Targeted Lung Health Check Programme

Final evaluation report: Appendices

November 2024

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1 Appendix One: Evaluation methodology overview

1.1 Overview of evaluation approach

The evaluation takes a theory-based approach, whereby the theory of how the programme is expected to achieve the desired its outcomes forms the overarching structure for the evaluation. The Theory of Change (TOC) for the programme is included in full in Appendix 4.

The approach has been both formative and summative; emerging findings have been reported at regular intervals throughout the implementation of the programme, to support the TLHC programme team and other stakeholders to adjust programme design and delivery in close to real-time. This final report deploys a summative tone, providing evidence on the overall effectiveness of the programme in achieving its intended outcomes, and summarising insights about how the programme delivered those outcomes.

Mixed methods, both qualitative and quantitative, have been used to collect evidence to answer the evaluation questions and test the programme TOC. These are briefly summarised in section 1.4 below; comprehensive methodological statements are included in Appendices 5, 6, 8 and 10.

The evaluation has comprised two phases: scoping and mainstage.

- The scoping phase ran from August 2019 to January 2020; the objectives of this phase were to: articulate a clear case for change and programme TOC; agree the evaluation objectives with relevant stakeholders; identify and map suitable data sources; design appropriate methodologies and data collection approaches; map and describe the TLHC projects; develop engagement and reporting plans; and identify evaluation risks and mitigation strategies.

- The mainstage ran from February 2020 to July 2024. The objectives of this phase were to collect data at agreed intervals, using the methods outlined in the scoping report, and produce formative evaluation reports periodically to share emerging findings with the TLHC programme team and the wider NHSE Cancer Programme, and other key stakeholders including the Cancer Analysis and Insights Team (CAIT), the TLHC Evaluation Oversight Group (EOG) and Expert Advisory Group (EAG), and the TLHC projects. Alongside formative progress reports, other technical reports were also produced during the mainstage, including the impact evaluation protocol and the economic evaluation protocol. These set out more detailed plans for these evaluation workstreams, once further scoping work had been completed.

1.2 Evaluation oversight

The EOG was convened by NHS England to oversee the TLHC Programme Evaluation and the evaluation of the Faster Diagnosis Programme. The group comprised members of the NHS England Cancer Programme, NHS England analysts, and clinical representatives. The group met quarterly between February 2021 and March 2024 to advise on various aspects of the evaluation methodology.

A Lung Cancer EAG was also established in 2020. The EAG was setup to provide a breadth of experience, expertise, and perspective from across the lung cancer screening pathway. The EAG has three key roles:

1. Providing advice and recommendations for the TLHC programme, supporting the development of guidance and implementation;

2. Providing knowledge and expertise into the NHS Cancer Programme Clinical Advisory Group and to the National Clinical Director for Cancer;

3. Providing comprehensive, accurate advice on research evidence for LDCT screening for the UK National Screening Committee (UKNSC).

Whilst the EAG was not set up to provide detailed advice and recommendations on the evaluation of the TLHC programme, the group has been kept abreast of evaluation findings and has contributed expertise and perspectives on an ad hoc basis at key points throughout the evaluation.

1.3 Methodology overview

This section summarises the evaluation activities that have taken place across the evaluation lifecycle.

1.3.1 Scoping phase

The scoping phase comprised the following evaluation activities, which took place between September 2019 and January 2020:

- **Literature review** – relevant literature was reviewed and summarised, setting out the evidence behind the core components of the programme theory.

- **Data scan** – wider data sources available to support the evaluation were reviewed and discussed with data owners.

- **Document review** – key programme documentation from NHSE was reviewed, including protocols outlining how the programme was expected to run, quality assurance documentation, and an outline of plans and risks from each project.

- **Familiarisation interviews** – telephone interviews were conducted with key stakeholders of the TLHC programme including members of the programme team and experts with experience of similar health interventions. These interviews provided information on evidence underpinning the programme theory, the aims of the programme and how it was expected to work, and wider programme context.

- **Initial project calls** – telephone interviews were conducted with the leads at each of the Phase 1 projects (except one). These interviews provided an understanding of the TLHC programme in more depth including local plans for implementation and explored options for including programme participants in the evaluation.

1.3.2 Mainstage: process evaluation

The mainstage comprised the following evaluation activities, which are summarised separately for the process, impact, and economic evaluation workstreams:

Qualitative fieldwork with programme stakeholders

Seven waves of qualitative fieldwork with programme stakeholders, totalling 148 semi-structured interviews (typically one-to-one, sometimes paired) and 8 focus groups. Fieldwork was undertaken at the

following time points: February to April, and September to October 2020; April to May, and September to October 2021; March to April, and November to December 2022; April to May 2024.

A wide range of stakeholders were consulted, some several times, during the evaluation. Interviewees included:

- TLHC project / programme managers;
- Staff involved in delivering the TLHC pathway including LHC nurses, radiographers, radiologists, and administrative staff (e.g. booking clerks);
- Clinical Directors and Senior Responsible Officers;
- Cancer Alliance leads with responsibility for the TLHC programme;
- NHSE Cancer Programme team members;
- TLHC Clinical Leads;
- Members of the TLHC EAG and members of the TLHC Evaluation Oversight Group;
- Members of the Public Health Commissioning Central Team at NHSE.

Within each fieldwork wave, a full thematic analysis of all interviews was undertaken, against a framework derived from interview topic guides and the programme theory. As programme delivery matured, a thematic approach was adopted for some fieldwork rounds to “deep dive” into themes of particular interest for the programme team, within the scope of the agreed evaluation framework. Example themes of interest included: health inequalities; LHC and CT scan uptake; and intervention model variations. Interviews and focus groups were audio recorded, where participant consent was provided. Transcripts and detailed notes were captured and coded using NVivo qualitative analysis software.

This report draws on qualitative data from across the whole mainstage evaluation period, with a particular emphasis on findings from the most recent fieldwork periods.

Qualitative fieldwork with LHC attendees

Qualitative fieldwork with LHC attendees took place over four separate waves, with each wave consisting of 25 interviews. Wave one took place in October 2021; wave two in January-February 2022; wave three in April 2022; and wave four in June 2022. Interviewees were recruited from participants who had completed the attendees’ survey and agreed to be re-contacted. Interviews took place via telephone or online and lasted up to 60 minutes. Quotas were used to ensure the sample for each wave included interviewees from all seven regions, and with a range of demographic and attitudinal characteristics.

As with stakeholder interviews, detailed notes were captured during participant interviews and then coded in NVivo. The discussion guide for the interviews with attendees was reviewed in two stages by the national programme team and Patient and Public Voice (PPV) group – once in mid-2020 and again closer to the start of fieldwork, in August and September 2021. The overall proposed approach and discussion guide were also reviewed by ethical experts within Ipsos in September 2021. Further detail on this methodology is provided in Appendix 9.

Attendees' and follow-up surveys

Participants were invited to complete the initial attendees' survey shortly after attending either an LHC or initial CT scan appointment. If participants agreed to be re-contacted, they were invited to complete a follow-up survey three to four months after their LHC or initial CT scan appointment. Both surveys were mixed mode; administered using both online and postal methods.

Findings from the attendees' survey are based on 11,979 responses received between 22 June 2021 and 17 May 2022 from 21 CCG areas covering 14 projects participating in the programme. It is not possible to provide a response rate for the attendees' survey, because projects did not record the number of times a survey had been offered. For example, when handing out surveys face-to-face, a participant could decline to take part in the survey, but this would not be recorded. Likewise, projects did not record and share with Ipsos the number of email or text invitations that were sent. Data from the follow-up survey is based on 2,296 responses received between 30 November 2021 and 14 September 2022. For the follow-up survey (distributed by Ipsos) the response rate was 23%.

Unless otherwise stated, any comparisons that are drawn using either the attendees' survey or using the follow-up survey are statistically significant. As standard, the base figures or counts for any percentages shown are not included to ensure that the results are easy to interpret.

Further detail on this methodology is provided in Appendix 9.

Non-attendees' tool data submissions

A subsample of 11 Phase 1 and 2 projects participated in the optional non-attendees' tool data collection between May 2022 and April 2023, across four submission quarters. As part of this, administrative staff were asked to record the reasons that individuals gave for not engaging with the service after receiving an invitation (referred to as non-engagement) or for booking an appointment but then not attending (non-attendance). In total, the reason for non-engagement or non-attendance was recorded for 81,270 individuals. Reasons were recorded in aggregate in an Excel spreadsheet using a codeframe of pre-determined reason options. Projects were also able to record 'other' options. Detailed instructions for administrative staff on how to use the tool are included within the tool itself, in addition to videos produced by the evaluation team demonstrating its use.

The non-attendees' tool data is included within Chapter 4. More detail on the non-attendees' tool dataset, including the limitations, is included in Appendix 9.

Monitoring information data collection

Monthly Management Information (MI) data was collected from all Phase 1 and 2 projects. A detailed record level dataset (Minimum Dataset – MDS) was collected from all Phase 1 projects and some Phase 2 projects, whilst the other Phase 2 projects submitted an aggregate level return. These returns were used to monitor the progress of the TLHC programme.

The record level dataset was linked to cancer diagnosis and staging data from the National Cancer Registration and Analysis Service (NCRAS). A combination of the 'gold standard' and the rapid cancer registration dataset (RCRD) was used. The datasets are linked on NHS Number and then logic is applied to assign the right cancer diagnosis to the right activity data. The NCRAS data covers lung cancers and all other cancer diagnoses. Data on cancer staging is variable with the RCRD, including more cancers that are unstaged.

The MI data is used in several chapters in this report. It was also used to develop the patient level analysis and to support the impact and economic analyses.

See Appendix 8 for an overview of the datasets each project is collecting, and which strand of the evaluation they are contributing to.

Patient-level data analysis

The patient level analysis uses the MDS to track participant pathways from invite to CT scan. The MDS is then linked to the combined NCRAS dataset to show participant outcomes (diagnosis and staging rates). This data is only available for the Phase 1 projects and any extensions of these projects in Phase 2. Where included in the report, this analysis is based on TLHC activity data submitted up to March 2024 and NCRAS lung cancer activity to August 2023.

A status for each participant was determined for milestones along the TLHC pathway, covering stages such as invites, LHC attendance (including mode of delivery and number of contact attempts), calculated risk assessment and the number of CT scans these participants underwent. Rules were applied to remove any double counting and manage data quality issues. This means that in some cases, the numbers will not match those used in the report.

These details, along with participant demographic characteristics and details about the project they were involved with, were aggregated up to produce summary counts of participants at key stages along the pathway.

An algorithm was written to calculate the flow of participants between steps for the whole programme, which allows for the selective use of filters to focus on a particular group, e.g. by organisation (project, or Cancer Alliance), typology (delivery model), and demographic factors (deprivation decile, age group, etc.). The outputs are created as Sankey diagrams, which are included in a standalone PowerPoint analysis report – Appendix 7.

Eligible population estimates

The report includes eligible population estimates data (referred to as ‘GPPS eligible population estimates’) produced by Ipsos to estimate demographics of TLHC eligible populations, split by geographic levels relevant to the TLHC programme.

These estimates were created using the GP Patient Survey (GPPS) 2022[1] data (that Ipsos delivers on behalf of NHSE) and ONS Population Estimates 2022[2] data. GPPS is a random probability survey, which means we can be confident that respondents to the survey are representative of the English population aged 16+ registered with each GP practice. The data is weighted to ensure those taking part are representative of the TLHC eligible population. This data is therefore suitable for use in these estimates, as the definition of eligibility for the TLHC programme includes a requirement that the individual is registered with a GP practice[3].

The TLHC eligible population estimates were created using GPPS 2022 data to identify the proportion of eligible individuals within the 55-74 age bracket and their demographics within relevant geographic

[1] See: https://www.gp-patient.co.uk/About [Accessed May 2024]
[2] See: https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationestimates [Accessed May 2024]
[3] See: https://www.england.nhs.uk/publication/targeted-screening-for-lung-cancer/ [Accessed May 2024]

footprints, applied to the same geographic footprints' ONS Population Estimates 2022 estimate figure. In **Chapter 4**, these estimates are used to analyse the demographics of participants invited to the TLHC programme and those who attend a LHC and CT scan, in TLHC projects that report record-level data.

Estimates are included as of 2022; it is not anticipated that the eligible population in each TLHC project will have changed substantially over the course of the evaluation. The year 2022 is used as a mid-point during the evaluation period (2019-2024) to best reflect the make-up of the eligible population during programme delivery.

1.3.3 Mainstage: impact evaluation

The impact evaluation uses a quasi-experimental design to estimate the impact of the TLHC programme. Using a propensity score matching – difference-in-differences (PSM-DiD) methodology – the estimated impacts can be attributed to the TLHC programme.

The impact evaluation explores the impact of the TLHC programme on the key outcomes in turn:

- The number of lung cancers diagnosed in the target population;
- The number of lung cancers diagnosed at stage 1 or 2, stage 3 or 4 and not staged at diagnosis within the target population; and,
- The number of deaths due to lung cancer within the target population.

Within each of the outcomes, descriptive evidence is first presented. This compares the areas that are part of the TLHC programme (THLC intervention areas) and all Middle layer Super Output Areas (MSOAs)[4] in England that did not participate in the TLHC programme (referred to as non-intervention areas). Note, descriptive statistics are not causal estimates of impact.

The descriptive evidence is followed by the results of the PSM-DiD design for each of the key outcomes. The results of the PSM-DiD can be interpreted as the causal impact of the TLHC programme, where any observed changes can be attributed to the programme rather than other factors. The results are presented in graphical form, using 'event study' graphs, which display the impact of the programme over time – presenting a measure of impact for each year following the introduction of the TLHC programme.

The impact evaluation also explores the extent to which there are differential impacts of the TLHC programme across different sub-groups, including, gender, age, ethnicity and level of deprivation. The causal impact analysis uses a PSM-DiD approach to explore whether there are differences in the number of lung cancer diagnoses (including number of diagnoses by stage) and deaths due to lung cancer in the target population between the sub-groups, exploring how these differences change over time between intervention and comparison areas.

A full technical appendix for the impact evaluation, including a detailed methodology, is included in Appendix 5.

[4] MSOAs are small geographical units that contain between 2,000 and 6,000 households (equivalent to 5,000 and 15,000 residents). 2011 MSOA boundaries are used throughout the analysis.

Descriptive analysis of secondary datasets

Descriptive analysis of Cancer Waiting Times (CWT) CWT is a national dataset that tracks patient care activity from referral, diagnosis and treatment, and is used to monitor cancer waiting times performance targets at the national, provider and commissioner level[5].was used within the impact evaluation to assess the achievement of the evaluation's secondary outcomes and their associated indicators (as outlined within the impact evaluation protocol).

This analysis presents and explores key points and insights from the data presented to aid interpretation by describing, demonstrating and summarising the data, such as changes over time and trends, and utilises charts to better visualise the data. No statistical approaches are utilised within this analysis and therefore any trends or patterns presented have not been tested for statistical significance.

1.3.4 Mainstage: economic evaluation

A Cost Consequence Analysis (CCA) framework was used to provide a comprehensive summary of the different costs and effects (i.e. consequences) of the programme economic surveys and associated data submission. The economic evaluation collected data through a cost survey of 24 projects to estimate the costs of setting up, and delivering, a LHC project. While detailed financial accounting is not necessary, to be useful, cost estimates are sufficiently accurate to understand the resourcing implications for the wider rollout across the population. Cost and resource information on labour, capital and supplies was collected. The survey informed estimates of average unit costs associated with the programme, which were then applied to each project to determine their overall cost.

Building on this primary data collected from projects, desktop research was used to estimate the associated costs of diagnosing additional cancers at an earlier stage, noting that long-term cost savings are not estimated within this analysis.

As part of the CCA, a 'Ready Reckoner Cost Tool' (RRT) was developed to synthesise and describe data on resource use and costs associated with setting up and delivering TLHC projects. The RRT can also be used to inform NHSE on the likely future costs associated with the future rollout, based on the cost exhibited by the early adopters of the programme.

1.4 Methodological limitations

Readers should bear the following methodological limitations in mind when reading this report.

- **Stakeholder interviews:** The qualitative data illustrates many of the dominant themes within the programme, rather than forming a representative sample. Engagement with frontline staff (e.g. LHC nurses) and wider clinical stakeholders at the local level (beyond the TLHC Clinical Directors) was relatively limited, due to their lack of capacity to engage with the evaluation.

- **Attendees' survey** – fieldwork took place between June 2021 and May 2022, meaning that the findings may not reflect any changes in participant experience since then. Not all projects distributed surveys across the whole fieldwork period, meaning that there were differences in sample sizes throughout the period. Projects' distribution methods varied, to ensure feasibility; they could choose whether to distribute the survey online, by post, or in person at CT scan

[5] https://www.england.nhs.uk/statistics/statistical-work-areas/cancer-waiting-times/

appointments. This limits the comparability of the survey results. The amount of time between a participant's LHC and when they received the survey varies by project. For practical reasons, projects were asked to survey a proportion of their participants rather than all participants. Some projects may have distributed all their surveys more quickly than others, depending on their throughput of attendees.

- **Attendees' follow-up survey** – fieldwork took place between November 2021 and September 2022, meaning that the findings may not reflect any changes in participant experience since then. Due to the number of overall responses some sub-group analysis is limited. Where base sizes are low, caution is noted.

- **Participant qualitative fieldwork** – fieldwork took place between October 2021 and June 2022, meaning that the findings may not reflect any changes in participant experience since then. Quotas were used to ensure an adequate distribution of participant characteristics, though the sample is not representative of all TLHC participants.

- **MI:** Record level MI data was submitted monthly by all phase 1 projects and phase 2 and 3 projects who chose to submit. All other phase 2 and 3 projects submitted an aggregate dataset. The aggregate dataset was a limited set of key metrics aggregated for the whole project each month. This did not include any demographic breakdowns and therefore these projects are excluded from the demographic analysis. It was also not possible to link the aggregate data to the NCRAS datasets and therefore these projects are not included in the patient level pathway reporting. It was also not possible to verify the cancer diagnosis data with the NCRAS datasets.

- **MDS linked with NCRAS datasets:** Rapid Cancer Registration Dataset (RCRD) is used for cancer diagnosis and staging. The data is linked to the record level MDS data using a pseudonymised NHS number and is therefore only available for projects that submitted record level data. If the NHS number submitted by the project is not correct that record cannot be matched to the RCRD. This is likely to be a small issue but it is not possibly to quantify with the data available. The RCRD used in the analysis was only available until August 2023, therefore aggregate data was used for September 2023 to March 2024 in the overall reporting. It is not possible to use this in the patient level pathway reporting and therefore this analysis is limited to activity up to the end of August 2023.

