip replacement Figure A7. This assumption is supported by the current number of patients currently waiting for hip replacement in the UK, which is high enough to fill up all the beds freed up annually by the four vaccination programmes under consideration.

Compared to no excess demand scenarios, the increase in value of vaccines across the three excess demand scenarios is very large. The savings stemming from vaccine-preventable hospitalisations are the same as in the base case. However, the NMB forgone from hip surgeries increases the opportunity costs by a factor of 10, when assuming excess demand from elective regular patients, and by an additional close to two-fold increase when assuming excess demand for both severe and regular patients.

FIGURE A7 ECONOMIC COSTS SAVED BY FOUR VACCINATION PROGRAMMES, ASSUMING EXCESS DEMAND FOR ELECTIVE HIP REPLACEMENT PROCEDURES
About us
Founded in 1962 by the Association of the British Pharmaceutical Society, the Office of Health Economics (OHE) is not only the world’s oldest health economics research group, but also one of the most prestigious and influential.

OHE provides market-leading insights and in-depth analyses into health economics & health policy. Our pioneering work informs health care and pharmaceutical decision-making across the globe, enabling clients to think differently and to find alternative solutions to the industry’s most complex problems.

Our mission is to guide and inform the healthcare industry through today’s era of unprecedented change and evolution. We are dedicated to helping policy makers and the pharmaceutical industry make better decisions that ultimately benefit patients, the industry and society as a whole.

OHE. For better healthcare decisions.

Areas of expertise
- Evaluation of health care policy
- The economics of health care systems
- Health technology assessment (HTA) methodology and approaches
- HTA’s impact on decision making, health care spending and the delivery of care
- Pricing and reimbursement for biologics and pharmaceuticals, including value-based pricing, risk sharing and biosimilars market competition
- The costs of treating, or failing to treat, specific diseases and conditions
- Drivers of, and incentives for, the uptake of pharmaceuticals and prescription medicines
- Competition and incentives for improving the quality and efficiency of health care
- Incentives, disincentives, regulation and the costs of R&D for pharmaceuticals and innovation in medicine
- Capturing preferences using patient-reported outcomes measures (PROMs) and time trade-off (TTO) methodology
- Roles of the private and charity sectors in health care and research
- Health and health care statistics