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What are the Benefits of Achieving the WHO Elimination Target?

CONTRACT RESEARCH REPORT
JANUARY 2024

Gayathri Kumar
Matthew Napier
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Gayathri Kumar
Office of Health Economics, London

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Corresponding Author:
Gayathri Kumar
gkumar@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 gcookson@ohe.org

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Table of Contents

Executive Summary

Characterising the pathway to elimination in the UK

Cervical cancer is the fourth most common cancer among women globally, but thanks to effective vaccination, screening, and treatment, it is considered a preventable disease. In 2020, the World Health Organisation announced its goal of eliminating cervical cancer by the end of the 21st century. In November 2023, NHS England announced their ambitious commitment to achieve elimination by 2040. However, the current incidence of cervical cancer in the UK is more than twice the WHO elimination target of 4 cases per 100,000 women. While this is a welcome commitment by NHS England, a UK-wide prevention strategy is needed to ensure momentum towards achieving elimination and realise a significant socioeconomic benefit for patients and their support systems, the NHS, and the wider society.

This report provides quantitative evidence of the socioeconomic burden of cervical cancer in the UK and the potential socioeconomic savings from reaching the WHO elimination target. Through a targeted literature review, expert interviews, and modelling, we derived estimates of the burden per cervical cancer case, the population-level burden in the UK, savings attributed to the preventable burden in current terms and cumulatively over time as the UK incidence is projected to fall to the WHO target.

Cervical cancer is associated with a lifetime cost of almost £210,000 per case

This value includes costs to the healthcare system, individual patients, and the wider society due to cervical cancer morbidity and mortality. The individual-level burden is driven by the loss of workplace productivity (accounting for 63% of the total cost) and informal care provided in the home by the patient (22%), mainly as a result of premature death. Healthcare system costs, and caregiver productivity losses are the next largest cost components and are of a similar magnitude, each accounting for 8% of the burden, followed by out-of-pocket (OOP) patient costs.

59% of the 2023 population-level burden in 2023 is preventable through screening and vaccination

At a current UK incidence of 9.7 per 100,000, the socioeconomic burden of cervical cancer in the UK is estimated at £691 million. This is equivalent to approximately 40% of the UK combined spending on immunisation and early detection programmes pre-COVID-19 (£1.7 billion in 2019) or, equivalently, to about 8% of the total UK pre-COVID-19 spending on preventative care (£8.3 billion in 2019) (ONS, 2023a).

At the target WHO elimination incidence rate, in 2023 costs, the estimated burden is £285 million. The preventable 'burden' is defined as the difference between socioeconomic costs at the current incidence rate of cervical cancer in the UK and the WHO elimination, which is equivalent to about £406 million. This means that 59% of the current socioeconomic burden of cervical cancer is preventable.

The UK incidence is expected to reach the WHO elimination target by 2046. This is based on elimination projections for countries with very high human development indexes (a measure of social and economic development), which includes the UK. We estimate that the UK could save around £2.6 billion in 2023-2046. Our estimate of the savings over time does not consider the cost required for vaccination and screening required to achieve elimination.

Ensuring momentum towards elimination is vital

This report highlights significant future socioeconomic savings that the elimination of cervical cancer can yield. While our estimates are based on the most recent data identified in the literature and feedback from expert interviews, they do not capture certain impacts that cervical cancer can have, such as educational attainment in children who have lost a parent or loss of economic activity or informal caregiving following retirement. Overall, it is likely that the estimated costs and savings underestimate the true scale of the socioeconomic burden associated with cervical cancer and the value of an effective elimination strategy in the UK.

NHS England's recent commitment to achieving elimination by 2040 may provide the impetus to improve vaccination and screening coverage to achieve earlier elimination, thereby reducing the cumulative socioeconomic burden further than our predicted estimates. However, it is crucial for this aspiration to be reinforced by the implementation of an action plan with measurable actions and milestones from the NHS. A similar action plan should focus on eliminating inequalities in access to prevention and early detection, be tailored to the needs of local populations, introduce educational activities to reduce stigma on HPV, target screening to vulnerable groups and improve data collection to ensure accurate monitoring of progress. In addition, both the commitment to elimination and a plan will need to be adopted in the other UK nations (Northern Ireland, Scotland, and Wales) to accelerate the path to elimination.

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1 Introduction

1.1 Background

Cervical cancer is the fourth most frequent cancer among women worldwide and a global public health issue (WHO, 2022). Over 95% of cervical cancer cases are caused by human papillomavirus (HPV) (ibid.). Thanks to effective vaccination against HPV and screening tests for pre-cervical cancer lesions, cervical cancer is nowadays considered a preventable disease. Preventative interventions have greatly contributed to a decline in cervical cancer cases and mortality. However, the associated health burden remains high, especially in low- and middle-income countries (Singh et al., 2023).

In 2020, the World Health Assembly adopted the Global Strategy to accelerate the elimination of cervical cancer, which is defined as a country reaching the incidence threshold of fewer than four new cases per 100,000 women (WHO, 2020). To achieve global elimination by the end of the 21st century, the World Health Organisation (WHO) recommends that the '90-70-90 target' for cervical cancer prevention and control be in place by 2030 (ibid.). The '90-70-90' target recommends that:

- 90% of girls are fully vaccinated by age 15;
- 70% of women are screened with a high-performance test by 35 and again by 45 years of age;
- 90% of women identified with cervical disease receive treatment.

The UK provides a comprehensive programme for the prevention of cervical cancer. HPV vaccination was introduced in the national immunisation programme in 2008 and was initially offered to girls aged 12-13 (UKHSA, 2023). In 2019, the UK moved to a 'universal' HPV vaccination programme, extending eligibility for HPV vaccination to boys in the same age group (Ibid.). A national screening programme is also in place, offering regular cervical cancer screening to all women aged 25 and over (NHS, 2023).

Cervical cancer prevention and control have facilitated significant progress in reducing the incidence of cervical cancer in the UK, including an estimated 87% reduction in cases among women aged 20 in England (Falcaro et al., 2021). Furthermore, NHS England recently vowed to eliminate cervical cancer by 2040, placing England among the first countries in the world to set this elimination ambition within the next two decades (NHS England, 2023).

However, the incidence of cervical cancer in the UK is still significantly higher than the WHO elimination target, with some variation across UK regions (Cancer Research UK, 2021). Further, recent data have shown declining rates of HPV vaccination among teenagers (UKHSA, 2022) and a record-high proportion of women who are not up-to-date with their screening (GOV.UK, 2023). Notably, in 2022, almost 1 in 3 women were not up to date with their cervical screening (NHS England, 2023c), while inequalities in screening rates and vaccination coverage are present across different UK regions and demographics (Jo's Cervical Cancer Trust, 2023).

Through effective vaccination, screening, and treatment, it is possible to achieve elimination in the UK. While NHS England's recent commitment to eliminate cervical cancer by 2040 is a welcome one, urgent steps to develop and execute an implementation plan are now necessary. If the UK loses momentum towards achieving elimination, there will be a significant burden, impacting patients and their support systems, the NHS, and the wider society.

1.2 Report overview

To demonstrate the importance of prevention strategies that will allow the UK to eliminate cervical cancer without delay, this project generated evidence of the current socioeconomic cost of cervical cancer to the UK health system, patients and society, and the potential savings from achieving the WHO elimination target.

We developed a model to quantify the socioeconomic cost of cervical cancer in the UK due to new cases at the current incidence rates. Our approach considers costs to the patients, healthcare system, and society. We then show the savings achievable by reducing the incidence up to the WHO elimination threshold.