- **GPPS eligible population estimates:** these are estimates only and are separate to the modelling used by the TLHC programme team to design and fund TLHC projects. The estimates do not take into account the fact that the gradual rollout of the TLHC programme means some Phase 1 and 2 TLHC projects have been funded to deliver to only part of their geographic footprint or that some TLHC project areas have had previous lung screening activity delivered within their footprint outside of the TLHC programme.

- **Non-attendees' tool** - there are some known inconsistencies in how projects recorded and reported this data, though given projects reported aggregate data only, it was not possible to assess the source of inconsistencies. As the data collection was optional and dependent on projects' local model, the figures and trends in the data should be considered as indicative of what projects experienced.

1.5 Data sources

For clarity on all data sources used throughout the report, the metrics they related to, their granularity, coverage and timescales they cover see the table below.

Metric	Phase 1[1]	Phase 2[2]	Phase 3[2]	Record level data available	Record level data available	Percentage of data submitted as record level as at March 24
Eligible for a Lung Health Check	Record level	Aggregate	Aggregate	April 19 to March 24	April 19 to March 24	33.0%
Invited to Lung Health Check (First Invites)	Record level	Aggregate	Aggregate	April 19 to March 24	April 19 to March 24	55.4%
Invited to Lung Health Check (Follow-up Invites)	Record level	Aggregate	Aggregate	April 19 to March 24	April 19 to March 24	64.2%
Accepted a Lung Health Check invitation	Record level	Aggregate	Aggregate	April 19 to March 24	April 19 to March 24	41.9%
Attended a Lung Health Check appt	Record level	Aggregate	Aggregate	April 19 to March 24	April 19 to March 24	52.9%
Attended a face-to-face Lung Health Check appt	Record level	Aggregate	Aggregate	April 19 to March 24	April 19 to March 24	51.3%
Attended a telephone Lung Health Check appt	Record level	Aggregate	Aggregate	April 19 to March 24	April 19 to March 24	53.1%
Did not attend a Lung Health Check appt	Record level	Aggregate	Aggregate	April 19 to March 24	April 19 to March 24	39.2%
Did not attend a face-to-face Lung Health Check appt	Record level	Aggregate	Aggregate	April 19 to March 24	April 19 to March 24	52.1%
Did not attend a telephone Lung Health Check appt	Record level	Aggregate	Aggregate	April 19 to March 24	April 19 to March 24	36.4%
Referred for a Low Dose CT Scan (LDCT)	Record level	Aggregate	Aggregate	April 19 to March 24	April 19 to March 24	56.1%
Triggered a risk score for referral but were ineligible for an initial LD	Record level	Aggregate	Aggregate	April 19 to March 24	April 19 to March 24	46.7%
Initial LDCT scan performed	Record level	Aggregate	Aggregate	April 19 to March 24	April 19 to March 24	59.3%
Did not attend their initial LDCT scan appt	Record level	Aggregate	Aggregate	April 19 to March 24	April 19 to March 24	38.4%
Follow up scans performed	Record level	Aggregate	Aggregate	April 19 to March 24	April 19 to March 24	61.6%
3 month follow up LDCT scan performed	Record level	Aggregate	Aggregate	April 19 to March 24	April 19 to March 24	65.1%
12 month follow up LDCT scan performed	Record level	Aggregate	Aggregate	April 19 to March 24	April 19 to March 24	53.1%
24 month follow up LDCT scan performed	Record level	Aggregate	Aggregate	April 19 to March 24	April 19 to March 24	62.7%
Total number of scans performed	Record level	Aggregate	Aggregate	April 19 to March 24	April 19 to March 24	59.9%
Referred to Lung Cancer Pathway following LDCT scan	Record level	Aggregate	Aggregate	April 19 to March 24	April 19 to March 24	44.8%
Number of Cancers diagnosed	Record level linked to Rapid Cancer Registrations Dataset	Aggregate	Aggregate	April 19 to August 24	April 19 to March 24	60.7%
Lung Cancer diagnosed at stage 1	Record level linked to Rapid Cancer Registrations Dataset	Aggregate	Aggregate	April 19 to August 24	April 19 to March 24	61.0%
Lung Cancer diagnosed at stage 2	Record level linked to Rapid Cancer Registrations Dataset	Aggregate	Aggregate	April 19 to August 24	April 19 to March 24	55.3%
Lung Cancer diagnosed at stage 3	Record level linked to Rapid Cancer Registrations Dataset	Aggregate	Aggregate	April 19 to August 24	April 19 to March 24	66.2%
Lung Cancer diagnosed at stage 4	Record level linked to Rapid Cancer Registrations Dataset	Aggregate	Aggregate	April 19 to August 24	April 19 to March 24	57.9%
Incidental findings	Record level	Aggregate	Aggregate	April 19 to March 24	April 19 to March 24	74.7%
Offered smoking cessation course	Record level	Aggregate	Aggregate	April 19 to March 24	April 19 to March 24	55.0%
Took up an offer of smoking cessation course	Record level	Aggregate	Aggregate	April 19 to March 24	April 19 to March 24	35.1%
Completed a smoking cessation course	Record level	Aggregate	Aggregate	April 19 to March 24	April 19 to March 24	46.9%

Notes

[1] demographic breakdowns and outcomes following specific events (e.g. lung cancer diagnosed following a baseline scan) are only available for phase 1 sites and any other site submitting record level data.

[2] some phase 2 and phase 3 projects submitted record level data. See separate projects list.

For clarity on the data submitted by each project, its granularity, and notes on each row, see the table below.

Project	CCG code	Phase 1 / Phase 2 / Phase 3	Data Available	Notes
Blackburn with Darwen and Blackpool	00Q	Phase 1	Record	
Corby	03V	Phase 1	Record	
Mansfield and Ashfield	04E	Phase 1	Record	
Luton	06P	Phase 1	Record	
Thurrock	07G	Phase 1	Record	
Doncaster	02X	Phase 1	Record	
Hull	03F	Phase 1	Record	
Newcastle Gateshead	13T	Phase 1	Record	
North Kirklees	03J	Phase 1	Record	
Southampton	10X	Phase 1	Record	
Tameside and Glossop	01Y	Phase 1	Record	
Cheshire and Merseyside	RBQ00	Phase 1 and 2	Record	Three projects (Halton, Knowsley and Liverpool) submit as one cancer alliance
Bradford District and Craven	36J	Phase 2	Record	
Coventry and Warwickshire	05A	Phase 2	Aggregate	
Manchester	14L	Phase 2	Aggregate	
Salford	01G	Phase 2	Aggregate	
Stoke on Trent	05W	Phase 2	Aggregate	
Hammersmith and Fulham	08C	Phase 2	Aggregate	
Hillingdon	08G	Phase 2	Aggregate	
Sutton	08T	Phase 2	Aggregate	
Southend	99G	Phase 3	Record	Submit with Thurrock
East Lancashire	01A	Record	Aggregate	Submit alongside Blackburn with Darwen and Blackpool
South Sefton & St Helens	01X & 01T	Phase 3	Aggregate	
Sunderland and South Tyneside	00P	Phase 3	Aggregate	
Tees Valley	16C	Phase 3	Aggregate	
North and NE Lincolnshire	03H & 03K	Phase 3	Aggregate	
Barnsley Bassetlaw Rotherham	02Q03L	Phase 3	Aggregate	
Nottingham and Nottinghamshire	52R	Phase 3	Aggregate	
Black Country and West Birmingham	D2P2L	Phase 3	Aggregate	
Birmingham and Solihull	15E	Phase 3	Aggregate	
North East Essex & Great Yarmouth	06L	Phase 3	Aggregate	
Brighton & Hove and Hastings	09D	Phase 3	Aggregate	
Crawley and Slough	09H	Phase 4	Aggregate	
Bath and North East Somerset, Swindon and Wiltshire (Swi	92G	Phase 3	Aggregate	
Kent and Medway (South Kent Coast)	91Q	Phase 3	Aggregate	
Portsmouth	10R	Phase 3	Aggregate	
Gloucestershire & Somerset	11M & 11X	Phase 3	Aggregate	
Kernow	11N	Phase 3	Aggregate	
South East London	72Q	Phase 3	Aggregate	
North East London	A3A8R	Phase 3	Aggregate	
North Central London	93C	Phase 3	Aggregate	
Dorset	11J	Phase 3	Aggregate	
SWAG	N48	Phase 3	Aggregate	
Bedfordshire, Luton and Milton Keynes	M1J4Y	hase 3 (expansion	Record	Submitted with Luton data
North Staffordshire	05G	hase 3 (expansion	Aggregate	
Hampshire, Southampton and Isle of Wight (Eastleigh)	D9Y0V	hase 3 (expansion	Aggregate	
Hammersmith & Fulham		Phase 3 (expansion	Aggregate	
Sutton	36L	hase 3 (expansion	Aggregate	
Coventry and Warwickshire	B2M3M	hase 3 (expansion	Aggregate	
Merton	08R	Phase 3	Aggregate	

2 Appendix Two: Summary of study results that preceded and informed the TLHC programme

Summaries of the studies are outlined below.

- The American **National Lung Screening Trial (NLST)** was the first large scale trial which utilised new low dose CT scanning technology in the 2000s to see its impact on lung cancer mortality. The trial was a two-armed randomised control trial (RCT), with the intervention arm receiving low dose CT and the control arm receiving the 'usual practice' of a chest radiograph. The trial found that low dose CT scans, as opposed to chest radiograph screenings, resulted in a 20% reduction in lung cancer mortality and a 6.7% reduction in overall mortality[6].

- Another key international trial was the European **NELSON** trial in the Netherlands and Belgium, which was a two-armed RCT with the intervention arm receiving low dose CT screenings during follow-up years 1, 2, 4 and 6.5, whereas the control group received no screenings. The trial found that about 50% of the cancers diagnosed in the screening arm were early stage, and 69% of these were stages 1A to 2, whereas about 70% of cancers in the control arm were stage 3 and 4 at diagnosis. At 10 years of follow-up, the cumulative rate ratio for death from lung cancer at 10 years was 0.76 (95% confidence interval [CI], 0.61 to 0.94; P=0.01) in the screening group as compared with the control group, similar to the values at years 8 and 9. Overall, the trial demonstrated that lung-cancer mortality was significantly lower among those who underwent volume CT screening than among those who underwent no screening[7].

- The **UK Lung Cancer Screening Trial** was the first UK-based trial which used low dose CT scanning, based in Liverpool and Cambridge. It was a two-armed RCT in which the intervention group received low dose CT and the control group received no screening. Overall, 85% of lung cancers diagnosed in the intervention group were detected at stage 1 or 2. Over 90% could receive potentially curative treatment. The trial found that this single-screen programme resulted in a non-significant impact on lung cancer mortality (RR 0.65 [95% CI 0.41-1.02]). It is important to contextualise this non-significant finding; the trial had been prematurely stopped at its pilot step, meaning that only 3,968 participants of the 16,000 planned were included in the analysis. A meta-analytical approach of multiple lung screening trials was therefore undertaken which showed that – taken together – all the included trials (except DEPISCAN which did not publish mortality data) showed an improvement in lung cancer mortality (0.84 [0.76-0.92]) as well as in overall mortality (0.97 [0.94-1.00])[8].

- The UK Lung Health Check Pilots associated with the **ACE Programme** (Accelerating, Coordinating and Evaluating innovations to bring about earlier cancer diagnosis) – **Liverpool Healthy Lung Project (LHLP), the Manchester Lung Cancer Early Diagnosis service, and the**

[6] https://www.nejm.org/doi/full/10.1056/NEJMoa1102873 Accessed May 2024
[7] https://www.nejm.org/doi/full/10.1056/NEJMoa1911793 Accessed May 2024
[8] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8589705/ Accessed May 2024.

Nottingham Lung Health MOT Pilot – each piloted lung health checks followed by low dose CT scans for high-risk individuals. The pilots did not include comparison groups. As previously mentioned, the Manchester study was instrumental in NHSE deciding to further pilot low dose CT more widely across the UK based on its promising results. In Manchester, following the first screening round 3% of participants were diagnosed with lung cancer, of these, 80% were early stage (1 or 2), 64% had surgical resection and 89% received treatment with curative intent[9]. In the second screening round, the incidence of lung cancer was 1.6%, most cancers were stage 1 (79%) and 89% of individuals with screen detected cancer were offered curative-intent treatment. Over both screening rounds, 4.4% of the cohort were diagnosed with lung cancer, equivalent to one cancer detected for every 23 people screened. This is high when compared with other studies and more than 2.5 times that seen in NLST and NELSON[10].

- The **Yorkshire Lung Screening Trial** is a two-armed RCT that aims to test targeted low dose CT screening in community settings concentrating on deprived areas of Leeds. The study is expected to run until July 2024 and therefore the results are not yet available.

- The **SUMMIT trial** based in London tested the effectiveness of using a cell-free nucleic acid blood test alongside low dose CT scanning. This trial is a prospective cohort observation for 50-77-year olds, made up of a high risk (group A) and low risk group (group B). Both groups give blood tests semi-regularly which are used for detecting multiple cancers at early stage. Group A are invited to a lung health check and are referred on to low dose CT if of a higher risk. Both groups receive two annual follow-ups to provide a blood sample (and a low dose CT scan if in group A). This study ran until May 2023; at the time of writing, results from the trial have not yet been published.

[9] https://pubmed.ncbi.nlm.nih.gov/29440588/ Accessed May 2024
[10] https://thorax.bmj.com/content/74/7/700 Accessed May 2024

3 Appendix Three: Demographic variation in key programme metrics

This Appendix complements Chapter 5, Section 1.35 within the main evaluation report.

3.1 Deprivation

Figure 1.1 and Tables 1.1 & 1.2 below shows the TLHC pathway by deprivation quintile in projects reporting record-level data (accounting for 71% of first invites sent) and should be read alongside the key points presented within the Section 1.35.2 within the main evaluation report.

Figure 3.1: Pathway breakdown, by deprivation quintile

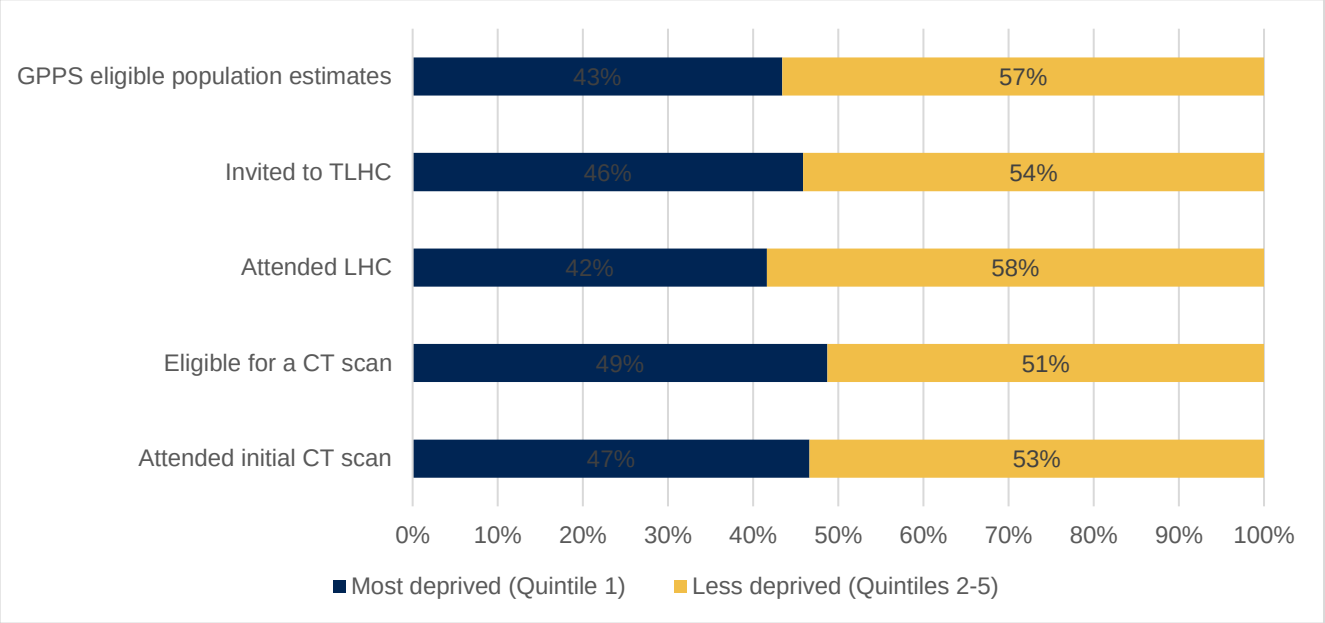


Table 3.1: Breakdown of invites sent, LHCs attended and LHC uptake, by deprivation quintile

Deprivation quintile	GPPS Eligible population estimates	Invited to TLHC	Attended LHC appointment	LHC uptake (%)
1 (most deprived)	**220,330 (43%)**	**252,652 (46%)**	**85,285 (42%)**	***34%***
2-5 (less deprived)	**287,158 (57%)**	**298,207 (54%)**	**119,727 (58%)**	***40%***
Total (excluding not known)	**507,489 (100%)**	**550,859 (100%)**	**205,012 (100%)**	***37%***
Not known		20,825	11,972	
Total	507,489	571,684	216,984	

Table 3.2: Breakdown of initial CT scan eligibility, attendance and conversion, by deprivation quintile

Deprivation quintile	Attended LHC appointment	Eligible for a CT scan	Attended initial CT scan	Conversion (eligible)	Conversion (realised)	Drop-off[11]
1 (most deprived)	**85,285 (42%)**	**53,332 (49%)**	**48,758 (47%)**	**63%**	**57%**	**-6pp**
2-5 (less deprived)	**119,727 (58%)**	**56,126 (51%)**	**55,835 (53%)**	**47%**	**47%**	**0pp**
Total (excluding not known)	**205,012 (100%)**	**109,458 (100%)**	**104,593 (100%)**	**53%**	**51%**	**-2pp**
Not known	11,972	7,779	9,835			
Total	216,984	117,237	114,428			

3.2 Age

Figure 1.2 and Tables 1.3 & 1.4 below shows the TLHC pathway by age band and should be read alongside the key points presented within the Section 1.35.3 within the main evaluation report.