Section 2 of this report explains our approach to defining and modelling the socioeconomic burden of cervical cancer in the UK. Section 3 presents the model's baseline results and scenario analyses. Section 4 discusses the findings, outlining the main limitations and how to interpret the results. Section 5 concludes the report.

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2 Methods

The aim of this analysis was to estimate the socioeconomic cost of cervical cancer in the UK and characterise its preventable burden to society. The preventable 'burden' is defined as the difference between socioeconomic cost at the current incidence rate of cervical cancer in the UK and the WHO elimination target of 4 per 100,000 women (WHO, 2020).

In order to create a complete picture of the current burden and how this is likely to evolve over time, we performed a series of estimations. These estimates include the current lifetime socioeconomic cost per case of cervical cancer, the UK population-level cost, the savings in 2023 if we had already achieved the WHO elimination target, and the potential cumulative savings if we achieve cervical cancer elimination by 2046. The latter is the anticipated year for the elimination target based on current preventive actions in the UK (80-100% vaccination coverage and gender-neutral vaccination).

To derive these estimates, we defined the cost components that encompass the socioeconomic cost of cervical cancer and estimated the value of each component. Then, through a five-step modelling approach, we synthesised the evidence to generate the results. The overall analysis was achieved in three stages.

1. We undertook a literature review to define the scope of the socioeconomic cost components relating to cervical cancer and to derive the associated input parameters.

2. We designed, developed, and populated a model in MS Excel. We generated initial results of the socioeconomic cost, and based on feedback from the interviews, these were updated to provide final estimates of the results.

3. We conducted four interviews with experts (health economist, epidemiologist, patient representative) to obtain expert opinion and validation of the modelling assumptions, the appropriate use of input parameters, and the model results.

A more detailed description of our methods, including the literature review, the modelling approach, data, and assumptions, as well as the expert interviews, can be found in the Appendix (Section 6.3).

2.1 Defining the socioeconomic burden of cervical cancer

The first stage in estimating the socioeconomic cost of cervical cancer was to outline the scope of what this encompasses. The literature review guided the selection of the cost components, and these were updated based on feedback from the expert interviews. Cost components were based on both the relevance to cervical cancer and the availability of data. The overall framework can be seen in Figure 1 below.

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FIGURE 1: FRAMEWORK OF CERVICAL CANCER SOCIOECONOMIC BURDEN
**** Productivity loss quantifications already include tax returns due to workplace absenteeism. From a societal perspective, tax returns and costs to the social security system (e.g., welfare payments, sickness benefits) are considered a transfer and, therefore, should not be included in the full cost of disease.***

The first component is the **healthcare system costs**. Since the analysis is from the perspective of the UK, this includes all the costs to the NHS due to cervical cancer, including inpatient and outpatient hospital care, chemotherapy and medications.

Costs to society comprise three separate cost categories. Firstly, there is the loss of the patient's workplace productivity due to both illness (absenteeism) and mortality. In addition, there are losses due to a patient's inability to perform informal caregiving tasks due to mortality or illness. On top of this, there is the loss of workplace productivity experienced by those caring for patients with cervical cancer.

Costs to individual patients encompass out-of-pocket (OOP) costs incurred as a result of diagnosis and treatment (e.g., cost of parking at the hospital when receiving treatment). Another cost to the individual is intangible costs. These are quality-of-life losses a patient internalises because of diagnosis, treatment, recovery, and survival from cervical cancer. In the presentation of the socioeconomic burden estimates, we omit intangible costs from our baseline results because their inclusion in the socioeconomic cost of disease is debated in the literature (e.g., due to the risk of double counting with other cost components) (Robinson et al., 2019). In addition, there is uncertainty over the willingness-to-pay threshold for Quality Adjusted Life Years (QALYs) that would be appropriate for an analysis of this kind. Therefore, we present the socioeconomic burden with intangible costs as part of a scenario analysis separate from the baseline estimates.

2.2 Modelling the socioeconomic burden of cervical cancer

The modelling was performed in five steps. Each step derives results and builds on one another, all with the aim of characterising and communicating the overall socioeconomic burden of cervical cancer. For a full methodological breakdown of each stage, refer to the Appendix (section 6.3).

1. We **estimated the average lifetime cost of cervical cancer per case** based on the cost to the NHS, society and the patient. This was achieved by weighting the probability of the outcome associated with the cost component (e.g., death) and by the proportion of the patient population incurring the cost. Costs occurring in the years after diagnosis were discounted at a rate of 3.5%, reflecting social preferences for the timing of consumption (HM Treasury, 2022) and adjusted for inflation.

   For example, when estimating the healthcare system cost, costs to the NHS in the first year since diagnosis were applied to all patients and not discounted. For illness costs incurred in the second

year onwards, these were applied only to the proportion of women who survived beyond the first year and were discounted and adjusted for inflation.

2. We derive an **estimation of the current UK population-level socioeconomic cost of cervical cancer**. We applied the current incidence rate of 9.7/100,000 (Cancer Research UK, 2021) to the cost per case, estimated in step one, deriving the population-level socioeconomic cost of cervical cancer in 2023.

3. The third step was to apply the WHO elimination incidence rate of 4/100,000 (WHO, 2020) to the cost per case in the same way as step two. This gave us the **population-level socioeconomic cost of cervical cancer if we had reached elimination in 2023**.

4. The fourth step was to **estimate the preventable burden of cervical cancer in 2023**. This is characterised by the difference between the population cost at the current incidence rate and at the target incidence rate. This is calculated by subtracting the result of step three from step two, representing the socioeconomic savings that are missed as a result of having an incidence rate more than twice that of the WHO target.

5. The fifth and final step was to **estimate the cumulative socioeconomic savings over time**. This was calculated by applying an elimination trajectory up to 2046 associated with preventative actions in the UK (Simms et al., 2019). For each year, the cost per case was applied to the modelled incidence rate to calculate the population-level socioeconomic cost. Then, the cost over time was calculated for a counterfactual scenario in which the incidence rate remains constant at the 2023 rate of 9.7/100,000. The difference between the two represents the potential cumulative socioeconomic savings.

3 Results

3.1 What is the burden of cervical cancer per person?

The lifetime socioeconomic burden of cervical cancer per newly diagnosed case is **£208,086**. Figure 2 presents the breakdown of the lifetime burden into cost categories.

The main driver of the lifetime cost is the patient productivity loss (£130,984), which comprises 63% of the individual burden and is largely due to the loss associated with cervical cancer mortality. The next largest component is the loss of informal care provided by the patient (22% of the individual cost), which is also driven by the risk of death associated with cervical cancer.