Figure 3.2: Pathway breakdown, by age band[12]

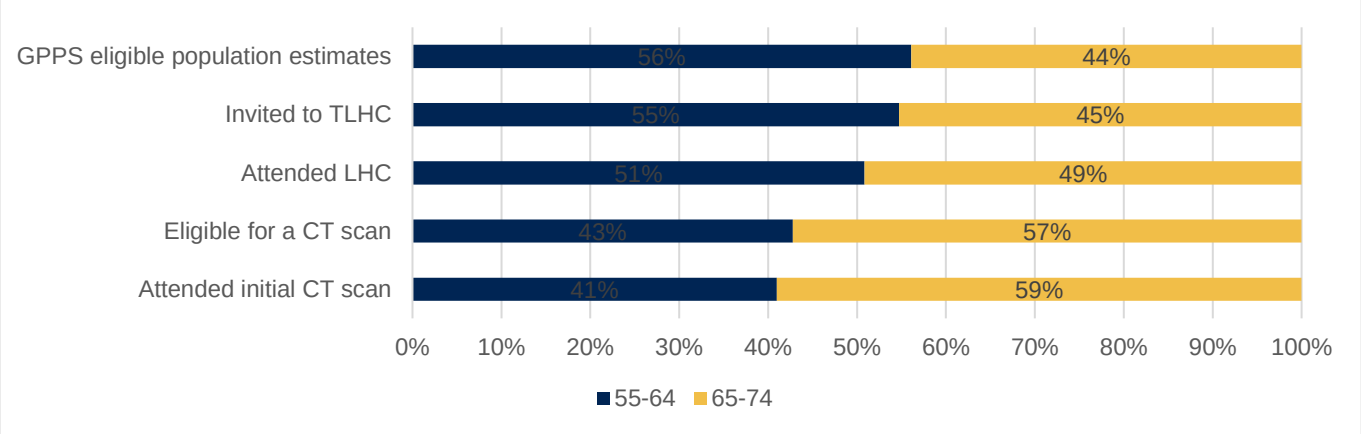


Table 3.3: Breakdown of invites sent, LHCs attended and LHC uptake, by age band

Age band	GPPS Eligible population estimates	Invited to TLHC	Attended LHC appointment	LHC uptake (%)
55-64	**284,666 (56%)**	**290,384 (53%)**	**96,695 (50%)**	***33%***
65-74	**222,873 (44%)**	**236,355 (43%)**	**91,385 (47%)**	***39%***
75		**10,243 (2%)**	**3,615 (2%)**	***35%***
Other		**8,065 (1%)**	**3,490 (2%)**	***43%***
Total (excluding not known)	**507,539 (100%)**	**545,047 (100%)**	**195,185**	***36%***

[11] CT scan "drop-off" can be defined as the difference between conversion (eligible) and conversion (realised), identifying the volume of eligible participants who do not proceed to receiving an initial CT scan.

[12] The 75 and 'other' variables have been excluded from this breakdown for the purposes of comparison with the GPPS eligible population estimates.

Not known		**26,637**	**21,799**	
Total	**507,539**	**571,684**	**216,984**	

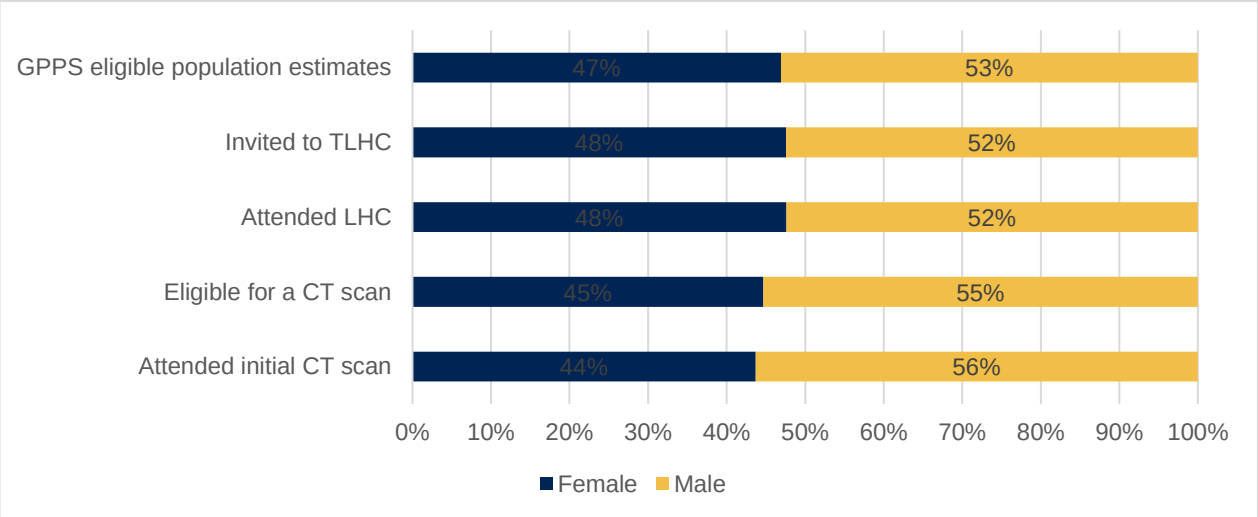
Table 3.4: Breakdown of initial CT scan eligibility, attendance and conversion, by age band

Age band	Attended LHC appointment	Eligible for a CT scan	Attended initial CT scan	Conversion (eligible)	Conversion (realised)	Drop-off
55-64	**96,695 (50%)**	**43,786 (39%)**	**41,880 (39%)**	45%	43%	**-2pp**
65-74	**91,385 (47%)**	**61,191 (55%)**	**59,985 (56%)**	67%	66%	**-1pp**
75	**3,615 (2%)**	**2,975 (3%)**	**3,041 (3%)**			
Other	**3,490 (2%)**	**2,922 (3%)**	**2,944 (3%)**			
Total (excluding not known)	**195,185**	**110,874**	**107,850**	***57%***	***55%***	**-2pp**
Not known	**21,799**	**6,363**	**6,578**			
Total	**216,984**	**117,237**	**114,428**			

3.3 Gender

Figure 1.3 and Tables 1.5 & 1.6 below shows the TLHC pathway by age band and should be read alongside the key points presented within the Section 1.35.4 within the main evaluation report.

Figure 3.3: Pathway breakdown, by gender[13]



[13] Non-binary and prefer to self-describe are not excluded from this breakdown as they are not recorded within the MDS.

Table 3.5: Breakdown of invites sent, LHCs attended and LHC uptake, by gender

Gender	GPPS Eligible population estimates	Invited to TLHC	Attended LHC appointment	LHC uptake (%)
Female	**237,356 (47%)**	**270,333 (48%)**	**103,312 (48%)**	***38%***
Male	**268,605 (53%)**	**298,071 (52%)**	**113,671 (52%)**	***38%***
Non-binary (GPPS only)	0,801 (0%)			
Prefer to self-describe (GPPS only)	0,666 (0%)			
Total (excluding not known)	507,428 (100%)	568,404 (100%)	216,983 (100%)	***38%***
Not known	0	3,280	5	
Total	507,428	571,684	216,988	

Table 3.6: Breakdown of initial CT scan eligibility, attendance and conversion, by gender

Gender	Attended LHC appointment	Eligible for a CT scan	Attended initial CT scan	Conversion (eligible)	Conversion (realised)	Drop-off
Female	***103,312 (48%)***	***52,378 (45%)***	***49,986 (44%)***	***51%***	***48%***	**-3pp**
Male	***113,671 (52%)***	***64,859 (55%)***	***64,441 (56%)***	***57%***	***57%***	**0pp**
Total (excluding not known)	***216,983 (100%)***	***117,237 (100%)***	***114,427 (100%)***	***54%***	***53%***	**-1pp**
Not known	5	0	5			
Total	216,988	117,237	114,432			

3.4 Ethnicity

Figure 1.4 and Tables 1.7 & 1.8 below shows the TLHC pathway by ethnicity and should be read alongside the key points presented within the Section 1.35.5 within the main evaluation report.

Figure 3.4: Pathway breakdown, by ethnicity

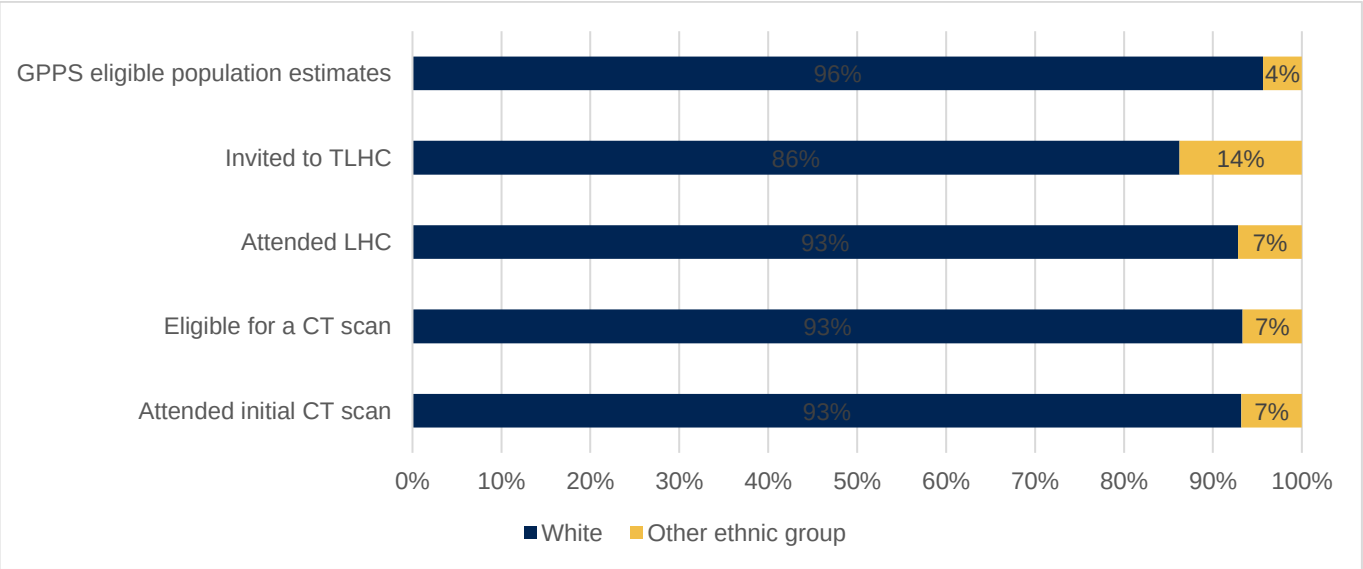


Table 3.7: Breakdown of invites sent and attended a LHC, by ethnicity

Ethnicity	GPPS Eligible population estimates	Invited to TLHC	Attended LHC appointment	LHC uptake (%)
White	**486,056 (96%)**	**290,475 (86%)**	**184,765 (93%)**	***64%***
Other ethnic group	**22,186 (4%)**	**46,327 (14%)**	**14,285 (7%)**	***31%***
Total (excluding not known)	**508,242 (100%)**	**336,802 (100%)**	**199,050 (100%)**	***59%***
Not known	0	185,814	13,924	
Total	508,242	522,616	212,974	

Table 3.8: Breakdown of initial CT scan eligibility, attendance and conversion, by ethnicity

Ethnicity	Attended LHC appointment	Eligible for a CT scan	Attended initial CT scan	Conversion (eligible)	Conversion (realised)	Drop-off
White	**184,765 (93%)**	**99,752 (93%)**	**95,060 (93%)**	***54%***	***51%***	**-3pp**
Other ethnic group	**14,285 (7%)**	**7,131 (7%)**	**6,936 (7%)**	***50%***	***49%***	**-1pp**
Total (excluding not known)	**199,050 (100%)**	**106,883 (100%)**	**101,996 (100%)**	***54%***	***51%***	**-3pp**
Not known	13,924	7,974	10,047			
Total	212,974	114,857	112,043			

4 Appendix Four: Comprehensive Theory of Change

4.1 Introduction

A TOC was developed for the programme in 2019 and included within the evaluation scoping report in both narrative and diagrammatic (logic model) formats. The TOC sets out the theory by which the programme is expected to achieve its objectives. The version in the scoping report covered a comprehensive set of TOC components, including inputs, activities, outputs, outcomes, impacts, assumptions, risks, and unintended consequences[14].

The programme has evolved substantially since its inception in 2019. There are several driving reasons for this, which are outlined below. The initial TOC has therefore been refreshed, in collaboration with the TLHC national programme team within NHSE, to better reflect programme objectives and the details associated with delivering the programme.

The three main phases of programme development are as follows. These have been discussed in significant detail in evaluation progress reports:

- **Original design** – the original design was captured in the first version of the Standard Protocol and was based on a number of previously developed trial protocols[15]. The TLHC national programme team and lead clinicians designed the original pathway, protocol, quality standards, and overall programme aims. This was underpinned by modelling of anticipated demand, throughput, and cancer diagnoses. The programme was initially planned as a discrete, four-year pilot programme to test the intervention at larger scale and in real world settings. The programme was designed and funded by NHSE, which selected tightly defined project areas, developed in relation to (former) CCG areas, to take part. The programme was designed to reach individuals living in areas with the highest lung cancer mortality, and so this was the key selection criterion for the pilot areas.

- **COVID-19 pandemic** – in March 2020, England went into lockdown in response to the COVID-19 pandemic. As such, aspects of the pathway and of the Standard Protocol were amended to enable the programme to continue to deliver despite restrictions. Original CCG pilot sites were given an additional year to deliver the four-year programme due to delays incurred by the necessary pausing and/or postponement of TLHC services. Not only did delivery change during this period, as most notably seen in the move to virtual lung health check appointments, but some of the

[14] Inputs are the resources that are invested in the intervention. These can be financial or non-financial, tangible or intangible (e.g., expertise or networks). Activities refer to the tasks that the intervention undertakes that will generate the outputs and outcomes; they describe what the intervention is practically doing. Outputs refer to what happens as a direct result of an intervention, such as a new service being rolled out or a certain number of people receiving training. Outcomes are the changes that are expected to happen as a result of the intervention. This may encompass change in individuals (attitudes, knowledge or behaviours), organisations, or strategic stakeholders, depending on the focus of the intervention. Outcomes are typically divided into those which are short-term and those which take longer to emerge **o**r require other changes to happen first. In complex interventions, outcomes can be divided into primary and secondary outcomes, to allow a focus on the most important changes that are expected to happen. Impacts are the high-level goals the intervention is expected to contribute to. They are often long-term, and it may not be possible to evaluate in the lifetime of the intervention whether it has had such impact.

[15] See page 20 for further information.

programme aims also started to evolve. One of the key reasons for this was that NHSE aimed to make up lost ground by mobilising more quickly. This meant greater emphasis was given to early diagnosis aims, with a reduced emphasis on other health aims that were originally planned (e.g. broader health and dietary advice, spirometry, and blood pressure checks). These aspects are therefore given less prominence in the revised programme TOC.

- **National screening service and the Health and Care Act 2022** – in 2022, the UK National Screening Committee (UK NSC) recommended that the four UK nations should introduce a national lung screening service to support the earlier diagnosis of lung cancers. This was followed by a government announcement in June 2023 of the roll out of a national targeted lung screening service. The implication for the TLHC pilot programme was that its aim moved beyond testing the intervention in real-world settings (the focus of delivery Phases 1 and 2), and became centred on how it could achieve full national coverage by 2028/29 (from Phase 3 onwards). The key programme aim remains improving the early diagnosis of lung cancer. However, following the UK NSC decision to support wider roll-out, based on review of evidence gathered from numerous trials, policy and programme emphasis has shifted from *whether* this can be achieved through TLHC to *how quickly* this can be achieved.

  In parallel, NHS commissioning was restructured via the Health and Care Act 2022, with CCGs being dissolved and their powers (including commissioning and funding) being transferred to Integrated Care Boards (ICBs). Following these developments came a change in governance for the TLHC programme, in which NHSE no longer selects CCGs to begin delivering the TLHC programme. Instead, NHSE has handed responsibility to Cancer Alliances to plan roll out across their patch against nationally set targets. Programme funding is now distributed to ICBs to fund the programme in their areas. The Standard Protocol has also been developed so that high-risk participants are re-called for a Computed Tomography (CT) scan every two years until they are over 75, and to ensure that participants previously deemed “low risk” are reinvited for a LHC .

The remainder of the narrative TOC covers the anticipated inputs, activities, outputs, outcomes, and impacts of the programme.

4.2 Inputs

4.2.1 NHSE programme delivery structure

NHSE invested £70m in total into delivering the TLHC programme across Phases 1 and 2 (which are within the scope of this evaluation). This team provides dedicated programme support in the form of a senior programme manager, two programme managers, a project manager, the input of two clinical leads on a part-time basis (0.2 fte), and support from the Cancer Alliance Data Evidence and Analysis Service (CADEAS – now the Cancer Analysis and Insights Team). Originally there was only one programme manager, but a second one was recruited in May 2021 to support the set-up and delivery of the expansion of the programme to Phase 3, which began in March 2022, and planning towards national roll-out (with funding assigned for this expansion - although outside the scope of the evaluation).

4.2.2 Evaluation, data collection and learning

Around £2m has been invested in a five-year process, economic and impact evaluation of Phases 1 and 2 of the programme, to provide continuous learning and a summative assessment of programme costs and outcomes. Alongside the key evaluation delivery partners (Ipsos and the Strategy Unit), the NHSE Insight and Feedback Team has invested time to enable access to, and analysis of, GP Patient Survey data for use within the evaluation.

In the 2022/23 financial year, NHSE commissioned the Behavioural Insights Team (BIT) to undertake a separate deep-dive evaluation into reasons for poor uptake of the programme, which included trying to recruit non-responders/engagers to investigate barriers to participation. This work was set up in response to the poor uptake of THLCs over people invited (national average).

BIT produced a report outlining their findings and a shortlist of recommendations for interventions to test and evaluate to improve uptake rates nationally. The national TLHC team is now working with the internal NHSE Behavioural Science Unit to implement and evaluate four interventions, to see if they improve service uptake.

From 2023/24, the North of England Commissioning Support Unit (NECS) has been contracted by NHSE to support Cancer Alliances in collecting and reporting programme monitoring data for all live TLHC sites. This activity is outside the scope of the evaluation.

4.2.3 Funding distribution

Programme funding was originally provided to projects on an annual basis, distributed through CCGs using the following model:

- Fixed proportion of the funding (£328,000 per year), covering the central costs of core staffing and clinical leadership. CCGs with populations of over 55,000 received additional core funding for project management; and

- Variable proportion of the funding, scaled to the number of low dose CT scans projects are expected to complete, with £264 per CT scan to cover the cost of scanning (including the cost of providing mobile CT capacity), teleradiology, costs associated with the lung health check, and travel/ other costs such as legal costs.

In April 2023 the funding model changed to correspond with the change to the way NHSE commissioned the programme. Cancer Alliances took on the role of determining roll-out plans across their geographies and deciding how many people to invite each year (against nationally set targets). Cancer Alliances work to a funding model calculated on a basis of:

- £255 per completed scan (not per participant);
- £50 per completed TLHC risk score;
- A 25% minimum guarantee of the estimated total funding allocation regardless of activity.

Annual funding allocations are calculated based on trajectories for completed TLHCs and scans submitted by Cancer Alliances at the start of the financial year. Funding is sent to Cancer Alliances via their lead ICB which then distributes funding to TLHC sites in their patch. Cancer Alliances work with sites to understand how much funding they need and keep abreast of activity levels as the year progresses to identify over/under spends. Funding is also intended to cover central Cancer Alliance TLHC delivery costs, such as a Cancer Alliance programme lead and analytical support.