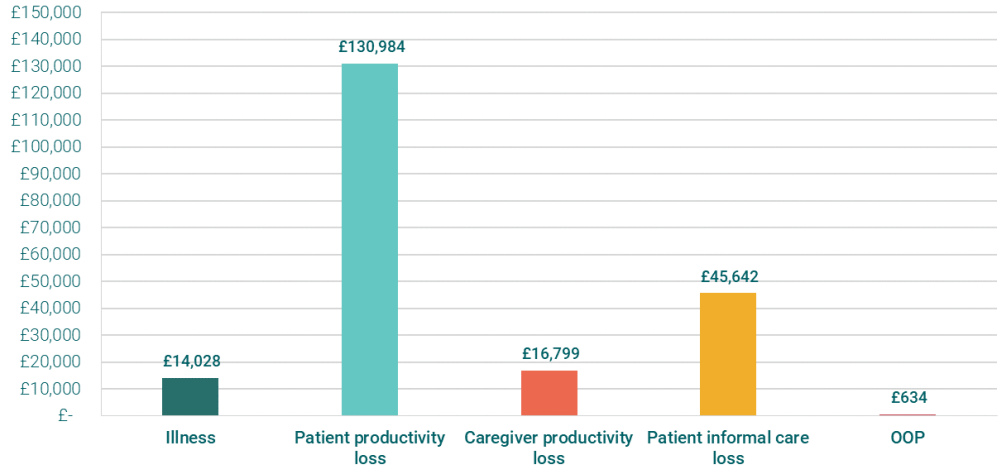

FIGURE 2: LIFETIME SOCIOECONOMIC COST PER NEWLY DIAGNOSED PATIENT, PRESENT VALUE IN 2023 TERMS

Illness cost and caregiver productivity losses are the next largest cost components and are of a similar magnitude (£14,028 and £16,799, respectively), each accounting for 8% of the burden. OOP patient costs (£634) constitute the smallest component at less than 1% of the lifetime cost.

Our results demonstrate that **socioeconomic losses to society account for most of the burden, i.e., patient productivity loss, caregiver productivity loss and patient informal care loss**. Figure 3 presents the breakdown of each of these categories into losses incurred during the treatment period (due to absenteeism and severely limited patients) and due to mortality. **All three categories are driven largely by mortality.** This suggests that the cost to society is driven by what is foregone when a patient dies ahead of their time, more so than the sum of other costs incurred whilst the patient is ill.

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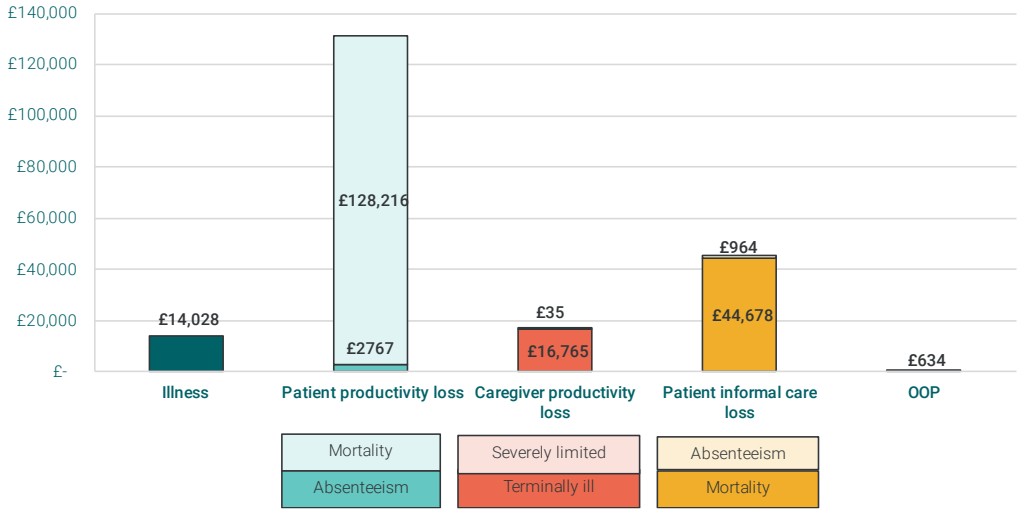

FIGURE 3: BREAKDOWN OF LIFETIME SOCIOECONOMIC COST PER NEWLY DIAGNOSED PATIENT, PRESENT VALUE IN 2023 TERMS

3.2 What does the burden look like at the population level?

Figure 4 presents the population-level socioeconomic burden of new cases of cervical cancer at the current and elimination target incidence rates. At the current UK incidence rate of 9.7 per 100,000 women, the estimate is **£691 million**. Applying the target incidence rate of 4 per 100,000 women to the individual lifetime burden results in an estimated burden of **£285 million**.

The **'preventable burden'** is defined as the difference between socioeconomic costs at the current incidence rate of cervical cancer in the UK and the WHO elimination, which is equivalent to about **£406 million.** Had the elimination target already been achieved by 2023, the socioeconomic burden of cervical cancer would be **59% lower** than the current total burden.

Incidence is the only input parameter that varies between these two estimates; therefore, the percentage reduction in the burden is directly proportional to the percentage reduction from the current UK incidence to the elimination target.

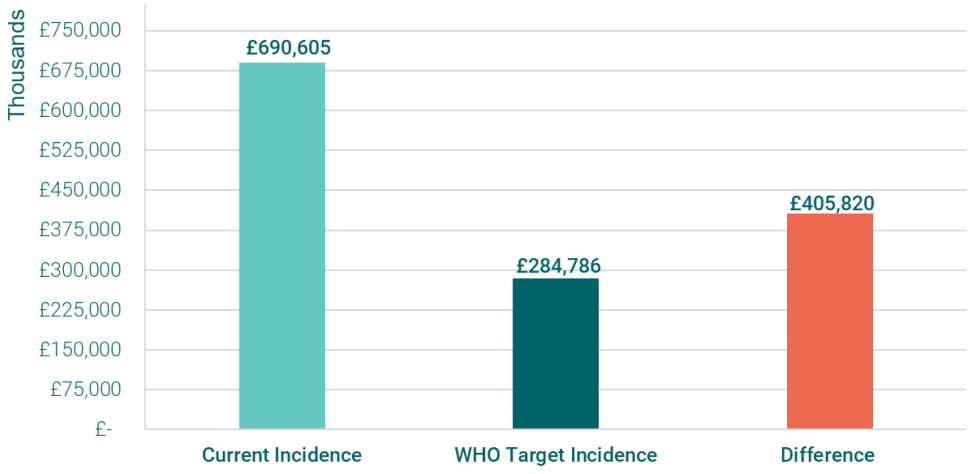

FIGURE 4: POPULATION-LEVEL BURDEN AND SAVINGS, PRESENT VALUE IN 2023 TERMS

3.3 How much could the UK save by achieving the WHO elimination threshold?

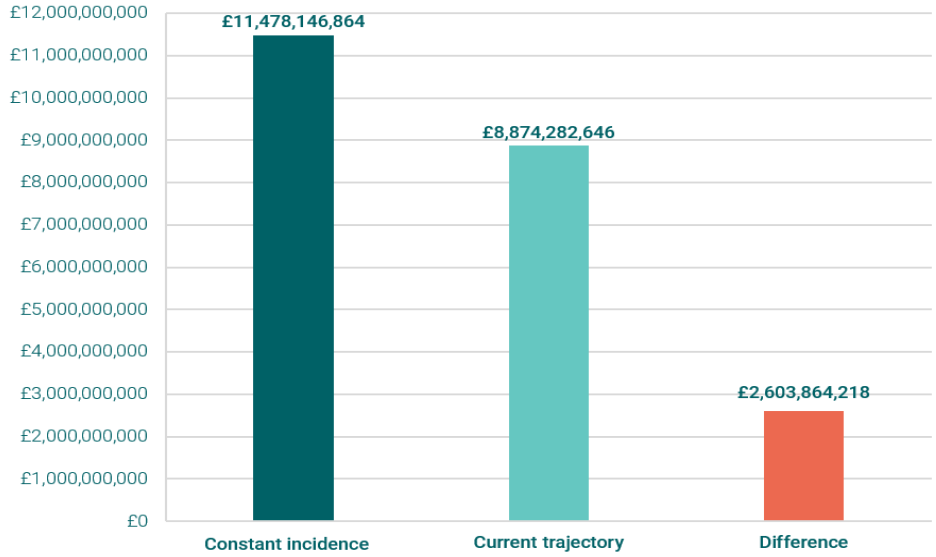

Figure 5 presents the socioeconomic burden associated with cervical cancer over time as the incidence rate declines towards the WHO elimination target. Based on the current trajectory of cervical cancer incidence in the UK (i.e., based on gender-neutral vaccination, vaccination coverage of 80-100% and current screening rates), the anticipated year for achieving elimination is 2046 (Simms et al., 2019). The cumulative burden placed on new patients diagnosed with cervical cancer between 2023 and 2046 is estimated to be £8.9 billion.