Since the 2022/23 financial year, the TLHC national programme team has offered Cancer Alliances the capital investment to procure a CT scanner with associated housing or installation. The offer is around £1.5m per scanner. In 2022/23, £12.4m was granted; raising to £20.4m in 2023/24. This funding is being offered to ensure that there is sufficient CT capacity for the TLHC programme, although it is not sufficient to meet demand on its own. Other scanning capacity will be leased from the private sector or provided

through Trust / Community Diagnostic Centre (CDC) scanners, using annual targeted funding budgets that Cancer Alliances receive.

4.2.4 Project staffing

For the programme to be run locally, several posts are required to be in place:

- Lung cancer screening Healthcare Assistants and/or nurses to conduct the lung health checks;
- Radiographers trained in performing low dose CT scans;
- Radiologists trained in reporting low dose CT scans;
- Clinical resource for key governance roles (each project requires an appropriate Clinical Governance Structure in place, comprised of a Clinical Director, a Responsible Assessor, a Responsible Radiologist, and a Responsible Clinician);
- Administration and project management resource.

The numbers of staff required in each of these roles vary by project according to population size. These positions have been filled either through recruitment, or redeployment of staff from other roles. Standards 1 and 2 of the TLHC Quality Assurance standards set out minimum qualifications and experience for relevant clinical post holders.

4.2.5 Cancer Alliance programme management

With the change to the Cancer Alliance delivery model, Cancer Alliances are now advised to recruit a specific TLHC programme management role to manage the programme across their patch. Some have appointed to this role full time whereas others have brought it into existing portfolios such as Early Diagnosis leads, etc. NHSE also recommends analytical resource, to support with modelling for expansion and the data reporting requirements, and marketing/communications support.

In some instances, and increasingly over time, projects have outsourced aspects such as the delivery of lung health check appointments, delivery of CT scans by radiographers, and the reporting of CT scans by radiologists. The decision to outsource aspects of the TLHC pathway can be driven by different factors, including: capacity constraints within local NHS teams; recruitment challenges; perceptions of cost-efficiencies enabled by outsourcing; perceived relative ease of managing outsourced services; and/or enhanced speed of local roll-out. A significant number of projects now outsource the whole end-to-end pathway to the private sector, from cohort identification and booking, through to scan reporting.

As the programme grew and became a key priority for NHSE and early diagnosis ambitions, Cancer Alliances and projects had to grow their network and gain contributions from other parts of the health and care system like Trusts, Primary Care Networks and GP practices, ICBs, secondary and tertiary care centres, national and regional specialised commissioning teams. Support is required for tasks such as the design of the local TLHC pathway, including referral pathways for incidental findings, the engagement of relevant stakeholders, procuring elements of the pathway (which can involve considering options for collaborative procurement) and managing downstream activity effectively.

4.2.6 System inputs

The TLHC programme funds activity up to and including participant communications and referrals (where relevant) following a low dose CT scan (baseline and follow-up scans). Following this, any further activity

is funded by the system (covered below). In many instances, this will include more and/or different types of activities than prior to TLHC. For example, systems are likely to begin funding a greater proportion of lung cancer treatment with curative intent. Funding and resources must therefore be provided at the local level to manage the delivery of these activities. The required resources has been explored through the economic evaluation workstream (Cost-Consequences Analysis).

4.2.7 Participant inputs

Participants input into the programme in the form of time taken to accept their invitation (for opt-in delivery models), attend their lung health check appointment, attend their CT scan appointment (where relevant) and engage with signposting and onward referrals as required. Some participants have also taken time to participate in evaluation activities including participant surveys, interviews, and follow-up calls with non-participants to understand their reasons for not engaging or not attending their appointment.

4.3 Activities

4.3.1 TLHC national programme team activities

The TLHC national programme team supports local projects to deliver their goals. The support offer includes:

- **Provision of a clinical and strategic framework** – including quality assurance documentation, the clinical protocol, and programme governance.
- **Modelling to support local planning** – including expected volumes to go through the TLHC programme to inform expectations of how many people stand to benefit from the programme, and to provide projects with information to help them plan services accordingly (i.e. anticipated demand for lung health checks and low dose CT scans, as well as wider system planning for the lung cancer treatment pathway).
  - Several assumptions underpinned the modelling, namely that 54% of those aged between 55 and 76 years smoke or have smoked, that 50% of eligible participants choose to attend a lung health check, and that 56% of those are offered a baseline low dose CT scan. These assumptions were primarily drawn from the Manchester Lung Health Check pilot, with other sources used to estimate the proportion of smokers (including Fingertips; GP practice data; GP Patient Survey data).
  - The TLHC evaluation has delivered additional analysis – using GP Patient Survey data and ONS Population Estimates – to show the demographic breakdowns of eligible populations within local areas. This activity further supports local planning given the variation in lung health check uptake and eligibility for low dose CT scan, across different demographic groups.
- **Design and implementation of an evaluation dataset**, reported at both patient-level and in aggregate; support offered via the national evaluation to local areas to enable data collection. Longer-term planning for a minimum dataset to support a national screening programme, drawing on learning from pilot areas.
- **Communication and engagement resources** – including a suite of publicity resources for local adaptation, participant engagement resources, and a range of programme communication documents such as invitation and results letter templates and a participant information booklet. The

programme team has translated participant materials into 11 different languages (reflecting project needs).

- **Community of practice** – various means to share best practice between the projects will be pursued, including weekly WebEx clinics in the early stages of programme delivery, quarterly collaboration events, a 'Support Pack' and a collaborative online sharing web space on the Cancer Alliance workspace. As programme delivery has matured, programme webinars have shifted to monthly and have been variously chaired by both the TLHC national programme team and projects. Cancer Alliances have also been involved.

- **Procurement support** – to ensure projects are assisted in their procurement of CT scanners where required.

- **Training** – NHSE has developed a framework to ensure clinical staff have the required level of training to carry out lung health checks, low dose CT scans and reporting. This is outlined in the TLHC Quality Assurance standards. The national training package encompasses:

  - British Society of Thoracic Imaging (BSTI) Lung Nodule Workshop training, which is mandatory for all radiologists reporting for the programme to complete before they start. This is captured in the TLHC Quality Assurance standards;

  - "Communicating with High Risk Individuals" training course created by the National Centre for Smoking Cessation and Training (NCSCT), which all project staff are required to complete;

  - Optional spirometry training delivered via Education for Health with Association for Respiratory Technology & Physiology (ARTP) accreditation, introduced following the pandemic in 2022/23 for any sites choosing to deliver spirometry through their TLHC service;

  - Other training for TLHC nurses, including consent training and ionising radiation (medical exposure) regulations [IR(ME)R] for referrers. Both TLHC nurses and support staff must participate in locally designed training covering telephone assessment process, call quality expectations and control measures, including identification of red flag symptoms;

  - Local and national training audits **–** locally, these include a minimum training and experience record for nurses, radiologists and other healthcare practitioners, and an audit of a proportion of telephone screening assessments conducted per quarter. Nationally, Clinical Directors of TLHC projects must report quarterly against Quality Assurance Standards 1 and 2 to confirm that nursing and support staff have completed requisite training.

- **Support** – to address health inequalities within local projects through charity partners, shared peer learning and analytical support. As an example, the programme has funded the Roy Castle Lung Cancer Foundation to deliver various activities, including a two-stage project to create resources for communicating and marketing the programme. Phase 1 consists of pre-education about the importance of early diagnosis of lung cancer; Phase 2 involves the development of more specific resources to explain the TLHC offer in more detail to potential participants.

  - These types of activity are designed in recognition of the existing health inequalities in the primary lung cancer outcomes that the programme is designed to improve (outlined below), as explained in the wider literature.

4.3.2 TLHC project activities

At the Cancer Alliance / project level, the following activities are required to enable the delivery of the TLHC programme:

- Recruitment and training of project teams and clinical staff.
- Procurement of low dose CT scanners (or ringfencing of scanner capacity, outsourcing of scanning, where relevant) and of the physical infrastructure required to house the new service. This includes, where relevant, a mobile or fixed location CT scanner capacity unit, and base for the service. The procurement of the scanner is an obvious rate limiting factor, as it takes anything upwards of three months to manufacture and there are only a handful of manufacturers operating in the UK.
- Delivery of the TLHC pathway: distribution of TLHC invitations; appointment booking and administration; follow-up calls with non-attenders/non-engagers; delivery of lung health check appointments; delivery of smoking cessation advice, signposting and referrals; low dose CT scanning; radiology reporting; participant communications; and onward signposting and referrals (for suspected lung cancer and for incidental findings).
- Establishment of appropriate settings for the mobile CT scanners where relevant, including the provision of appropriate security measures, and access to teleradiology.
- Project management to oversee the implementation and delivery of the programme, alongside clinical oversight and local governance.
- Strategic planning of various project activities, including decisions about the most appropriate order for engaging GP practices in inviting participants, and planning the most suitable locations for mobile scanning units.
- Engagement of healthcare providers in the local system to ensure agreement on the process for inviting individuals, management of incidental findings, support in publicising the programme, and referral pathways for smoking cessation advice.
- Participation in the evaluation and provision of monthly datasets for evaluative purposes.
- Communication and marketing to market TLHCs across populations and encourage attendance. More emphasis has been put on this as time has gone on, in response to the poor uptake rates achieved initially and recovery required post pandemic. There is a particular emphasis on encouraging groups more likely to experience health inequalities to participate in the programme. A wide variety of activities are delivered to address this, including outreach through faith and community groups, tailored campaigns to “myth bust”, and family fun days.

4.3.3 Cancer Alliance activities

In addition to supporting delivery of some of the activities listed above, Cancer Alliances also deliver the following:

- Analytical support to help with modelling expansion of each Cancer Alliance’s patch and what is required to reach national roll-out by 2028/29 at the latest.

- Set up and running of governance and steering groups that bring together projects within a Cancer Alliance to share learnings and ideas and enable the Cancer Alliance to fulfil their responsibility of governing the programme at an Alliance level (e.g. data management, keeping abreast of project activity/risk/issues).

- As the programme expands, more involvement is required from the Cancer Alliance to support procurement of suppliers to run the service. In particular, where a number of projects within a Cancer Alliance are subcontracting to the private sector, Cancer Alliance involvement might be required to agree contracts across multiple places to take advantage of economies of scale and ensure prices are fair and competitive.

4.3.4 System activities

The wider system must respond to the demand that results from the TLHC pathway. This includes, but is not limited to, the following: lung cancer diagnostics and treatment; management and/or treatment of incidental findings (in primary/secondary/tertiary care settings); and provision of smoking cessation courses. As discussed, this is likely to include a greater proportion of lung cancer treatment with curative intent, as well as earlier-stage treatments for other cancers diagnosed and incidental findings identified through the programme.

4.4 Outputs

There are several key measures of programme outputs, many of which will provide early indicators of success for the programme:

- Number of initial invites and reminders issued as a proportion of the eligible population for each area;

- Number of lung health checks completed:

  - *Lung health check uptake:* proportion of those invited to participate who then complete a lung health check;

- Baseline low dose CT scans completed:

  - *CT scan conversion (eligible):* proportion of people who attend a LHC who are eligible and referred for a baseline CT scan;

  - *CT scan conversion (realised):* proportion of people who attend a LHC, are eligible and referred for a baseline CT scan and complete a baseline CT scan.

- Follow up low dose CT scans completed.

- Number of referrals (for suspected lung cancer, incidental findings, and smoking cessation services).

- Demographic breakdowns of the above metrics.

These measures are critical assessments of programme progress; projects collect and report monitoring information evidencing these outputs monthly. There is expected to be variation in uptake of the service across the programme; within projects there is likely to be variation based on demographic

characteristics, as well as a range of other factors relating to an individual's ability and proclivity to attend such an appointment (for example, the location of the project).

Other key outputs include the establishment of referral pathways both for incidental findings – to secondary care and to primary care – as well as to smoking cessation services for those projects that choose to establish formal referral processes.

4.5 Outcomes and impact

The following section forms the focus of this impact evaluation protocol.

4.5.1 Primary outcomes

There are three identified primary outcomes, which are considered as the most important among the several outcomes that are to be explored in this evaluation. For the TLHC programme, all primary outcomes relate to lung cancer:

Shorter-term

- **Short-term**[16] **sharp increase in lung cancer diagnoses** *(expected because of a lack of pre-existing, systematic screening in each new geography)*
  - The programme expects to observe a short-term increase in the number of people with a lung cancer diagnosis, leading to an increased lung cancer diagnosis rate for individuals aged 55-76 years[17]. This is because there will be a concentration of clinical investigation and diagnostic activity that would not have otherwise taken place amongst asymptomatic individuals; this activity would instead have taken place at a later stage, usually amongst symptomatic individuals;
  - Once the initial eligible cohort has been scanned, it is anticipated that the lung cancer diagnosis rate will level out to the usual diagnosis rate. Although modelling indicates that additional diagnoses and early diagnoses will remain high post 28/29 when national rollout has been achieved.
  - Lung cancer is defined using the following ICD-10 codes: C34-39 (lung cancer) and C45 (mesothelioma) with Group II (neoplasms).
- **Greater number of cancers diagnosed at earlier stage** *(expected because proactive screening is considered likely to identify pre-symptomatic cancers)*
  - Amongst individuals aged 55-76 years, the proportion of people with a lung cancer diagnosis at Stages 1 and 2 is greater than would have otherwise been the case.
  - This is expected because the programme is screening non-symptomatic individuals who are at higher risk than the average population of having lung cancer (due to being ever smokers). Due to being asymptomatic, individuals are more likely to be diagnosed with early-stage disease

[16] Note that anticipated time periods such as "short-term" are not defined within the Theory of Change.
[17] Eligibility for an initial lung health check includes being aged between 55 and 74 and 364 days at the point of receiving baseline CT scan. However, due to the time associated with follow-up scanning, primary outcomes will be measured for individuals aged 55 to 76.

than those presenting with symptoms (e.g. at their GP or at A&E), who tend to be at a later stage;

- This trend of earlier-stage diagnosis is expected to endure as programme delivery continues; there is no reason to assume this would fall back to pre-intervention levels.

Longer-term

- **Improved lung cancer mortality rates** *(expected because of the improved treatment options associated with earlier diagnosis)*

  - Assuming that relevant services are available and accessible, it would be expected that participants will have access to treatment that may not have been available if they had presented symptomatically;

  - Earlier access to treatment increases the likelihood of successful treatment outcomes and reduces the risk of mortality.

Health inequality outcomes

- **Reducing variation for the primary outcomes listed above within the intervention areas, compared to what would have otherwise happened,** between groups that are more and less likely to experience health inequalities.

  - This is expected because of the delivery of targeted engagement activities to encourage particular demographic groups to attend their lung health check and CT scan appointment (where relevant) at both programme and project levels.

4.5.2 Secondary outcomes

There is a large set of anticipated secondary outcomes associated with the TLHC programme. These can be grouped into four themes: participant experience[18]; incidental findings; smoking cessation; and wider system outcomes.

Participant experience

- The programme expects to see a **positive participant experience of the programme** – from invitation through attendance and on to onward referral.

Incidental findings

- The programme expects to see **increased identification of incidental findings** *(expected due to the range of other conditions likely to be identified through the TLHC scan)*[19]

[18] Note that participant experience is not covered in the impact protocol; it is comprehensively explored as part of the participant experience workstream and process evaluation.

[19] An increased identification of incidental findings is expected, though there are inherent challenges in making comparisons to usual incidence due to issues including data access, applicability to TLHC, and inability to account for pre-diagnosed conditions. See Section 5.4 for further discussion.

  - The programme is expected to generate a greater volume of incidental findings being identified than would have been the case without the TLHC programme. This would be expected to lead to a growth in demand for services (at least initially) as a result of incidental findings (for example, COPD and some cardiovascular conditions).

  - In previous studies, the diagnostic tests and wider health checks which have been used have been shown to identify a range of conditions in addition to lung cancer. This includes incidental findings through the lung health check appointment, spirometry (where relevant) and the low dose CT scan.

  - Specifically, it is anticipated that there will be an increased diagnosis of other cancers (in addition to lung cancers) as a result of the low dose CT scan, given that this scan can also support the diagnosis of cancers in a similar part of the body e.g. breast cancer.

- **More participants access monitoring or treatment pathway (for incidental findings)** *(expected as a result of increased identification of incidental findings).*

  - Increased identification means **more individuals are treated or monitored for these issues**.

Smoking cessation

- **Increased number of individuals accessing smoking cessation services** *(expected because of the requirement to deliver smoking cessation advice during the TLHC)*

  - As a result of smoking cessation advice and referrals offered through the TLHC programme, it is expected that an increased number of individuals will go on to access support from smoking cessation services.

- **Increased number of participants who have i) reduced; and ii) stopped smoking following participation in TLHC** *(due to factors including earlier / increased access to smoking cessation services)*

Wider system outcomes

- **Short to medium term growth in demand for lung cancer services** *(expected due to proactive scanning of unsymptomatic population, leading to spike in diagnoses)*

- **Fewer emergency diagnoses (A&E)** *(expected as a result of earlier diagnoses)*

- **Skills gaps and shortages are filled** *(expected as a result of system responses to changing demand for care)*

4.5.3 Impact

The TLHC programme ultimately aims to generate the following impacts in the longer term:

- The increased life-time treatment costs for the programme participants (due to earlier presentation and longer life span) are offset by the corresponding Quality Adjusted Life Years (QALY) gains, thus demonstrating the programme to be cost-effective;

  - Note that the Cost-Consequences Analysis conducted through the TLHC national evaluation will not be able to demonstrate this impact. A Health Economics team at the University of Exeter is

developing a model which will provide estimates of the QALYs associated with the programme. The TLHC national evaluation will contribute to the wider evidence base by providing more granular, “real-world” data on true programme costs.

- The evaluation provides sufficient evidence for the wider roll-out of the TLHC programme, and a set of key principles for commissioners is developed.