We compare this estimate to a counterfactual scenario, where we assume the incidence rate remains constant at the 2023 rate of 9.7/100,000. The cumulative burden predicted from 2023 to 2046 is £11.5 billion.

The difference of £2.6 billion between the two scenarios represents the preventable cumulative burden over the time taken to achieve the WHO elimination threshold. The percentage reduction of reduction in the socioeconomic burden of 23% reflects the evolving incidence rate and the impact of inflation and social time preference discounting applied to the cases avoided from 2023 to 2046.

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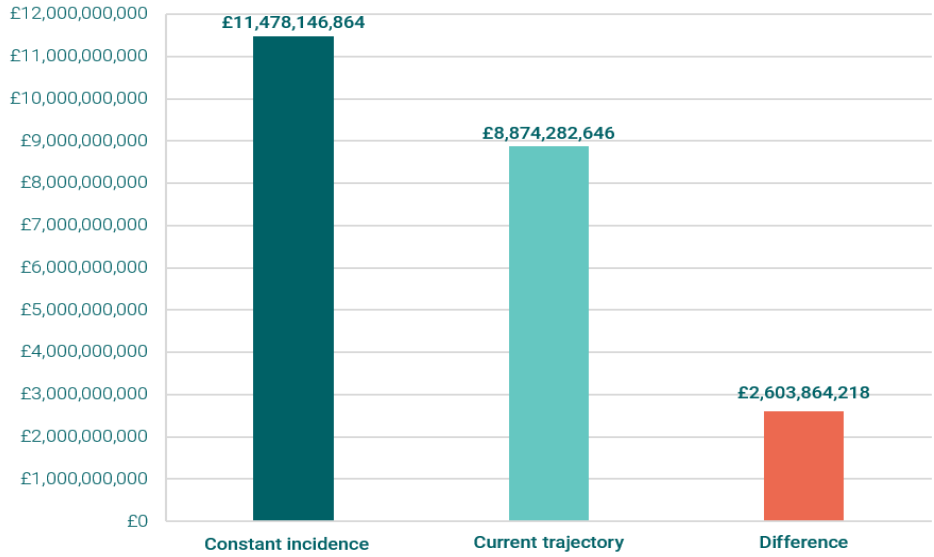

FIGURE 5: SOCIOECONOMIC BURDEN OVER TIME TO ELIMINATION (2023-2046), PRESENT VALUE IN 2023 TERMS

3.4 Scenario analyses

Our approach to estimating the socioeconomic burden is based on assumptions that are likely to result in a conservative estimate of the socioeconomic burden. We vary quantifiable assumptions in scenario analyses to demonstrate the impact on the baseline estimate.

3.4.1 Absenteeism period

The absenteeism period refers to the treatment duration over which time a patient is unable to work or undertake informal care and incurs OOP costs associated with cancer treatment and recovery. A patient expert provided feedback that the base case estimate of six weeks could underestimate the time needed for recovery before returning to full productivity both at work and in the home.

We vary this assumption in line with the patient expert's experience of returning to full-time employment after a longer duration of six months. This scenario extends the duration of time over which patient productivity loss, patient informal care loss and OOP costs are incurred.

A longer absenteeism period of six months is associated with a higher population-level burden of £739 million or an additional £48 million relative to the base case. Increasing the absenteeism duration by four-fold increases the absenteeism duration only by seven per cent. The impact of the scenario is small as it applies to the smallest cost components presented in Figure 3, which, in total, account for 2% of the lifetime cost in the base case.

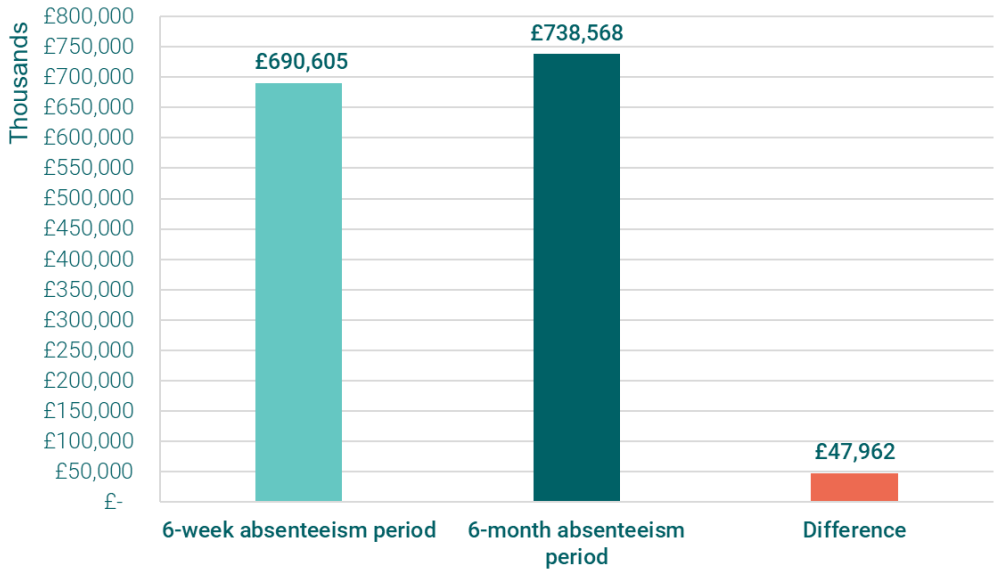

FIGURE 6: POPULATION-LEVEL BURDEN AND SAVINGS – LONGER ABSENTEEISM PERIOD, PRESENT VALUE IN 2023 TERMS

3.4.2 Monetised QALYs

An individual patient is expected to experience a loss in quality of life associated with treatment, recovery and survivorship associated with cervical cancer. The loss represents an intangible cost that is internalised by the patient and not accounted for in other monetary input parameters (e.g., healthcare costs and patient productivity losses). We measure the impact in terms of quality-adjusted life years (QALYs) lost and monetise the loss using The National Institute for Health and Care Excellence's (NICE) threshold of £20,000 per QALY.

We estimate that an individual patient experiences a loss of 0.77 quality-adjusted life years (QALYs) over their lifetime due to the quality-of-life impact of diagnosis, treatment and survivorship, which adds £15,400 to the individual lifetime cost when monetised. Figure 7 depicts the population-level socioeconomic burden from including monetised QALYs: the burden increases by £51 million to a total of £742 million across the total UK population. Incorporating intangible patient costs in terms of monetary QALY losses increases the socioeconomic burden by 7%.

We do not incorporate monetised QALYs in the base case, as survival estimates may improve over time as new treatments become available, which would overestimate the burden.

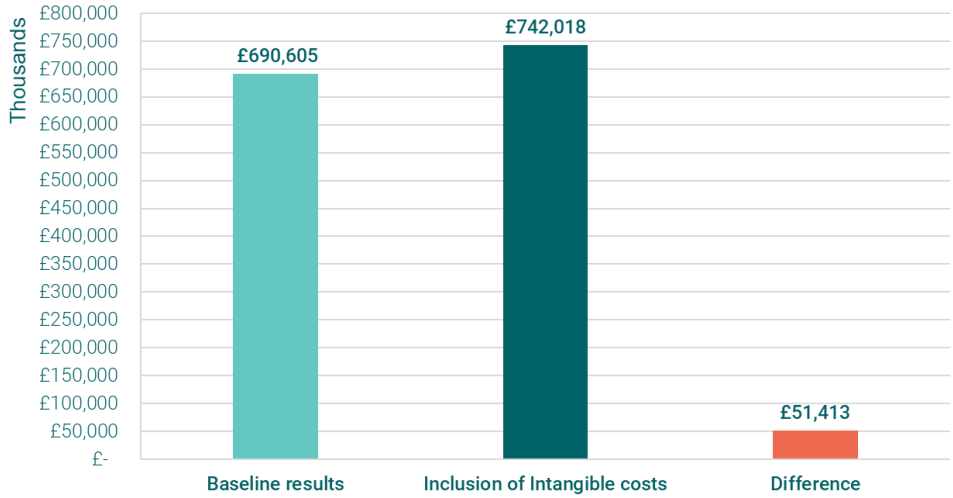

FIGURE 7: POPULATION-LEVEL BURDEN AND SAVINGS - INCLUSION OF MONETISED QALYS, PRESENT VALUE IN 2023 TERMS

3.4.3 Rare cancer threshold

The WHO target of 4 per 100,000 women is based on the global average age distribution, which skews younger than the UK. An alternative definition of 'elimination' for an older age disease distribution may be the rare cancer threshold of 6 per 100,000. Based on our elimination trajectory, this threshold is estimated to be reached in 2039 (Simms et al., 2019).

In Figure 8, we compare the cumulative socioeconomic burden associated with the UK's preventative actions over the period 2023 to 2039 with a 'no preventative actions' counterfactual over the same period. Reaching the rare cancer threshold by 2039 reduces the socioeconomic burden relative to 'no preventative actions' by £1.4 billion or a reduction of 15%.

While NHS England's commitment to elimination likely refers to the WHO target of 4 per 100,000, the rare cancer threshold scenario analysis demonstrates that significant gains can be made at interim time points. This would represent a first step towards the WHO elimination objective, an approach taken by Australia (Cancer Council NSW, 2019).

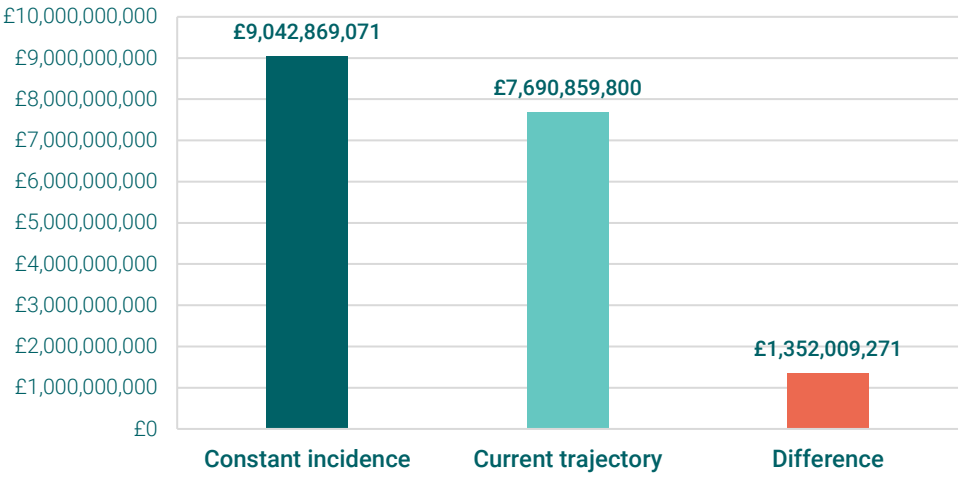

FIGURE 8: CUMULATIVE SOCIOECONOMIC BURDEN OVER TIME TO ELIMINATION (2023-2039), PRESENT VALUE IN 2023 TERMS

4 Discussion

This report provides quantitative evidence of the socioeconomic burden of cervical cancer in the UK and the potential socioeconomic savings from reaching the WHO elimination target of fewer than 4 cases per 100,000 women.

We estimate that **cervical cancer is associated with a lifetime cost of £208,086 per case**. This value includes costs to the direct healthcare system, individual patients, and the wider society due to cervical cancer morbidity and mortality. This analysis demonstrates that the socioeconomic burden falls mainly on wider society and families through the loss of income and informal care responsibilities (accounting for 85% of the total burden), far exceeding the proportion that is borne by the healthcare system (8%). The loss of income and informal care responsibilities are driven primarily by premature mortality relative to the losses incurred while the patient is ill.

At the current incidence rate of 9.7 cases per 100,000, **the total socioeconomic burden of new cervical cancer cases in the UK is approximately £691 million**. We further estimate that if the WHO elimination target had already been achieved today in the UK (in 2023), there would be an instant 59% reduction in the socioeconomic burden, equivalent to £405 million. It is challenging to compare these figures with estimates of those of other cancers and chronic diseases because of the heterogeneity of approaches and cost components considered in the disease socioeconomic burden literature. However, to put these figures into perspective, the current socioeconomic burden of new cervical cancer cases in the UK is equivalent to approximately 40% of the UK combined spending on immunisation and early detection programmes pre-COVID-19 (£1.7 billion in 2019) or, equivalently, to about 8% of the total UK pre-COVID-19 spending on preventative care (£8.3 billion in 2019) (ONS, 2023a).

The UK could save around £2.6 billion by achieving the WHO elimination threshold. This figure represents the cumulative savings over time in the period 2023-2046, compared to taking no action on cervical cancer elimination. This is obtained by considering an elimination pathway that mirrors elimination projections of countries with very high human development indexes (including the UK) and corresponds to a gender-neutral vaccination strategy and screening (Simms et al., 2019). Of note, our estimate of the savings over time does not consider the cost required to achieve elimination in terms of spending on prevention and control measures such as vaccination and screening, which would reduce the total savings.

We consider the elimination target year of 2046 to provide a reasonable approximation of NHS England's recent announcement to eliminate cervical cancer by 2040, as our model takes a UK-wide perspective. The incidence of cervical cancer is higher in Scotland and Wales (11.7 and 11.0 per 100,000, respectively (Cancer Research UK, 2021)); it seems reasonable that the UK-wide elimination target may be reached later than 2040. Moreover, while vaccination rates fell short of the target in 2021-22, likely due to the impact of the COVID-19 pandemic, they fall within the 80-100% range associated with the elimination trajectory that informs our target year (UKHSA, 2022).

Nonetheless, we hope that NHS England's renewed commitment to elimination provides the impetus to improve vaccination and screening coverage and implement a clear strategy to accelerate elimination. These combined efforts may reduce the cumulative socioeconomic burden further than our predicted estimates. However, they require a **concrete action plan from the NHS aiming to overcome barriers to access, education, and awareness while maintaining sufficient funding and resources**. Further, a **commitment to elimination needs to be made by Scotland, Wales, and Northern Ireland** to ensure there is a UK-wide drive towards elimination.