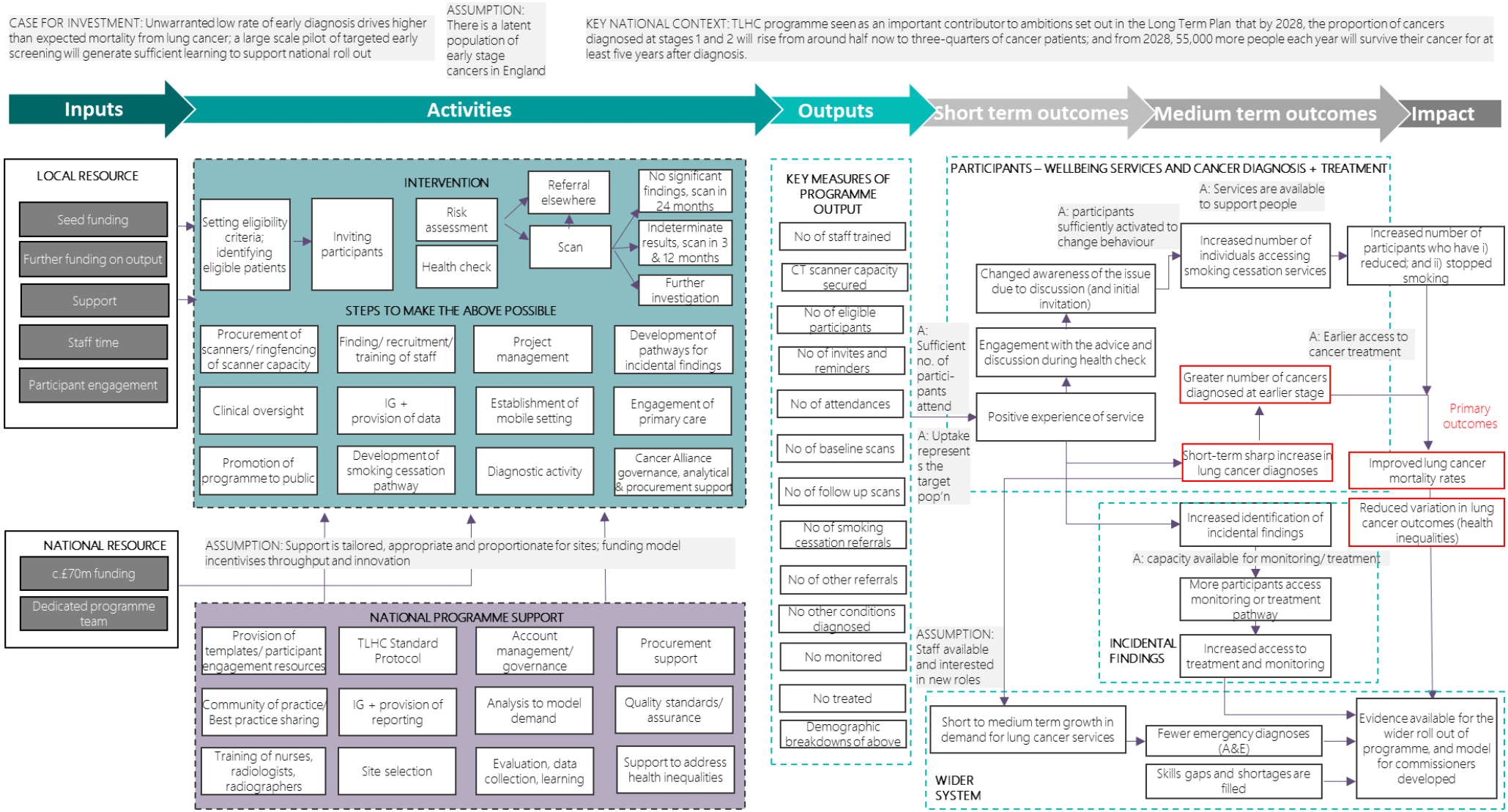
Though no targets have been set concerning the key outcomes and impacts of interest, some indications of ambitions were expressed in the stakeholder interviews, including that a minimum of 50% attend the lung health check from initial invitation. It has also been reported that a successful programme will deliver an intervention which might be expected to identify lung cancer in about 2% of the patients that are screened, with 70-80% of these at stage 1 or 2, and approximately 80% of patients offered curative treatment. These aspirations also reflect similar figures that have been achieved in previous studies of low dose CT screening:

- NELSON trial: 0.9% of screenings resulted in lung cancer diagnoses, of which 69% were diagnosed at stage 1 to 2.
- UKLS trial: 2.1% of screenings resulted in lung cancer diagnoses, of which 85% were stage 1 or 2 and over 90% were able to receive potentially curative treatment.
- Manchester pilot: 3% of screenings resulted in lung cancer diagnoses, of which 80% were early stage (1 and 2) and 89% received treatment with curative intent.
- Liverpool pilot: 1.9% of screenings resulted in diagnoses of lung cancer, of which approximately 76% were diagnosed at stage 1 or 2.

Diagrammatic Theory of Change

A diagrammatic representation of the Theory of Change, reflected as a Logic Model, is shown in Figure 2.1.

Figure 4.1: Diagrammatic Theory of Change



5 Appendix Five: Impact evaluation technical report

5.1 Introduction

This Technical Appendix sets out the methodology and results for the impact evaluation of the Targeted Lung Health Check (TLHC) programme. This document is supplementary to the Main Evaluation Report, providing a detailed account of:

- The quasi-experimental approach used to assess the causal impact of the TLHC programme.
- Findings from the analysis.
- Robustness checks used to increase confidence in the results.

5.1.1 Background

The TLHC programme aims to address priorities set out in the NHS Long Term Plan (2019) to improve cancer survival rates by promoting the diagnosis of lung cancers at earlier and more treatable stages. The programme involves:

- Inviting those at a higher risk of developing lung cancer (due to a history of smoking and due to their age[20]) are invited to participate in a lung health check (LHC) with a qualified professional.
- If deemed to be at high risk of developing lung cancer, based on a risk score generated during the appointment, the participant is referred for a baseline and follow-up low dose computed tomography (LDCT) scans.
- Where lung cancer is suspected, the individual is referred from the TLHC programme to secondary care lung cancer services for further investigations and potentially diagnosis and treatment.
- The programme also aims to identify and manage onwards referrals for incidental findings arising during the LHC or a LDCT scan and to reduce smoking rates by offering current smokers access to smoking cessation advice, formal smoking cessation service referral on an opt-out basis, and treatment such as nicotine replacement therapy.

Further detail about the programme theory, including intended outcomes, is provided in Appendix 4 and in the main report.

5.1.2 Key hypotheses

This report aims to test the hypotheses in relation to the anticipated impacts on lung cancer diagnosis and mortality as follows:

[20] Eligibility is based on several criteria. Participants must be “ever smokers”, meaning having smoked at least 100 cigarettes in their lifetime. Participants must be aged between 55 and 74 years, and 364 days at the date of the first low dose CT scan, and they must also be registered with a GP practice.

- The programme was expected to lead to a **short-term**[21] **sharp increase in the number of lung cancer diagnoses**, leading to an increased lung cancer diagnosis rate for individuals aged 55-76.[22] This arises from clinical investigation and diagnostic activity amongst asymptomatic individuals that would instead have taken place at a later stage. Once the initial eligible cohort has been scanned, it is anticipated that the lung cancer diagnosis rate will return to the usual diagnosis rate.

- It was anticipated that the programme will lead to an **on-going increase in the share of cancers will be diagnosed at earlier stages** (Stages 1 and 2) than would have otherwise been the case as consequence of screening asymptomatic populations characterised by higher risk.

- In the longer-run, this is expected to lead to **improved lung cancer mortality rates** as those receiving a lung cancer diagnosis receive treatment at an earlier stage, increasing the likelihood of successful treatment outcomes.

- The programme was also expected to **reduce variation in the primary outcomes above** between demographic groups that are more and less likely to experience differences in health outcomes. This is expected because of the delivery of targeted engagement activities to encourage particular demographic groups to attend their lung health check and CT scan appointment (where relevant) at both programme and project levels.

5.1.3 Evaluation Scope

The evaluation focuses on the first two phases of programme delivery, the initial pilot projects that were launched in 2019 (Phase 1) and an onboarded set of projects (Phase 2) made up of sites where locally led targeted lung screening initiatives were already underway prior to TLHC programme commencement. Figure 5.1 shows the geographic distribution of the participating projects. Phase 2 projects were onboarded to the programme in 2020. The evaluation concludes at a time when the initial eligible population for each Phase 1 and Phase 2 project have been invited to participate and – where applicable – attended an LHC, and all relevant scans up until the 24-month follow-up scan.

5.1.4 Structure of the Report

The remained of this Technical Appendix is structured as follows:

- **Section 5.2** – describes the measurement of the key outcomes of interest, including a discussion of data sources used to underpin the analysis.

- **Section 5.3** – presents the analytical framework, including a discussion of the rejected analytical approaches.

- **Section 5.4** – reviews the results for each of the key outcomes in turn, first presenting descriptive statistic before presenting the results of the causal impact analysis.

- **Section 5.5** - Explores whether there were any differential impacts on the key lung cancer outcomes between different demographic sub-groups.

[21] Note that anticipated time periods such as “short-term” are not explicitly defined within the Theory of Change.
[22] Eligibility for an initial lung health check includes being aged between 55 and 74 and 364 days at the point of receiving baseline CT scan. However, due to the time associated with follow-up scanning, primary outcomes will be measured for individuals aged 55 to 76.

- **Section 5.6** – presents the results of the robustness checks.
- **Section 5.7** – sets out an assessment of an alternative design and the reason for its rejection.

5.2 Measurement of outcomes

This section sets out how the primary outcomes, namely the lung cancer outcomes as detailed in the Theory of Change (ToC) (see Appendix 4 and the main report), have been measured. This includes a description of the relevant data sources and an explanation of the approach to assessing differential impacts in outcomes across sub-groups.

5.2.1 Unit of analysis

An impact evaluation requires measures of the outcomes of interest both before and after programme intervention to capture changes that have been brought about since their introduction. The nature of the programme and its anticipated outcomes means that it is highly challenging to understand its effects at the individual level:

- The 'intervention group' for the programme comprises all individuals that have been invited for lung-health checks.
- However, records of those invited to checks cannot be linked to records of diagnostic or mortality outcomes at the individual level as patient level information is anonymised and does not contain any information that would allow linkage to other health records.
- It is also not feasible to construct an equivalent comparison group at the individual level (i.e. a group of individuals in the at-risk population residing outside of the programme area) as the records available only include those receiving a lung cancer diagnosis. As such, this will omit those individuals that would have been invited to checks, but did not receive a lung cancer diagnosis.

Given these issues, the following analyses have completed by focusing on changes in population level outcomes (such as the number of lung cancer diagnoses per 10,000 residents in the target population). This enables us to consistently measure how these outcomes have changed over time within pilot areas and compare those changes to those seen in areas that did not benefit from the programme.

The intervention was originally configured at the level of Clinical Commissioning Groups (CCGs).[23] However, the statistical power of comparisons between participating and non-participating CCGs was constrained by the low number of CCGs involved in the pilot (23 CCGs in total). To maximise statistical power, the analysis has instead focused on smaller Middle Layer Super Output Areas – small geographical units containing between 2,000 and 6,000 households used for the reporting of Census statistics (using the areas defined for the 2011 Census).

5.2.2 Definition and identification of the target population

The target (or 'at risk') population for the TLHC intervention is defined as individuals aged 55-76 and who currently smoke or have previously smoked:

[23] Whilst CCGs were disbanded in July 2022 and replaced with Integrated Care Boards, to ensure consistency with the original design and rollout of the TLHC programme CCG boundaries are used.

- **Intention-to-treat analysis:** The analysis focuses on outcomes for the target population for the intervention rather than those that attended TLHCs. This approach tends to provide more robust comparisons as they are not distorted by differences between individuals that do and do not attend checks. However, it should be noted that the size of the effects of the programme will be contingent on (a) the share of the population that were invited to checks and (b) the share that (and characteristics of those) that attended checks. While a 'treatment on treated' analysis focused on those attending checks may have been informative, it was not feasible as there is no comprehensive data available about individuals who have attended the TLHC.

- **Inclusion of non-smokers in the definition of the target population:** Due to the lack of data, or poor data quality, on smoking status in the general population, it is not possible to quantify the size of the target population for TLHC (see Table 5.2 for further information). As a result, outcomes have been expressed as a share of the number of residents aged between 55 and 76 in each MSOA, based on the 2021 Census.[24] This includes non-smokers in the definition of the outcome variable. Comparisons between pilot and non-pilot areas could therefore be biased if there are differences in the share of the resident population with a history of smoking, and more details on how these issues have been controlled for are set out later in the appendix.

5.2.3 Definition and identification of intervention areas

Intervention areas are defined as MSOAs[25] delivering Phase 1 and 2 projects between 1st January 2019 and 31st March 2023. The identification of intervention areas for TLHC is challenged by the fact that the programme, originally defined at the CCG level, was not rolled out in all CCGs in the same way. Some CCGs rolled out the programme across the whole geographic footprint; some did not. For the purposes of this analysis, an MSOA was classed as an intervention area as follows:

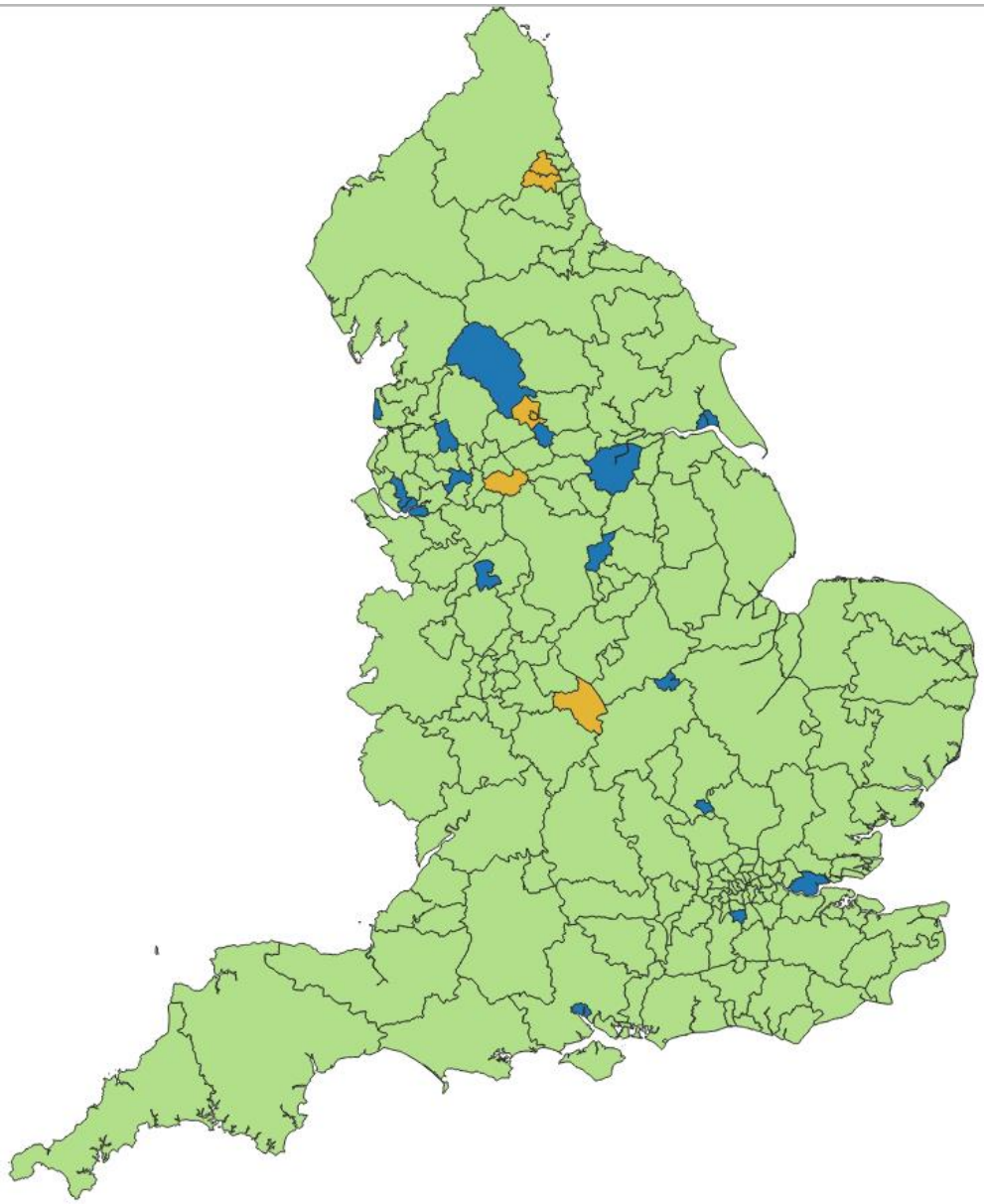
- **For CCGs where TLHC was fully rolled out:** All MSOAs within a 'fully participating' CCG in which all GP practices were able to invite patients have been defined as an intervention area.

- **For CCGs where TLHC was partially rolled out:** Information on GP practices that invited patients was used to determine which MSOAs within the CCGs were participating (noting that this data is only available for Phase 1 and a subset of Phase 2 projects). MSOAs were classed as part of the intervention area if at least one resident attended a lung health check (noting that patients invited to the checks might not live in the same MSOA of the GP practice).

The geographic distribution of the participating CCGs can be found in Figure 2.1 below.

[24] This means that smoking incidence cannot be accounted for in matching intervention and counterfactual areas, though deprivation and average area income levels – which are highly correlated – will be.
[25] 2011 MSOA boundaries were used throughout the analysis.

Figure 5.1: Map of CCGs (fully and partially) participating in the TLHC programme (using 2019 CCG boundaries)



Source: Ipsos analysis of TLHC programme data. Blue shading represents a full intervention CCG; yellow shading represents a partial intervention CCG; green shading represents a CCG not participating in Phase 1 or 2 of the TLHC programme.