To help shape such an action plan, the HPV Coalition's roadmap towards elimination offers a set of milestones and targets for achieving elimination equitably across all UK nations (HPV Coalition, 2023). These include:

- **Putting health equity needs at the centre of the elimination plans**, through both national and local leadership, alongside targeted actions to address inequalities in screening and vaccination.
- **Tailoring the elimination plan to local populations** to account for differences in socioeconomic, cultural, and environmental factors. Local systems should appoint accountable leads for elimination, working across the NHS, public health and voluntary sector organisations (such as Integrated Care Systems in England).
- **Educational initiatives should be implemented by 2025** to drive progress in reducing stigma and confusion surrounding HPV, with a particular focus on more marginalised groups.
- **A more targeted approach to screening**, ensuring adequate protection for age groups who have not been eligible for vaccination and setting clear targets for underrepresented and vulnerable groups to meet the WHO elimination screening target of 70% by 2030.
- **Better collection of demographic data and regular reviews of national and local datasets** to identify those missing out on preventative measures and to identify trends which can influence future communications and campaigns.

In December 2023, NHS England published its vaccination strategy (NHS England, 2023a), which will play an important role in enabling some of these changes. However, it is vital that the promised implementation plans for each pillar of the ambition are brought forward without delay.

To estimate the socioeconomic burden of cervical cancer, we had to make several simplifications due to evidence gaps. For these reasons, **our baseline estimates may provide an underestimation of the socioeconomic burden of cervical cancer and the savings associated with elimination**.

For example, we assume that a patient returns to full-time employment as soon as treatment is finished, but this can often be a staggered return and a longer absence from work. This may also affect the duration of OOP expenditures for the patient. In addition, even while a patient has returned to work, their productivity at work may be less compared to pre-diagnosis due to side effects, fatigue, or psychological distress (i.e., presenteeism).

Similarly, the intangible losses quantified in terms of monetised QALY losses only consider the patient's loss of quality of life associated with treatment, recovery, and survivorship. There may be other elements of quality of life that are impacted but have not been measured in the literature, for example, the impact on social life or psychosexual well-being of patients, the quality of life loss for family members or caregivers, or the impact of grief.

Due to a lack of data on post-retirement activity, we were not able to consider the lost value of production among women, who may continue to work or switch to part-time work after retirement age, or the lost informal care beyond the retirement age for grandchildren, partners, or other relatives.

Further, the available evidence and data on the cost of treating cervical cancer do not allow us to consider additional non-hospital costs, e.g., GP and laboratory costs, the cost of newly approved high-cost therapies for cases that do not respond to standard treatment, or the cost of caregiving provided by charities and not-for-profit organisations.

Finally, there may be additional externalities that affect the wider society from eliminating cervical cancer that could not be robustly quantified. One example is the impact of the loss of a parent on children's educational outcomes and, in the long run, their future earnings. In addition, achieving elimination could substantially reduce the burden on the NHS and free up valuable resources in times of high pressure.

5 Conclusions

This analysis has provided quantitative estimates of the socioeconomic burden of cervical cancer in the UK, most notably a lifetime cost per individual case of £208,086, a population-level estimate of £691m at current incidence compared to £285m at the target incidence, and a total saving of £2.6 billion from achieving elimination in 2046 compared to taking no action on cervical cancer elimination.

Our findings demonstrate that the socioeconomic burden to society falls not only on the healthcare system but also on wider society and families through the loss of income and informal care responsibilities and that most of the losses are driven by premature mortality.

Our report demonstrates the importance for patients, the health system, and society of following through on increasing the coverage of preventative and early detection interventions that have already been implemented in the UK. A loss of momentum in screening and vaccination could delay elimination and place a significant and preventable burden on society.

In addition, NHS England's recent commitment to achieve elimination by 2040 would reduce the socioeconomic burden further than our estimates of the cumulative burden. However, it is crucial for this aspiration to be reinforced by an implementation plan of measurable actions and milestones from the NHS and for a similar strategy to be adopted throughout the UK to accelerate the path to elimination.

OFFICE OF HEALTH ECONOMICS
CONTRACT RESEARCH

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7 Appendix

7.1 Literature review

We conducted a pragmatic literature review to define the cost components relating to the socioeconomic cost of cervical cancer, estimates of these costs, as well as defining additional economic parameters (e.g., value of informal care).

Searches were performed in PubMed, with results limited to the last 10 years. The search string entailed free text and MeSH terms for cost of illness, informal and social care, productivity, and out-of-pocket expenditure. The full search string can be seen below in Table 1.

TABLE 1: FULL PUBMED SEARCH STRING

Search Number	Query	Results
1	Cervical uterine neoplasms[MeSH Terms]	87,781
2	"cervical cancer"[Title/Abstract]	59,398
3	"cervical neoplasm"[Title/Abstract]	272
4	"cancer cervix"[Title/Abstract:~2]	6,125
5	"neoplasm cervix"[Title/Abstract:~2]	74
6	#1 OR #2 OR #3 OR #4 OR #5	107,539
7	health expenditures[MeSH Terms]	26,024
8	economics[MeSH Terms]	662,610
9	"cost of illness"[Title/Abstract]	2,768
10	costs and cost analysis[MeSH Terms]	265,252
11	productivity[Title/Abstract]	80,921
12	Out Of Pocket Expenditure[MeSH Terms]	26,024
14	Out-Of-Pocket Expenditure[Title/Abstract]	758
15	"informal care"[Title/Abstract]	2,538
16	"social care"[Title/Abstract]	9,014
17	#7 OR #8 OR #9 OR #10 OR #11 OR #12 OR #14 OR #15 OR #16	745,380
18	#6 AND #17	2,450
19	#6 AND #17	1,096

Since we are estimating the socioeconomic costs to the UK, we decided not to apply costs from studies from non-UK contexts where possible, as there can be significant variations across different settings. In total, the searches produced 1096 results, of which 23 were UK studies, although only 11 of these provided relevant data for estimating the socioeconomic burden.

The primary reasons for exclusion included a lack of generalisability based on geographical context, interventions of publicity campaigns, or a lack of any reported costs or parameters. One hundred and ten non-UK economic evaluation studies published since 2018 were identified. However, these

provided little relevant information that could be used to inform the model development and were excluded.

7.2 Interviews

Interviews were conducted with various stakeholders and experts in the cervical cancer space. We did this to obtain and validate certain model assumptions, our methodology and results.

The background and aims of the project were presented, as well as the approach we took and some of the initial modelling results that we derived. In addition, we highlighted key questions and assumptions where we felt like the interviewees, based on their experience, could help us validate the approach taken.

The interviews we conducted were with two health economists, two epidemiologists, and a patient representative. A summary of the most relevant topics and key questions on which each stakeholder provided responses and validation is summarised in Table 2.

TABLE 2: SUMMARY OF INTERVIEWS

Stakeholder group	Topics of most relevance	Examples of key questions
Health economist	Healthcare system, productivity costs, informal care loss, caregiver loss	• Should we/how can we account for high-cost therapies in addition to the illness cost? • Can you comment on our assumptions around productivity costs and informal care loss?
Epidemiologist	Burden framework, elimination trajectory	• What are plausible scenarios for the trajectory of elimination? • Is the framework reflective of the burden of cervical cancer? • Do we need to account for population growth over 2023-2055?
Patient representative	Individual costs, other aspects of the patient journey through the health system	• Are there any individual costs that are not accounted for in our framework? • Are there other aspects of OOP costs that have not been captured? • We have assumed that OOP costs are incurred during treatment. Can you comment on this assumption?