5.2.4 Outcomes measurement framework

The quantitative impact evaluation will focus on the primary outcomes identified within the ToC (see Appendix 4 and the main evaluation report). The table below summarises these outcomes and the metrics for their measurement. The evaluation will focus on disease-specific mortality but not on one-year survival. This is in line with the aim of the TLHC which, as with all screening programmes, aims at improving diagnosis at an earlier stage rather than survival.[26]

[26] One year survival is also commonly associated with lead time bias – which is where survival outcomes are over estimated due to bringing forward the point of diagnosis rather than changing the point at which a death occurs. See "Computed Tomography Screening for Lung Cancer: Back to Basics" *Clinical Radiology* (2001) 56: 691±699 *doi:10.1053/crad.2001.0850*

Table 5.1: Primary Lung cancer outcomes measurement framework

Relevant evaluation question	Primary outcome	Detailed definition	Primary indicator	Numerator	Denominator	Data source(s)	Lag in data	Frequency of dataset reporting
3.2. What was the lung cancer conversion rate through the programme (i.e. the number of lung cancer diagnoses as a proportion of participants invited)?	Short-term **sharp increase in the number of lung cancer diagnoses** *(expected because of lack of pre-existing, systematic screening in each new geography)*	Short-term increase in the number of people with a lung cancer diagnosis, leading to an increased lung cancer diagnosis rate for individuals aged 55-76 years. • Once the initial eligible cohort has been scanned, the lung cancer diagnosis rate would fall back to pre-intervention levels. • Lung cancer is defined using the following ICD-10 codes: C34-39 (lung cancer) and C45 (mesothelioma) with Group II (neoplasms).	Number of lung cancers diagnosed per 10,000 people aged 55-76	Number of individuals in the target population (55 to 76 years old) receiving a lung cancer diagnosis	Total number of individuals in the target population (55 to 76 years-old)	National Cancer Registration Dataset (NCRD)	14 months	Monthly
						ONS 2021 Census population estimates	NA	Every 10 years
3.1. Was the programme successful in enabling earlier stage lung cancer diagnosis?	**Greater number of cancers diagnosed at earlier stage** *(expected because proactive screening considered likely to identify pre-symptomatic cancers)*	Amongst individuals aged 55-76, the proportion of people with a lung cancer diagnosis at Stages 1 and 2 is greater than would have otherwise been the case.	Number of lung cancers diagnosed by stage per 10,000 people aged 55-76	Number of individuals amongst the target population (55 to 76 years old) with a lung cancer diagnosed at stage 1 and 2; stage 3 and 4; and not staged at diagnosis	Total number of individuals in the target population (55 to 76 years-old)	National Cancer Registration Dataset (NCRD)	14 months	Monthly
						ONS 2021 Census population estimates	NA	Every 10 years
	Reduction in the number of deaths due to lung cancer *(expected over the longer-term because of the improved treatment options*	Number of deaths where lung cancer is recorded as the underlying cause of death are reduced amongst those aged 55-76,	Number of deaths due to lung cancer per 10,000 people aged 55-76	Number of individuals in the target population (55 to 76 years old) who have died with lung cancer recorded as the underlying cause of death	Total number of individuals in the target population (55 to 76 years old)	ONS Civil Registration – Death	Up to 20 days	Monthly
						National Cancer Registration Dataset (NCRD)	14 months	Monthly

Relevant evaluation question	Primary outcome	Detailed definition	Primary indicator	Numerator	Denominator	Data source(s)	Lag in data	Frequency of dataset reporting
	associated with earlier diagnosis)	compared to what would have otherwise been.[27] [28] Cause of death will be established from ONS Deaths data, using underlying cause of death only (not secondary causes)				ONS 2021 Census population estimates	NA	Every 10 years
4.4 What impact has the programme had on reducing **the variation in lung cancer outcomes** across each of the projects?	**Yearly difference between primary lung cancer outcomes** in groups of interest (by gender / ethnicity / age / level of deprivation)	See above for the detailed definition of each outcome.	Difference in mortality rates across demographic groups Difference in the number of lung cancers diagnosed across demographic groups	See above for the numerator used in each outcome.	See above for the numerator used in each outcome.	The same considerations on data sources, lag and frequency of the data apply to the sub-group analysis.		

[27] Note that the impact on this outcome may not be seen in the first few years following the start of TLHC, as the numerator for this indicator will include patients that were diagnosed and treated before the start of the programme.

[28] One-year survival rates are not utilised as an indicator due to lead time bias identified in the wider literature. For example, see: "Computed Tomography Screening for Lung Cancer: Back to Basics" *Clinical Radiology* (2001) 56: 691±699 *doi:10.1053/crad.2001.0850*

5.2.5 Sub-group analysis

Relevant evaluation question

As set out in the key evaluation questions, this evaluation also examines whether TLHC induced differential impacts between different demographic sub-groups: ***What impact has the programme had on reducing the variation in lung cancer outcomes across each of the projects?***

To address this question, differences in outcome indicator by sub-group are defined at the MSOA level. These are then used as the outcome variable in the analysis described in Section 5.4.[29] The sub-groups have been defined as the **difference in the primary outcome measures between the demographic groups of interest**:

- **Level of deprivation:** Differences in the number of diagnoses and deaths due to lung cancer per 10,000 (of the target population) between MSOAs in Index of Multiple Deprivation deciles 1 and 2 (20% most deprived) and deciles 3 to 10 (80% least deprived).
- **Gender[30]**: Differences in the number of diagnoses and deaths due to lung cancer per 10,000 (of the target population) between male and female.
- **Ethnicity[31]:** Differences in the number of diagnoses and deaths due to lung cancer per 10,000 (of the target population) between those that identify as white British and non-white British.
- **Age[32]:** Differences in the number of diagnoses and deaths due to lung cancer per 10,000 (of the target population) between those that are aged 55 – 65 and 66 – 76.

5.2.6 Data sources

Several datasets were used to measure primary outcomes of TLHC. These were accessed via the NHSE Secure Data Environment (SDE), to which Ipsos was authorised pseudonymised linked-data access via an approved Data Access Request Service (DARS) application. The relevant datasets are described below.

National Cancer Registration Dataset (NCRD)

The National Cancer Registration and Analysis Service (NCRAS) is the population-based cancer registry for England. It collects, quality assures and analyses data on all people living in England who are diagnosed with malignant and pre-malignant neoplasms, with national coverage since 1971. It produces the National Cancer Registration Dataset (NCRD) for England. The primary role of NCRAS is to provide near real-time, cost-effective, comprehensive data collection and quality assurance over the entire cancer care pathway. To achieve this, it receives data from across the NHS. The NCRD covers key data

[29] Analysis that assesses the impact at the project level was deemed out of the scope of this evaluation. In principle, a separate model could be created for each project area, and then outcomes compared against a comparison group of areas. This would create an impact evaluation at the project level, opposed to the programme level.

[30] Evidence indicates that men have a higher risk of developing lung cancer than women. https://www.cancerresearchuk.org/health-professional/cancer-statistics/statistics-by-cancer-type/lung-cancer/risk-factors#heading-Zero

[31] Research indicates differences in lung cancer incidence and mortality for different ethnic groups. https://www.kingsfund.org.uk/publications/health-people-ethnic-minority-groups-england; https://www.uklcc.org.uk/our-reports/november-2022/bridging-gap

[32] Older age groups experience higher lung cancer incidence and mortality. https://www.cancerresearchuk.org/health-professional/cancer-statistics/statistics-by-cancer-type/lung-cancer/mortality#heading-One

items including: demographics (date of birth, ethnicity, sex etc), geography (e.g. postcode at diagnosis), tumour (tumour site, stage at diagnosis etc), treatment (e.g. type of treatment event etc) and death (e.g. date of death, underlying cause of death). Further information about the NCRD can be accessed here.

The lung cancers among those aged 55-76 were defined using International Classification of Diseases 10th Revision (ICD-10 codes). Within this evaluation, the ICD-10 codes C34-39 (lung cancer) and C45 (mesothelioma) with Group II (neoplasms) were used to classify lung cancers. The data was further sorted by excluding those who were outside age 55 to 76 at the point of diagnosis.

Limitations of the data source:

- In up to 2% of cancers, registrations may not be complete and stable until five years following the diagnosis date. These inaccuracies are attributed towards three main reasons[33]:

  1. New cancer cases will be registered, including new 'late' registrations where a cancer is registered after statistics have been published.

  2. Cancer records may need amending if revised diagnostic information becomes available.

  3. In some rare cases revised diagnostic information can mean cancelling a cancer registration.

- Methodological changes in how cancers are registered and defined. From the 2021 release onwards (cancers registered up to and including 2019), cancers diagnosed from 2013 are registered using the ICD-03 codes and defined using the ICD-10 codes. These changes are expected to have a minimal impact on reported statistics.[34]

- 14-month lag from when a cancer is diagnosed to when it is first reported.

The NCRD contains over 98% complete cancer registration and diagnosis records in England. It represents the single comprehensive record of cancers in England and the methodological changes are not expected to have a material impact on the evaluation. The main concern of the NCRD is that the 14-month lag may present a challenge in detecting the longer-term impacts of the programme.

The Rapid Cancer Registration Dataset (RCRD), which would provide a more real time account of cancer registrations, cannot be used in the analysis as the data does not contain the required geographic information (i.e. LSOA or MSOA codes) to link patients to the intervention, potential counterfactual, or excluded areas.

Office for National Statistics (ONS) Civil Registration Deaths

Death statistics are compiled from information supplied when deaths are certified and registered as part of civil registration (a legal requirement). Death statistics reported include counts of deaths by age, sex and underlying cause. For the purposes of the TLHC evaluation, the focus was on the deaths where the underlying cause of death is due to lung cancer.

[33] National Disease Registration Service (2021) *Data collection and quality assurance of administrative data*

[34] https://files.digital.nhs.uk/7B/D4B3C5/Impact_paper_on_the_change_of_ICD-10_coding.pdf

The deaths attributable to lung cancer were determined by including deaths where the underlying cause of death was listed as a lung cancer, which cited the relevant ICD-10 codes: C34-39 (lung cancer) and C45 (mesothelioma) with Group II (neoplasms). The data was further sorted by excluding those who were outside age 55 to 76 when they died.

The two main limitations of the data source are:

1. Due to registration delays on mortality statistics, deaths by date of occurrence are always somewhat incomplete, whereas deaths by date of registration may include deaths that occurred months or even years earlier.

2. The data only contains information that is collected as part of the civil registration, and some of this information is based on the details provided by the informant (usually a close relative).

Despite minor limitations, the death statistics published by the ONS are the most complete record for deaths that occur in England and Wales. The data source also provides a near real-time view of deaths in England and Wales (an 11-day lag). The above limitations are not expected to impact the analysis.

2021 Census Data

The England and Wales census, delivered by the ONS, happens every 10 years, providing detail information about the characteristics of all the people and households in England and Wales. The 2021 Census achieved a response rate of 97% of all the usually resident population of England and Wales.

The census is the most comprehensive measure of the population of England and Wales, and low-level population estimates (as low as Output Level) can be obtained. The 2021 Census data has been within the analysis to normalise outcomes across all years in the analysis.

The ONS note that the COVID-19 pandemic may have led to changes in peoples' usual responses on the day of the census, for example their place of residence, so there may exist a risk that the reported population estimates are not fully representative of pre- or post- pandemic places of residence. However, despite this, the 2021 Census represents the single best data source for providing population data at the required level of geography and within the desired time frame.

2011 Census Data

The 2011 Census was used to provide the most comprehensive pre-intervention account of local demographics (namely ethnicity) for low levels of geography prior to the rollout of TLHC.

Whilst other data sources (e.g. the Annual Population Survey) could have been used, the required level of geography is not publicly available, and therefore cannot be linked to data within the SDE.

Index of Multiple Deprivation 2019 at the MSOA level

The Ministry of Housing, Communities and Local Government publishes an LSOA level index of multiple deprivation (IMD), which provides a 'deprivation' score to each LSOA. In partnership with the University of Sheffield, MHCLG produced a series of higher-level geography IMD values, including at the MSOA level which is used within this analysis.

The aggregated scored represent a population-weighted average of the LSOA IMD values, for each LSOA within the MSOA.

Some potential limitations of the IMD values are that they represent the average characteristics of people living in that particular area – as such, in cases where there is extreme diversity in deprivation within a given area (e.g. very low and very high-income families living in close proximity), the IMD can return a middling score that washes out the true level of deprivation. This feature is expected to be more prominent in densely populated urban areas, as well as at higher levels of geography. IMD scores also struggle to represent mobile communities, or those experiencing homelessness. However, it would be expected that these potential limitations would affect both intervention and non-intervention to the same extent and are not thought to pose a significant threat to the robustness of the analysis.

Income estimates for small areas

Income estimates for small areas in England and Wales are national statistics providing income data for MSOAs in England and Wales.[35] The small area income estimates draw on several data sources, including the Family Resource Survey (FRS), Census data, DWP claimant counts, ONS house price data, energy consumption data, PAYE data, VOA council tax bands and region fixed effects. The income estimate is based on the area-level relationship between income (from the FRS) and covariates (from the other administrative datasets listed above). A fitted regression model can be used to make out-of-sample area income estimates (using the covariates from the administrative sources) to estimate income in areas which were not sampled in the FRS.

Radon

The UK Health Security Agency in partnership with the British Geological Survey produced a data set containing levels of radon potential – which provides an assessment of the likelihood of an 1kmx1km area containing levels of radon above the Action Level.[36,37] The estimates are based on the 2021 Radon potential for Great Britain version 3.0 British Geological Survey. Despite being after the rollout of the TLHC programme, this remains the most comprehensive (and publicly accessible dataset) available at the time of writing.

To transform the radon potential for each 1kmx1km square into MSOA estimates, GIS software was used to average the values of the squares which overlapped the MSOA boundaries.[38] It should be noted that radon potential levels can vary considerably across small areas, even across orthogonal cells. However, the absence of MSOA level data sets on radon potential requires such a transformation to be made to allow radon potential levels to be controlled for. Given that there is no data to map exactly where each patient lives (i.e. if there are specific parts within the MSOA which have higher levels than others), aggregating radon potential at the area level is not expected to affect the credibility of the analysis by including this within the matching model (see Section 5.3).

5.2.7 Evaluation limitations

[35] https://www.ons.gov.uk/employmentandlabourmarket/peopleinwork/earningsandworkinghours/datasets/smallareaincomeestimatesformiddlelayersuperoutputareasenglandandwales

[36] The radon Action Level is a threshold where radon concentrations above this are strongly advised to see radon mitigation measures. The recommended Action Level is 200Bq/m^3.

[37] https://www.bgs.ac.uk/datasets/radon-data-radon-potential-dataset/

[38] The average was weighted by the proportion of the square that overlapped the boundary. For example, a square fully inside the MSOA boundary had a weight of 1, where as a square that was 25% within the boundary had a weight of 0.25.

In addition to the data limitations outlined above, Table 5.2 summarises the main limitations associated with the impact evaluation of the primary outcomes.

The following criteria have been used to rate the impact of the analytical limitations:

- **High** = the originally planned analysis is not possible to conduct and/or the robustness and validity of the analysis is significantly impacted.
- **Medium** = the analysis is impacted, though can still be conducted with sufficient robustness and validity.
- **Low** = negligible impact on the analysis with limited/no impact on the robustness of the analysis.

Table 5.2: Limitations of the analysis

Limitation	Mitigation	Impact
Lack of individual-level data for all Phase 2 projects prevents a thorough contamination analysis for Phase 2 projects.	▪ Contaminated areas have been inferred from information in Phase 1, and as such estimates represent a lower bound estimation of the impact of the TLHC programme.	Medium
Lack of individual-level data for individuals who did not receive a cancer diagnosis prevents an individual-level QED analysis.	▪ A robust QED analysis is conducted at the MSOA level. It compares the number of lung cancers and deaths due to lung cancer within the eligible population between intervention and comparison areas at low levels of geography to provide insights on the impacts of those living within TLHC areas. ▪ Propensity score matching is also used to control for observable differences between intervention and comparison MSOAs (see Section 5.3) to increase the confidence with which differences in observable outcomes can be attributed towards the TLHC programme.	Low
Lack of individual-level postcode data in the SDE prevents a precise identification of the participating MSOAs in CCGs which partially rolled out the TLHC programme.	▪ GP practice registration data has been used to determine intervention areas within partial intervention CCGs. ▪ To understand the extent of the issue, an analysis using only full intervention CCGs and partial intervention CCGs will be run as part of the robustness checks, and the results compared	Medium
No availability of data after 2023 due to the 14-month lag in the data challenges the estimation of long-term effects of the intervention and effects of the 24-months scans.	▪ The results obtained from the causal impact analysis will be appropriately caveated to note that they are short-term.	Low
Incomplete and poor-quality information on smoking status	▪ At risk population will be defined in terms of geography and age only. The estimated effects will be likely smaller than the actual effects.	Medium

prevents alignment of definitions of 'at risk' population in the analysis with the actual 'at risk' population	▪ DiD is in principle robust against time-invariant effects. Assuming the level of smoking in the target population remains (relatively) constant over time, this would not be expected to induce bias. ▪ To mitigate possible biases, we will control for additional lung cancer risk factors in the non-smoking population, e.g. radon potential	

5.3 Analytical Framework

This chapter outlines the theoretical framework for propensity score matching and difference-in-difference, the QED methodology used to estimate the causal impact of the TLHC programme. After a discussion of the main methodological issues, the adopted method is described. A discussion of a rejected analytical approach (a geographic regression discontinuity design) can be found in Annex 2.

5.3.1 Methodological considerations

Selection bias

A robust assessment of the impacts of the TLHC programme requires an assessment of what may have occurred to participating areas in its absence (i.e., a counterfactual). This typically requires the selection of a group of patients or areas that have not benefitted from the intervention but are equivalent to TLHC areas in all other respects (the comparison group).

If intervention areas had been randomly assigned to the programme, randomisation would have guaranteed that non-participating areas would be similar (on average) to the intervention ones in all relevant observable and unobservable characteristics. In this instance, simple comparisons between intervention and non-intervention areas would have been sufficient to measure the impact of the programme.

In the absence of randomisation, an impact evaluation should consider the potential for systematic differences between intervention and non-intervention areas which could i) drive selection into participation in the intervention, and ii) influence the outcomes of interest, hence biasing the results (i.e. **selection bias**). For instance, suppose that only the most deprived areas decided to take part in the programme. As deprivation is also associated with worse lung cancer outcomes, a simple comparison between intervention and non-intervention MSOAs may lead to an overestimation of the effect of the TLHC programme.

In the context of the TLHC programme, the main sources of potential selection bias are the criteria used to select intervention areas. For **Phase 1** projects, these were:

- **Mortality rates in the at-risk population**: CCGs with the highest lung cancer mortality rates for those aged 55 to 76 years[39,40].

[39] Where two CCGs had the same mortality rate, it was anticipated that the CCG with the highest lung cancer incidence would be selected. However, as no ties occurred, incidence data was not used in the selection process.

[40] Note that – whilst this was the age range used in the initial selection process - the intervention is targeted at individuals aged between 55 and 74 and 364 days at the point of receiving a baseline low dose CT scan. Due to the time associated with surveillance scanning, primary outcomes will be measured for individuals aged 55 to 76.

- **Population:** CCGs with a population of at least 50,000 people. If the CCGs were smaller, they were paired with the CCG with the next highest mortality rate in the Cancer Alliance. Projects with paired CCGs were not required to be geographically adjacent to one another.
- **Only one project per Cancer Alliance**, though this could include more than one CCG.
- **No similar programmes**: CCGs that have previously delivered, or are currently implementing similar, screening programmes were excluded as they were in receipt of other funding and to ensure TLHC projects followed a similar implementation plan.

All selected CCGs for Phase 1 accepted the opportunity to take part in the TLHC programme. **This considerably simplifies the problems related to selection bias driven by unobservable characteristics, as all factors considered to select sites into the programme (primarily lung cancer mortality rates) can be observed and controlled for in the selection of comparators.**

Phase 2 areas were those that – at the outset of the national TLHC programme – were already delivering, or preparing to deliver, lung cancer screening projects. These areas were incorporated (or "onboarded") into the TLHC programme and broadly share the same characteristics (in terms of mortality rates and population) as Phase 1 areas.

Potential comparison areas

To ensure that findings were not contaminated by the delivery of parallel initiatives, the following MSOAs were excluded as potential comparison areas (highlighted in pink in the Figure 3.1):

- Any MSOA delivering TLHC pre- 1st January 2019, including intervention projects that have now been integrated into the TLHC programme, including Royal Marsden Partners Health Checks, Liverpool Healthy Lungs Programme and the Manchester Macmillan Cancer Improvement Pilot. These have been excluded to have a consistent baseline (i.e. a 'no intervention period') for all intervention and potential counterfactual areas.
- Areas benefitting from Phase 3 projects that launched before March 2023.
- Any non-TLHC concurrent intervention[41], including Leeds Lung Health Check, Oncimmune, SUMMIT and the PEOPLE-Hull Study. Areas delivering concurrent interventions were excluded from the potential comparison group to avoid attenuation bias in the impact evaluation.
- Welsh MSOAs, as they are outside the scope of programme.

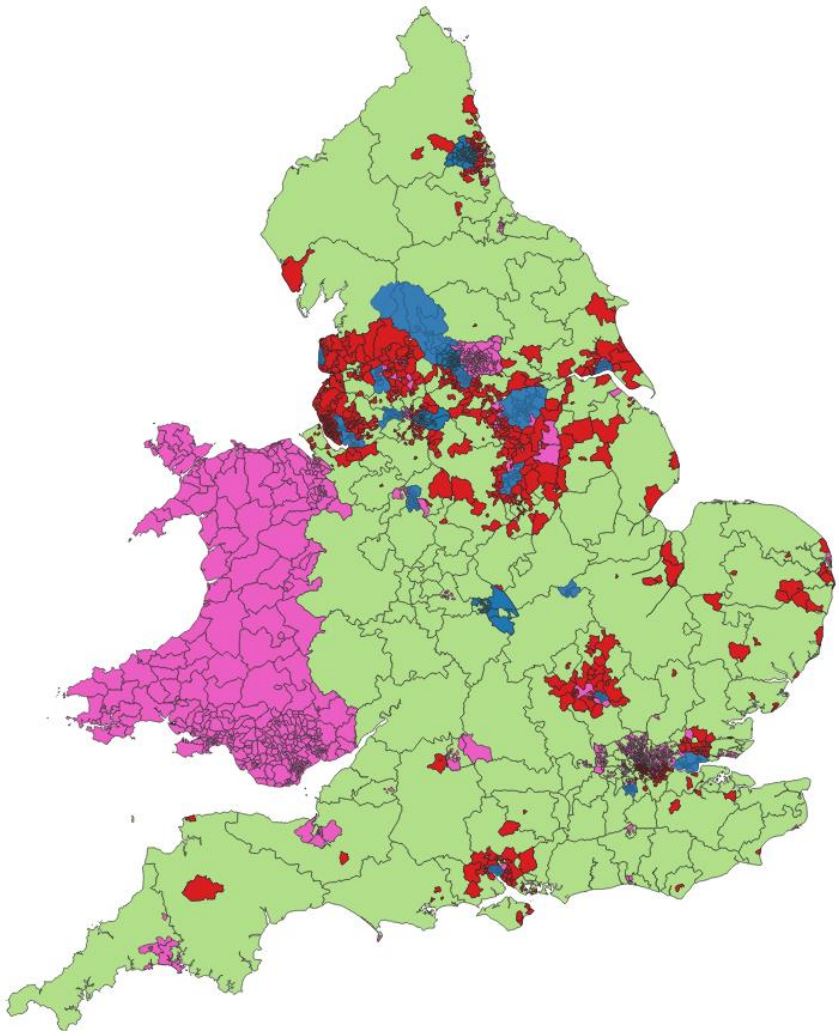
Additionally, it was known that individuals living outside intervention CCGs were sometimes invited to the programme. It is not possible to say for certain why this occurred, though a likely reason is that individuals are not obliged to register as a patient at their closest GP practice. It is possible to register at a GP practice that is otherwise convenient, for example close to an individual's workplace. It is at the discretion of the practice as to whether or not they accept patients from outside their typical catchment

[41] From a selected list provided by the NHSE Cancer Programme, TLHC EAG and TLHC EOG.

area[42]. If patients living outside the programme boundaries also received a LHC, this may result in an underestimate the effects of the programme.

To determine the extent of this issue, intervention CCGs were mapped alongside programme data which contained information on the MSOA where the patient lives (this data was only available for Phase 1 and some Phase 2 projects).[43] The results of this mapping exercise are presented in **Error! Reference s ource not found.**. Blue areas represent intervention MSOAs, which match the 2019 CCG footprints. The red areas show contaminated areas, i.e., MSOAs outside an intervention CCG where some patients were invited to a LHC. The analysis identifies a relatively high degree of contamination around the treatment areas. This is shown by the large groupings of red areas around the blue areas, These areas were also excluded as potential comparators in the analysis.

Figure 5.2: Classification of MSOAs with the TLHC programme



Note: Blue areas are treated MSOAs, red areas are contaminated MSOAs, and green areas are potential counterfactual areas. Pink areas are MSOAs that were excluded from the analysis. See section 4.1.3 for details.

Source: Ipsos computations based on project data.

[42] https://www.nhs.uk/nhs-services/gps/registering-with-a-gp-outside-your-area/ [Accessed 22/09/2023]

[43] It should be noted that this analysis was based on participants' postcodes of residence. This aligns imperfectly with the mapping of project footprints, where instead the GP practice postcode was used.

5.3.2 Analytical Methodology: Propensity Score Matching and Difference-in-Difference

As part of the evaluation scoping work undertaken to assess the causal effect of the TLHC programme, two methodological approaches were explored:

- A Difference-in-Differences (DiD) design applied to intervention and comparison MSOAs chosen through Propensity-Score Matching (Level 3 of the Maryland Scientific Method Scale).
- A Geographic Regression Discontinuity Design (GRDD), comparing intervention and comparison MSOAs that share a CCG border (Level 4 of the Maryland Scientific Method Scale.

Scoping work identified that the PSM-DiD approach was feasible, and so was adopted for the purposes of the evaluation. It was concluded that the GRDD approach was not considered feasible given that MSOAs either side of the CCG boarder exhibited notable differences in their observable characteristics. The remainder of this section sets out the overarching theoretical framework for PSM-DiD, whilst a discussion around the feasibility of GRDD approach can be found in Annex 2.

Differences between treatment areas and other areas

To assess balance between TLHC pilot and comparison areas, standardised mean differences (SMD) are used. SMD are a measure of the size of the difference between two groups; and are calculated by dividing the difference in the means of the two groups by the pooled standard deviation of the groups. Following best practice set out in health economics literature, an SMD greater than 0.1 denotes meaningful imbalance in the baseline covariates (Austin, 2009).[44]

Balance tests indicated that in TLHC pilot areas exhibited meaningful levels of difference to non-intervention areas prior to matching. Across all matching variables, the mean SMD was 0.36. Table 5.3 below presents the results of the balance tests.

[44] Austin, P,C. 2009, Balance diagnostics for comparing the distribution of baseline covariates between treatment groups in propensity-score matched samples, *Statistics in Medicine*, 28.3083-3107. doi:10.1002/sim.3697

Table 5.3: Comparisons between pilot areas and non-pilot areas, pre-programme characteristics

Variable	Mean		SMD
	Pilot areas	Non-pilot areas	
Number of lung cancers per 10,000 in 2016	22.671	15.644	0.55
Number of lung cancers per 10,000 in 2017	21.885	15.877	0.50
Number of lung cancers per 10,000 in 2018	21.941	15.973	0.47
Number of deaths due to lung cancer in 2016	15.652	10.59	0.51
Number of deaths due to lung cancer in 2017	14.779	10.459	0.43
Number of deaths due to lung cancer in 2018	14.85	10.061	0.49
Number of lung cancers diagnosed at stage 1 and 2 per 10,000 in 2016	5.4301	3.858	0.27
Number of lung cancers diagnosed at stage 1 and 2 per 10,000 in 2017	5.6369	4.0542	0.29
Number of lung cancers diagnosed at stage 1 and 2 per 10,000 in 2018	5.7004	4.1901	0.26
Number of lung cancers diagnosed at stage 3 and 4 per 10,000 in 2016	15.571	10.594	0.51
Number of lung cancers diagnosed at stage 3 and 4 per 10,000 in 2017	14.59	10.668	0.42
Number of lung cancers diagnosed at stage 3 and 4 per 10,000 in 2018	14.598	10.626	0.42
Number of lung cancers not staged at diagnosis per 10,000 in 2016	1.6634	1.1631	0.17
Number of lung cancers not staged at diagnosis per 10,000 in 2017	1.6356	1.1249	0.18
Number of lung cancers not staged at diagnosis per 10,000 in 2018	1.7241	1.1331	0.20
2019 IMD	30.119	19.634	0.77
Population of 55-76 year olds in 2021	1863.7	2031.6	-0.31
Total number of GPs in MSOA	1.083	0.89262	0.18
Radon potential	2.0858	1.9927	0.08
Proportion of MSOA that is White British	0.85817	0.88064	-0.13

Following best practice, (the absolute value of the) SMD > 0.1 indicate that there are meaningful levels of imbalance between intervention and comparison areas.
Source: Ipsos analysis of National Cancer Registration Dataset and ONS Civil Registration – Deaths.
Sample size: 537 TLHC intervention MSOAs, 537 matched comparison MSOAs and 4,840 potential counterfactual MSOAs.

TLHC pilot areas differed in significant ways in terms of past outcomes measures (i.e. an SMD greater than 0.1):

- TLHC pilot areas had higher levels of lung cancer incidence, by approximately six diagnoses per 10,000 people aged 55-76, across pre-intervention periods compared to non-intervention areas. The SMD between pilot areas and non-intervention areas ranged between 0.47 and 0.55 between 2016 and 2018, signalling a meaningful imbalance in pre-intervention levels lung cancer diagnostic volumes.

- THLC pilot areas had more deaths due to lung cancer, approximately 5 more deaths per 10,000 people aged 55-76 than non-intervention areas. SMD ranged from 0.43 to 0.51 in pre-intervention periods.

There were also key differences in local area characteristics:

- THLC pilot areas were in more deprived areas than non-intervention areas, demonstrated by the higher IMD score with an SMD of 0.77.
- There were also differences in the demographic make-up of the population, with pilot areas having less white British residents than non-intervention areas (SMD of -0.13). Controlling for ethnicity is important as there are known differences between ethnic groups.[45]
- Levels of Radon, a known cause of lung cancer[46], also differ between pilot and non-intervention areas. However these differences fall within the acceptable levels.

This therefore suggests that naïve comparisons between the intervention areas and the non-intervention areas would likely lead to biased results. The fundamental difference in observable characteristics suggests that the average of all non-intervention areas is unlikely to resemble what would happen to the intervention areas in the absence of the TLHC programme. The next section describes steps to manage this risk.

Propensity score matching

Propensity score matching (PSM) is a statistical technique that can be applied to ensure that comparisons are made between MSOAs that shared similar observable characteristics at the time that the intervention was rolled out. For this evaluation, PSM will be used to form a robust comparison group, prior to estimating the impact of the TLHC programme using a Difference-in-Differences (DiD) design. Combining the two approaches reduces differences between intervention and comparison MSOAs by selecting units that share similar characteristics, and therefore would be expected to exhibit similar outcomes in the absence of the intervention. This will increase the robustness of the analysis.

The results could also be at risk of bias if there is differential exposure to other causes of lung cancer in the intervention/control areas, e.g., air pollution or radon exposure. For example, if the comparison areas were subject to growing levels of air pollution in the years preceding the programme (relative to the intervention areas), the number of lung cancers may increase in the comparison areas and the impact of the programme would be understated. To mitigate this potential bias, the level of radon potential is controlled for by including it in the matching model.

The following steps set out how PSM was applied to the analysis:

- **Step 1:** For each intervention and non-intervention MSOA, a propensity score was estimated. This is the probability that the area would be in the intervention group, conditional on observed characteristics ('matching variables'). A probit model[47] was used for the estimation of the propensity score:

$$P(D_i = 1|X_{it}) = \Phi(X_{it}\beta) \qquad (1)$$

[45] Delon, C. *et al.* (2022) Differences in cancer incidence by broad ethnic group in England, 2013 – 2017. *British Journal of Cancer*, 126, 1765 – 1773. [accessed: 30/05/2024]; Arnold. M., Razum. O. and Coebergh, J.W. (2010) Cancer risk diversity in non-western migrants to Europe: An overview of the literature, *European Journal of Cancer*, 46,14,2647-2659. [accessed: 30/05/2024].
[46] Riudavets *et al.* (2022) Radon and Lung Cancer: Current Trends and Future Perspectives, *Cancers (Basel)*, 14(13). Accessed 03/06/2024.
[47] A Logit model could also have been used without affecting the size and significance of the coefficients in the propensity score. Logit and probit models usually yield very similar results in the absence of extreme outliers.

This estimates the probability, P, of an MSOA being a TLHC intervention area, $D_i = 1$, given a set of baseline characteristics X_{it} recorded from MSOA i at time t. Φ is the cumulative distribution function of the standard Normal distribution.

The matching variables X_{it} were chosen as factors that are assumed to influence both the selection into the intervention and outcomes of interest. It is important to control for these factors to prevent potential differences between areas biasing the estimated impact These factors include:

- **Values of the outcome variable in 2016, 2017 and 2018.** Past outcome values are likely to be influenced by the same unobservable factors as future values. Controlling for these factors is a way to indirectly mitigate the effect of bias due to unobservable factors in the model. The past outcome measures include the number of lung cancers per 10,000 in the target population, the number of lung cancers diagnosed at stage 1 and 2, stage 3 and 4 or not staged at diagnosis per 10,000 in the target population and the number of deaths due to lung cancer per 10,000 in the target population.

- **The number of GPs in each MSOA in England in 2023**. Increases in the number of GPs covering an MSOA are assumed to increase the probability of the corresponding MSOA to implement the programme, and therefore the probability to observe outcomes of interest (if GPs invite patients to the health checks).

- **The population aged 55-76 in the MSOA in 2021**, sourced from the ONS 2021 Census. The larger the at-risk population in an MSOA, the higher the probability that the MSOA will implement the programme and the larger the probability of observing outcomes for that population group.

- **The 2019 Index of Multiple Deprivation Score**, aggregated to the MSOA level, using published datasets from the University of Sheffield in collaboration with the Department for Levelling Up, Housing and Communities. More deprived areas are typically associated with worse lung cancer outcomes, primarily through increased exposure to smoking than less deprived areas.[48]

- **Radon potential levels**, radon is a radioactive gas which is the main risk factor of lung cancer in non-smokers.[49] Higher levels of radon exposure are therefore correlated with a higher number of lung cancers and as such should be controlled for to avoid differential levels of radon confounding the estimated impact of the TLHC programme.

- **Proportion of MSOA that identifies as white British**. Those who identify as white British typically engage with unhealthy behaviours such as smoking, poor diet and carrying excess body weight.[50] It therefore may be expected that areas with a higher proportion of the population who identify as white British exhibit worse lung cancer outcomes than areas with a lower

[48] Redono-Sanchez *et al*. (2022) Socio-Economic Inequalities in Lung Cancer Outcomes: An Overview of Systematic Reviews, *Cancers (Basel),* 14(2). Accessed 03/06/2024

[49] Riudavets *et al.* (2022) Radon and Lung Cancer: Current Trends and Future Perspectives, *Cancers (Basel)*, 14(13). Accessed 03/06/2024.

[50] Arnold. M., Razum. O. and Coebergh, J.W. (2010) Cancer risk diversity in non-western migrants to Europe: An overview of the literature, *European Journal of Cancer*, 46,14,2647-2659. [accessed: 30/05/2024].

proportion of people identifying as white British, all else held equal. Controlling the proportion of the population who identify as white British is therefore important to prevent differences between areas biasing the estimated impact.

- **Step 2:** A comparison group of MSOAs is then established by matching each TLHC-intervention MSOA with one non-intervention MSOA that has a similar value of the propensity score estimated in Step 1.[51]

  The nearest neighbour without replacement matching algorithm is described below:

  - **Nearest neighbour without replacement:** each intervention MSOA is matched to only one MSOA from the pool of non-intervention MSOAs that is closest in terms of their propensity score. Each MSOA from the non-intervention MSOAs can only be used once when matched without replacement.

  MSOAs that are not matched to an intervention MSOA are excluded from the analysis to ensure that comparisons are made between areas that are as similar as possible in terms of their observed characteristics.

  The common support condition is imposed. This condition implies that, for any given value of the propensity score, there should be both TLHC intervention and comparison observations. THLC intervention or comparison areas that do not meet this condition are dropped from the analysis.[52] The common support condition further ensures that the treatment and comparison group are as similar as possible in terms of their observed covariates.

- **Step 3:** The quality of the matched sample is assessed by comparing standardised mean differences across covariates. As previously described, SMDs are a measure of the size of the difference between two groups. The SMD explains how much of the selection on observable characteristics was able to be accounted for through matching.

Assessing the quality of the matching: Balance tests

The result of the balance test is presented in Figure 5.3. The first row of the Figure is the overall mean bias (the mean taken over all the SMDs), which can be interpreted as the average bias in the covariates before and after matching. The subsequent rows in the Figure are the differences in the mean of the individual matching variables between intervention and non-intervention areas before and after matching.