The aim of the interviews with the health economists was to get their expert opinions on certain assumptions, particularly when calculating the lifetime cost per case of cervical cancer. In particular, the assumptions around how best it would be to capture the productivity losses, more specifically, which of either the human capital approach or the friction cost method was more appropriate for the analysis.

The focus of the interview with the epidemiologists was to establish the most likely elimination trajectory of the prevalence of cervical cancer and how this should be modelled over time.

The interview with the patient representative was undertaken to ensure the out-of-pocket costs, as well as other aspects of the patient's journey, accurately reflect current practice.

7.3 Data and assumptions

In this section, we will outline the methods, assumptions and sources of information that have informed the modelling of the socioeconomic cost of cervical. Each sub-section will relate to a cost component, in addition to a section on how the burden has been estimated over time.

A key assumption underlying the model is the use of population-level values rather than the use of a cohort simulation. A cohort simulation would model patients with cervical cancer individually, using age-specific incidence rates. Undoubtedly, this would lead to more precise estimates of the socioeconomic burden of cervical cancer. However, it is not clear whether this would represent an increase or decrease in comparison to the estimations we derive.

All costs incurred from year two onwards are discounted, and long-term inflation is accounted for as per the HM Treasury Green Book (HM Treasury, 2022). All sources of the cost estimates before 2022 are inflated to 2022 prices. All data sources used were the most recently available at the time of developing the model in September 2023.

7.3.1 Healthcare costs

To estimate the average cost per patient, we used a previous estimate that analysed Hospital Episode Statistics data from 2015-2018 (Fabiano et al., 2023). This estimate includes hospital inpatient treatment, outpatient appointments, chemotherapy, and radiotherapy. All costs are presented in Table 3, and we assumed that all cervical cancer patients incur these direct medical costs.

TABLE 3: HEALTHCARE COSTS

	Value	Source
Year 1 inpatient episodes	£5,103	Fabiano et al (2023)
Year 1 outpatient	£5,779	
Year 2 inpatient episodes	£1,004	
Year 3 inpatient episodes	£834	
Social Time Preference Rate for discounting future costs	3.5%	HM Treasury Green Book (2022)

Based on the available data, this will provide us with the best estimation of the associated healthcare costs. However, it is likely that this underestimates the true burden on the NHS due to some simplifying assumptions. The healthcare costs have excluded non-hospital costs, such as GP visits and laboratory tests, as these were unavailable in Fabiano et al. (2023) and are unlikely to be available in current databases.

In addition, we have excluded the newly approved high-cost therapies from the estimation, as there is limited publicly available data on costs, outcomes, and uptake rates. Their inclusion would increase the cost to the health system.

7.3.2 Loss of patient's workplace productivity

Workplace productivity losses are calculated with respect to both absenteeism and mortality. The losses relating to the absenteeism period apply to the days that are taken off work due to sickness. An estimate of this is provided by from a study undertaking a cost-benefit analysis of HPV vaccination (Park, Jit and Wu, 2018). This figure and the assumptions from the study are applied to UK demographic data (ONS, 2022a, 2023b), namely the median annual pay for full-time employees and the percentage of women in employment (see Table 4). This gives the lost value of production due to absenteeism.

TABLE 4: PRODUCTIVITY LOSSES DUE TO ABSENTEEISM

	Value	Source
Median annual pay, full-time employees	£33,000	ONS (2022a)
% of women in employment	72.3%	ONS (2023b)
Absenteeism days due to sickness	0.116 years	Park et al (2018)

To estimate productivity loss due to mortality, we applied the human capital approach to calculate the lost value of production. The human capital approach assumes that when a patient dies, their productivity loss is equivalent to the value of the remainder of their working life until retirement. The friction cost approach is another methodology to value productivity losses due to premature mortality. In this case, productivity losses are assumed during the period it takes to replace a worker (the so-called 'friction period'). As a result, the friction cost approach typically leads to lower estimates of productivity losses due to mortality than the human capital approach. Based on feedback from the expert interviews, in this work, we adopted the human capital approach to represent productivity losses from a patient perspective, while the friction cost approach would solely reflect productivity losses from an employer's perspective.

To calculate productivity losses due to mortality, we multiplied the median annual pay in the UK by the proportion of women in employment. As this is a cost incurred annually until retirement, we multiplied the years remaining to retirement from the average age at diagnosis (Cancer Research UK, 2021; ONS, 2022b) by the ONS mortality rates at the discrete time periods of one, five and ten years (ONS, 2019). As before, all costs incurred beyond year one are discounted appropriately.

TABLE 5: PRODUCTIVITY LOSSES DUE TO MORTALITY

	Value	Source
Median annual pay, full-time employees	£33,000	ONS (2022a)
Mean age at diagnosis	52	Calculated using Cancer Research UK, (2021); ONS, (2022)
Retirement age	68	(Department for Work & Pensions, 2014)
Cervical cancer survival		
1 year	81%	ONS (2019)
5 years	59.8%	
10 years	51.2%	

OFFICE OF HEALTH ECONOMICS
CONTRACT RESEARCH

Social Time Preference Rate for discounting future costs	3.5%	HM Treasury Green Book (2022)

To quantify this burden, a few simplifying assumptions had to be made. Firstly, it is assumed that the survival rate of cervical cancer will remain stable over time. Advanced therapeutics and earlier diagnosis will lead to improvements in survival over time, therefore reducing the loss of productivity due to mortality. This will likely lead to an overestimation of this cost component.

We assume that once women reach retirement age, all economic activity ceases. Some women may continue to be in full-time employment or switch to part-time after reaching retirement age. In addition, we assume that patients return to full-time employment as soon as treatment is finished and that they are fully productive. Whereas often, there can be a staggered return to work, or a longer absence from work. Both factors likely underestimate the true burden.

7.3.3 Informal care losses of patients

Patient informal care losses refer to the unpaid informal labour carried out within the home that cannot be undertaken by the patient during their illness or following their death. We followed the same approach as we did for workplace productivity losses, whereby we calculated the losses in terms of both mortality and sickness/treatment. The same survival estimates and duration of treatment are applied as per Tables 4 and 5. In addition, we assume that the caregiver's responsibility lasts until the woman is of retirement age.

We multiplied the value of the care loss by the proportion of women who are economically inactive, as we assume these women to have full-time employment equivalent to caregiving (See Table 6). Another assumption we make here is that the value of unpaid labour is equivalent to that of paid labour, an assumption also used in the Park et al. (2018) study.

TABLE 6: INFORMAL CARE LOSSES OF PATIENTS

	Value	Source
Median annual pay, full-time employees	£33,000	ONS (2022a)
Mean age at diagnosis	52	Calculated using CRUK (2021) ONS (2021)
Retirement age	68	(Department for Work & Pensions, 2014)
% women, economically inactive	25.2%	ONS (2023)
Absenteeism days due to sickness	0.116 years	Park et al (2018)

In addition to the assumptions around the time spent caring and the value of the care provided, other assumptions were made similar to those made when calculating workplace productivity losses. Again, we applied survival estimates that remain stable over time when calculating informal caregiving losses due to mortality losses. In the same way as economic activity, we have assumed that informal caregiving ceases at retirement. Informal care may be provided beyond retirement, whether to grandchildren, partners, or other relatives. The overall impact of the assumptions on the direction of our estimates is uncertain.

7.3.4 Loss of caregiver's productivity

This loss of productivity applies to the family members of cervical cancer patients who spend additional time on informal caregiving activities. To quantify this value, we reproduce an approach

taken by researchers estimating the informal caregiving losses of colorectal cancer using generic input data from all cancers (Henderson et al., 2021). They assume that caregiving losses may occur in patients who are severely limited or terminally ill (See Table 7).

For the proportion of patients who are severely limited, the hours of caregiving they are expected to receive are multiplied by the average hourly salary of an informal caregiver. The hourly salary is obtained by calibrating the median annual UK salary, assuming 230 working days per year and 8-hour working days. It's assumed that caregiving for severely limited patients takes place only in the first year of their illness period.

For those patients who are terminally ill, the hours spent on informal caregiving are multiplied by the average hourly rate of informal caregivers. This is then applied to the proportion of patients who have died at the discrete time periods reported in Table 5, using the cervical cancer survival data applied previously (ONS, 2019).

TABLE 7: LOSS OF CAREGIVERS PRODUCTIVITY

	Value	Source
Total hours of informal care received by severely limited cancer patients	396.36	Henderson et al. (2021)
Total hours of informal care received by terminally ill cancer patients	1132.75	Henderson et al. (2021)
Hourly wage value of caregivers	£17.93	Calculated
The probability of being severely limited by cancer	0.1031	Henderson et al. (2021)
Probability of receiving care in case of severely limited patients	0.0473	Henderson et al. (2021)
Probability of receiving care in case of terminally ill patients	0.84	Henderson et al. (2021)

7.3.5 Cost to the individual

We quantify the cost to the individual patient with cervical cancer as the out-of-pocket expenses they incur as a result of their diagnosis. A Demos report commissioned by Jo's Cervical Cancer Trust estimated the out-of-pocket expenses incurred by patients as a result of cervical cancer diagnosis and treatment (Salter, 2014).

We sum the monthly expenses for cost categories that are generalisable to the wider UK population. Certain costs are excluded. Including those related to private medical fees, inpatient hospital stays, specialist equipment and hospital fees, to minimise the risk of double counting other medical costs. The monthly out-of-pocket costs by the duration of treatment and allocated this to all women with cervical cancer in the first year of diagnosis (See Table 8).

TABLE 8: OUT-OF-POCKET COSTS TO THE PATIENT

	Value	% of women
Childcare	£263	14
Paid household help	£246	14

Special diets or dietary supplements	£109	49
Prescription medicines or medicinal products	£96	24
Private transport for appointments	£94	66
Complementary and alternative therapy sessions	£82	34
Specialist, additional or differently sized clothing	£73	44
Public transport for appointments	£66	35
Hospital car parking charges	£64	59
Non-prescription medicines or medical products	£62	48
Natural or homoeopathic medicines	£62	26

An individual patient is expected to experience a loss in quality of life associated with treatment, recovery and survivorship associated with cervical cancer. The loss represents an intangible cost that is internalised by the patient and not accounted for in other monetary input parameters (e.g., healthcare costs and patient productivity losses). We have excluded these costs from the base case analysis as discussed in the methodology. Table 9 includes the data used to calculate the scenario analysis's intangible costs.

TABLE 9: INTANGIBLE COSTS

	Value	Source
Remaining life expectancy for the general population at the age of diagnosis (50-54 years)	32.35 years	(Castañon, Rebolj and Sasieni, 2019)
Age-specify QALY weight for the general population at the age of diagnosis (45-54 years)	0.824	
Diagnosis and treatment	-0.285 for 0.116 years	
Survivorship	Linear change from -0.285 to -0.0305 in 1.5 years	
WTP threshold	£20,000/QALY	(NICE, 2022)
Social Time Preference Rate for discounting future health effects	1.5%	HM Treasury Green Book (2022)

7.3.6 Estimating the burden at the population-level

We used the size of the 2023 UK female population, and current and target incidence rates to extrapolate the average lifetime cost per cervical cancer case at the population level. The difference between the lifetime cost at the current and target incident population levels represents the saving in the socioeconomic burden of cervical cancer had the WHO elimination target already been achieved by 2023.

TABLE 10: POPULATION-LEVEL BURDEN

	Value (low, high)	Source
UK total female population 2023	34,214,835	ONS (2023b)
Cervical cancer incidence rate per 100,000 (all ages)	9.7 (9.5, 9.9)	Cancer Research UK (2021)
Elimination rate incidence target rate per 100,000	4	WHO (2020)

7.3.7 Modelling the incidence over time

We estimated a plausible elimination trajectory curve for the UK using data informed by a group of countries with very high human development index (Simms et al., 2019) and summed the socioeconomic burden that occurs for the incident cohort in each year until the predicted year of elimination. The UK is predicted to achieve the WHO's elimination target in 2045-2050 (Simms et al., 2019). Based on current preventative actions against cervical cancer (80-100% coverage, gender-neutral vaccination, and current annual screening rates) and the trajectory curve in Simms et al. (2019), the UK is predicted to achieve elimination in 2046.

We calculate the cumulative burden incurred in each of the years from 2023 to 2046 with the elimination trajectory and compare this to the cumulative burden under a counterfactual 'constant incidence' scenario under which current UK incidence is maintained along the same time horizon. We estimate the savings associated with elimination as the difference between the cumulative burden obtained under the 'constant incidence' and 'current incidence' strategies. In doing so, we assume stable survival rates over time and a constant lifetime cost per case. However, it is worth noting that advanced therapies and earlier diagnosis will likely lead to improvements in survival, reductions in costs linked to survival (productivity loss and informal care loss) and QALY losses over time.

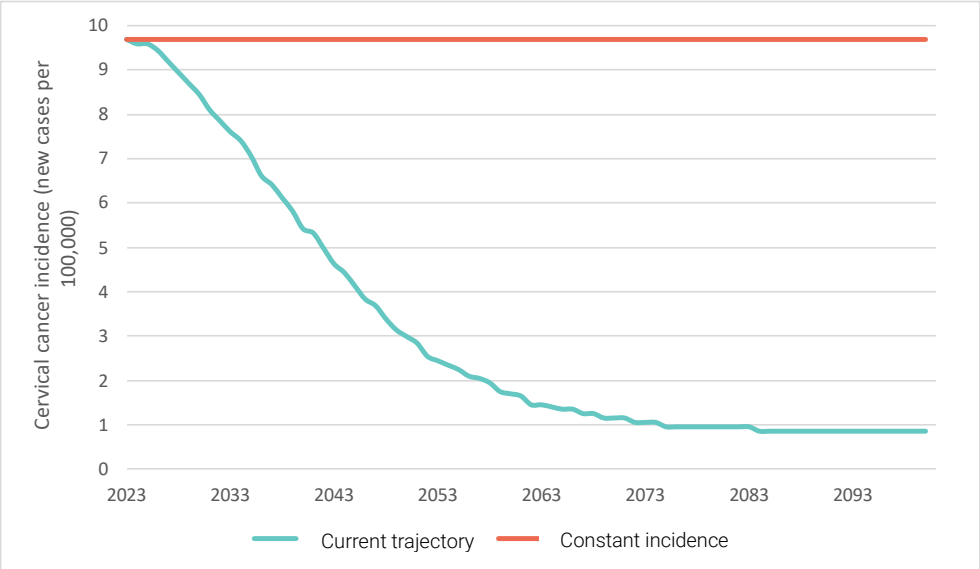

FIGURE 9 UK INCIDENCE TRAJECTORY BASED ON SIMMS ET AL. (2019) AND A CONSTANT INCIDENCE RATE

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- 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

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