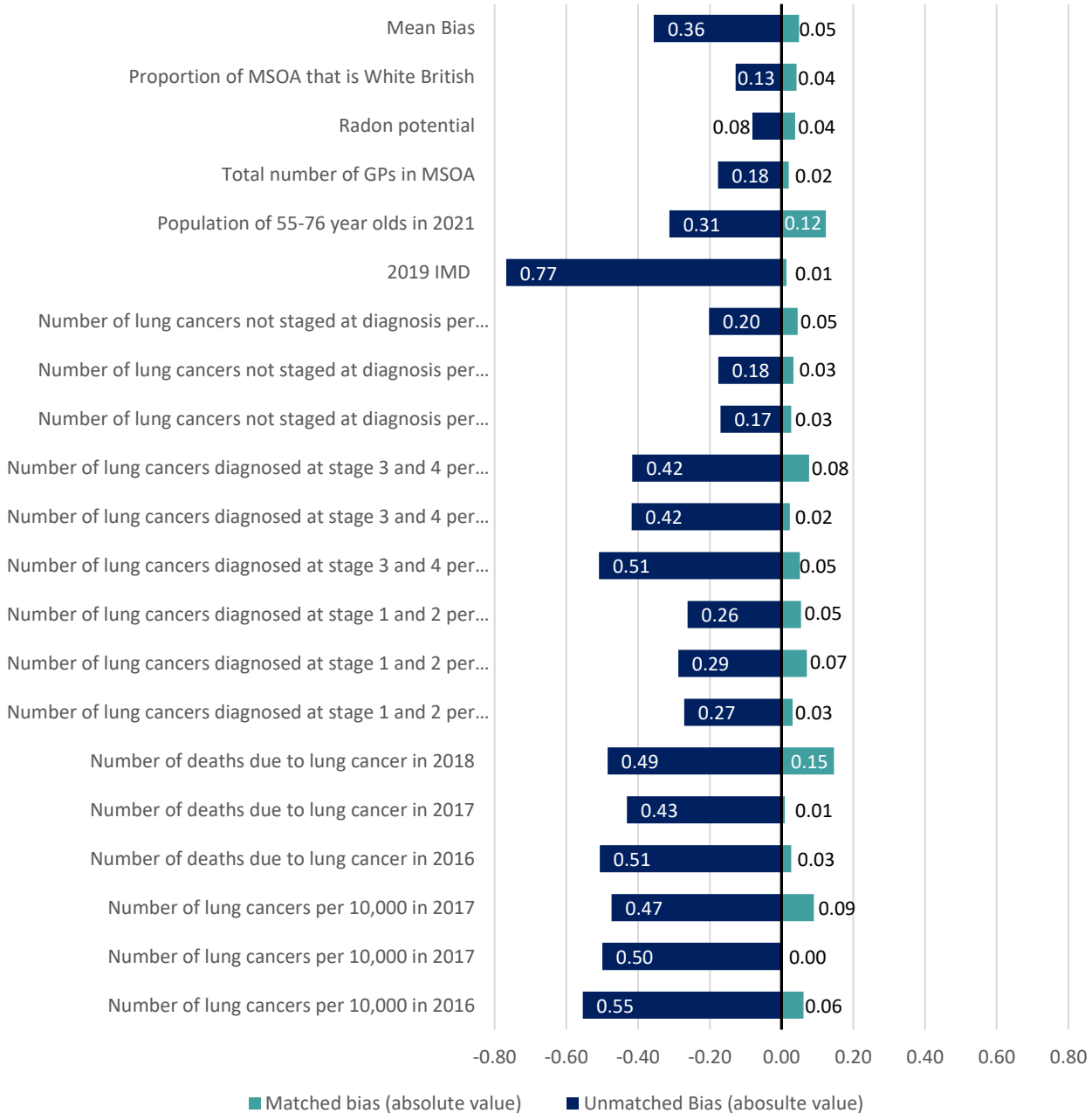
The results of the matching exercise suggest that a high-quality match is achieved. Individually, the SMD of each matching variable falls under the 0.1 threshold recommended within the literature

[51] Whilst several matching algorithms exist, only the nearest neighbour without replacement algorithm is used. Nearest neighbour matching without replacement produces a weight of 1 for each matched comparison unit (as each TLHC area has a single corresponding match). However other matching algorithms typically match multiple comparison units to each intervention area, meaning they get fractional weights (i.e. weights that are not equal to 1). The DiD estimator used for this analysis calculates its own internal propensity score weights, and these cannot be combined with the fractional weights estimated via other matching algorithms. Nearest Neighbour without replacement matching on the other hand in essence only identifies the corresponding match for each intervention area and therefore the weights do not have to be used in the analysis by simply excluding MSOAs that did not return a match.

[52] This can be implemented in statistical analysis software ©Stata using the psmatch2 package, and corresponding psmatch2 commands. The probability of treatment is estimated using the default Probit model.

(Austin, 2009). When considering the overall balance (the first row in Figure 5.3) the standardised mean difference between the comparison group and THLC intervention areas drops from 0.36 in the unmatched sample to 0.05 in the matched sample – comfortably below the 0.1 threshold. The quality of the match increases confidence that observable characteristics have been effectively controlled – and subsequently generated a credible counterfactual. This provides and additional layer of confidence that any differences in outcomes between the intervention and comparison group identified through difference-in-differences (see below) can be attributed to the TLHC programme.

Figure 5.3: Nearest Neighbour Matching Balance Tests Using Standardised Mean Differences



Note: The absolute value of the SMD is used here for presentational purposes. In practice it is the absolute value which is used as a cut off and so does not have a material impact on the interpretation of the plot.
Sample size: 537 TLHC intervention MSOAs, 537 matched comparison MSOAs and 4,840 potential counterfactual MSOAs.
Source: Ipsos analysis of National Cancer Registration Dataset and ONS Civil Registration – Deaths.

Further details of the effectiveness of the matching algorithm are set out in the following table.

Table 5.4: Balance tests for nearest neighbour matching algorithm

Variable	Matched/ Unmatched	Mean		SMD	%reduction |bias|
		Treatment	Control		
Number of lung cancers per 10,000 in 2016	Unmatched	22.671	15.644	0.55	
	Matched	22.671	23.448	-0.06	88.9%
Number of lung cancers per 10,000 in 2017	Unmatched	21.885	15.877	0.50	
	Matched	21.885	21.936	0.00	99.1%
Number of lung cancers per 10,000 in 2018	Unmatched	21.941	15.973	0.47	
	Matched	21.941	20.807	0.09	81.0%
Number of deaths due to lung cancer in 2016	Unmatched	15.652	10.59	0.51	
	Matched	15.652	15.917	-0.03	94.8%
Number of deaths due to lung cancer in 2017	Unmatched	14.779	10.459	0.43	
	Matched	14.779	14.874	-0.01	97.8%
Number of deaths due to lung cancer in 2018	Unmatched	14.85	10.061	0.49	
	Matched	14.85	13.407	0.15	69.9%
Number of lung cancers diagnosed at stage 1 and 2 per 10,000 in 2016	Unmatched	5.4301	3.858	0.27	
	Matched	5.4301	5.6111	-0.03	88.5%
Number of lung cancers diagnosed at stage 1 and 2 per 10,000 in 2017	Unmatched	5.6369	4.0542	0.29	
	Matched	5.6369	6.0296	-0.07	75.2%
Number of lung cancers diagnosed at stage 1 and 2 per 10,000 in 2018	Unmatched	5.7004	4.1901	0.26	
	Matched	5.7004	5.391	0.05	79.5%
Number of lung cancers diagnosed at stage 3 and 4 per 10,000 in 2016	Unmatched	15.571	10.594	0.51	
	Matched	15.571	10.072	-0.05	89.9%
Number of lung cancers diagnosed at stage 3 and 4 per 10,000 in 2017	Unmatched	14.59	10.668	0.42	
	Matched	14.59	14.375	0.02	94.5%
Number of lung cancers diagnosed at stage 3 and 4 per 10,000 in 2018	Unmatched	14.598	10.626	0.42	
	Matched	14.598	13.86	0.08	81.4%
Number of lung cancers not staged at diagnosis per 10,000 in 2016	Unmatched	1.6634	1.1631	0.17	
	Matched	1.6634	1.7425	-0.03	84.2%
Number of lung cancers not staged at diagnosis per 10,000 in 2017	Unmatched	1.6356	1.1249	0.18	
	Matched	1.6356	1.5387	0.03	81.0%
Number of lung cancers not staged at diagnosis per 10,000 in 2018	Unmatched	1.7241	1.1331	0.20	
	Matched	1.7241	1.5908	0.05	77.4%
2019 IMD	Unmatched	30.119	19.634	0.77	
	Matched	30.119	30.392	-0.01	98.2%
Population of 55-76 year olds in 2021	Unmatched	1863.7	2031.6	-0.31	
	Matched	1863.7	1797.4	0.12	60.5%
Total number of GPs in MSOA	Unmatched	1.083	0.89262	0.18	88.8%
	Matched	1.083	1.1042	-0.02	
Radon potential	Unmatched	2.0858	1.9927	0.08	53.4%
	Matched	2.0858	2.1293	-0.04	
	Unmatched	0.85817	0.88064	-0.13	67.4%

Proportion of MSOA that is White British	Matched	0.85817	0.85083	0.04	

Following best practice, (the absolute value of the) SMD > 0.1 indicate that there are meaningful levels of imbalance between intervention and comparison areas.
Source: Ipsos analysis of National Cancer Registration Dataset and ONS Civil Registration – Deaths.
Sample size: 537 TLHC intervention MSOAs, 537 matched comparison MSOAs and 4,840 potential counterfactual MSOAs.

Difference-in-Differences

The matched comparison group was used within a Difference-in-Differences (DiD) design to estimate the causal impact of TLHC programme.

DiD is based on comparing changes in outcomes between pre- and post-intervention periods, between an intervention and comparison group. In the context of the TLHC programme, it will compare changes in key outcomes over time between MSOAs that are classified as TLHC intervention areas and MSOAs which were matched through the PSM algorithm.

This design exploits the longitudinal nature of the data, and as such it is able to account for unobserved, time-invariant sources of bias. It is more robust than evaluating the impact with only PSM, as PSM alone can only account for biases due to systematic differences in observable characteristics. For example, the health behaviours and attitudes towards health (e.g. physical health, diet, level of exercise, alcohol consumption or smoking habits) are difficult to directly (and accurately) observe and if not controlled for would introduce bias into the estimates. The use of DiD design would enable a degree of control for health behaviours and behaviours for each area (as these variables are likely to be relatively constant over time), limiting the extent of the bias induced due to differences in unobservable factors between the intervention and matched comparison areas.

Staggered Rollout of the TLHC programme

A feature of the TLHC programme is that each CCG began engaging with the programme at different points in time – CCGs first adopted TLHC programme in April 2019, and the last Phase 2 project to adopt the TLHC programme was in December 2021.[53] This is referred to as a 'staggered rollout'. As such it would be anticipated that the overall programme level impacts would vary over time, due to the speed of the rollout and the number of projects engaging with the programme at any given time.

In practice, the official start date for each CCG is not known with certainty. As a simplifying assumption, it is assumed that projects went live (and therefore MSOAs are classified as 'intervention areas') when they first started to invite patients.

When the rollout of a programme is staggered, it is important that the estimation of DiD design accounts for potential biases arising from comparisons between later and earlier adopters of the programme, and from heterogeneous effects across groups.[54]

To robustly estimate impacts where there is a staggered rollout, a non-parametric estimator developed by Callaway and Sant'Anna (2021) is adopted.[55] The Callaway and Sant'Anna (2021) DiD estimator can

[53] The MSOAs follow the start date of their corresponding CCG.
[54] See Goodman-Bacon (2021) or de Chaisemartin and D'Haultfoeuille (2022) for a comprehensive overview of the potential biases that may occur when estimating a DiD within a staggered-rollout setting.
[55] Callaway, B. and Sant'Anna, P.H., 2021. Difference-in-differences with multiple time periods. *Journal of econometrics*, 225(2), pp.200-230.

be used to provide an overall estimate of the impact of the TLHC programme over the entire period from when the first CCG began the programme in April 2019, to the end of the available data in December 2023. In addition to this, it is also possible to estimate dynamic year-by-year effects of the TLHC programme.[56] This would better reflect the staggered rollout of the programme – for example, the majority of projects begin in 2021, so more cancers would be expected to have been diagnosed in 2021 than in 2020 and 2019 (where fewer projects had begun). For the purposes of this evaluation, both estimates of the overall impacts and the dynamic year-by-year impacts are reported through the use of event study charts.

The intuition behind this estimator is to compute different impacts for each group that adopted the programme at different dates. The group-time-specific impacts can be averaged to present an overall estimate of the (causal) impact of the programme. The expression for the group-specific impact at time t is:

$$ATT(g,t) = E\left[\left(\frac{G_g}{E[G_g]} - \frac{\frac{p_g(X)C}{1-p_g(X)}}{E\left[\frac{p_g(X)C}{1-p_g(X)}\right]}\right)Y_t - Y_{g-1}\right] \quad (2)$$

Where the weights p are propensity scores, G is a binary variable that is equal to one for MSOAs first adopting the TLHC programme in year g, and C is a binary variable equal to one for MSOAs in the comparison group which never implemented the programme.

Equation (2) gives the estimated impact at time t for the group of MSOAs beginning the programme at time g, and it is computed by comparing changes in outcomes for group g between periods $g-1$ to that of a comparison group of that are not part of the TLHC programme(C).[57]

The year-by-year impacts estimated through equation 2 can be aggregated to generate an overall effect of participating in the TLHC programme:

$$\theta = \sum_{g\in G}\sum_{t=2}^{T} w(g,t)\cdot ATT(g,t) \quad (3)$$

Where θ is the overall effect of participating in the programme, $w(g,t)$ is a weighting function, and $ATT(g,t)$ are the estimated group-time impacts.

Credibility of the Difference in Difference Design – Parallel Trends

The key identifying assumption under which DiD produces robust causal estimates of impact is the **parallel trends** assumption**.** This assumption states that, in the absence of the intervention, differences in the outcome between intervention and comparison groups would have remained constant during the post-intervention period. To improve the chances that this assumption is credibly met, comparison

[56] The Calloway and Sant'Anna (2021) DiD estimator for staggered treatment effects can be implemented in the software ©Stata using the user-written command 'csdid'.

[57] There is also a version of the estimator using only not-yet-treated units. This is not described here because in this setting there is a large group of non-intervention areas.

MSOAs are selected using PSM, which led to a considerable reduction in differences in observable characteristics between intervention and comparison MSOAs (see Figure 5.3).[58]

Whilst it is not possible to directly test whether the TLHC intervention areas would have exhibited the same outcomes as the comparison group in the absence of the TLHC programme (because this is a hypothetical scenario and therefore cannot be observed), it is possible to test whether the THLC intervention areas and the matched comparison areas exhibited the same trend in outcomes *before* the introduction of TLHC. Finding evidence of parallel trends in outcomes before the intervention, coupled with the similarities in observed characteristics identified through the PSM increases the credibility of the assumption that that the TLHC intervention areas would have exhibited the same outcomes as the comparison group in the absence of the TLHC programme. This therefore increases the confidence in which estimated impacts can be attributed to the TLHC programme.

To test the plausibility of the parallel trends assumption, a parallel trends test is undertaken to examine whether the differences between the TLHC intervention areas and the comparison group (in terms of the outcome of interest) prior to the start of the TLHC programme are jointly equal to zero.[59] The results of this test are presented in Table 5.5 below.

Table 5.5: Testing the parallel trends assumption across the different primary outcomes

	Number of lung cancer diagnosed per 10,000 people in the target population	Number of deaths where lung cancer is the primary cause per 10,000 people in the target population	Number of stage 1 or 2 lung cancer diagnosed per 10,000 people in the target population	Number of stage 3 or 4 lung cancer diagnosed per 10,000 people in the target population	Number of non-staged lung cancer diagnosed per 10,000 people in the target population
Null Hypothesis	Differences between TLHC intervention and comparison areas are jointly equal to zero for all pre-TLHC periods				
Chi-squared	10.10	15.69*	5.54	7.74	3.09
p-value	0.342	0.074	0.785	0.561	0.961

Note: *** represents statistically significant difference at the 99% confidence level; ** represents statistically significant at the 95% confidence level; * represents statistically significant at the 90% confidence level.

The results indicate that across all primary outcome measures, the parallel trends assumption holds at the 95% confidence level. It therefore can be reasonably assumed that in the absence of the TLHC programme, the number of lung cancers diagnosed (in total and by stage) and the number of deaths due to lung cancer in the target population in intervention area would have continued to trend in the same

[58] Past outcome values are likely to be influenced by the same unobservable factors as future values. Controlling for these factors is a way to indirectly mitigate the effect of bias due to unobservable factors in the model.

[59] i.e. a joint significance test on all pre-TLHC intervention coefficients from the event study model, under the null hypothesis that the coefficients are jointly equal to zero.

way as in comparison areas. Therefore, any deviation from trend observed in the TLHC intervention areas can be interpreted as the causal impact of the TLHC programme.

Assessing parallel trends within the sub-group analysis

To assess the impact of the TLHC programme on different groups within society, sub-group analysis is used to understand whether differential impacts are observed between different demographic groups. Section 5.6 discusses the sub-group analysis in more detail.

The sub-group analysis uses the same PSM-DiD design as the main analysis, and as such similarly relies on the parallel trend assumptions to confidently attribute observed differential impacts to the TLHC programme.

The table below presents the parallel trends tests for the outcomes when explored by sub-group. The table shows that there are some instances where there is evidence to suggest that the parallel trends assumption is violated (rows with red text) and as such any observed impacts cannot be confidently attributed to the TLHC programme.

Table 5.6: Testing the parallel trends assumption across the sub-group analysis

Sub-Group Outcome	Chi-squared	p-value
Differential impacts in the number of lung cancers diagnosed in the target population between males and females	11.77	0.227
Differential impacts in the number of lung cancers diagnosed at stage 1 or 2 in the target population between males and females	5.77	0.763
Differential impacts in the number of lung cancers diagnosed at stage 3 or 4 in the target population between males and females	30.56	>0.000
Differential impacts in the number of lung cancers not staged at diagnosis in the target population between males and females	3.98	0.679
Differential impacts in the number of deaths due to lung cancer in the target population between males and females	7.68	0.567
Differential impacts in the number of lung cancers diagnosed in the target population between those identifying as white British and non-white British	15.68	0.074
Differential impacts in the number of lung cancers diagnosed at stage 1 or 2 in the target population between those identifying as white British and non-white British	7.12	0.625
Differential impacts in the number of lung cancers diagnosed at stage 3 or 4 in the target population between those identifying as white British and non-white British	15.36	0.081
Differential impacts in the number of lung cancers not staged at diagnosis in the target population between those identifying as white British and non-white British	5.21	0.518
Differential impacts in the number of deaths due to lung cancer in the target population between those identifying as white British and non-white British	39.75	>0.000
Differential impacts in the number of lung cancers diagnosed in those aged 66-76 and 55-65	23.39	0.005
Differential impacts in the number of lung cancers diagnosed at stage 1 or 2 in those aged 66-76 and 55-65	7.01	0.636
Differential impacts in the number of lung cancers diagnosed at stage 3 or 4 in those aged 66-76 and 55-65	6.69	0.669
Differential impacts in the number of lung cancers not staged at diagnosis in those aged 66-76 and 55-65	1.17	0.978
Differential impacts in the number of deaths due to lung cancer in those aged 66-76 and 55-65	15.45	0.079
Differential impacts in the number of lung cancers diagnosed in the target population between those living in IMD quintiles 2-5 and quintile 1	11.80	0.225
Differential impacts in the number of lung cancers diagnosed at stage 1 or 2 in the target population between those living in IMD quintiles 2-5 and quintile 1	17.85	0.037
Differential impacts in the number of lung cancers diagnosed at stage 3 or 4 in the target population between those living in IMD quintiles 2-5 and quintile 1	7.27	0.608
Differential impacts in the number of lung cancers not staged at diagnosis in the target population between those living in IMD quintiles 2-5 and quintile 1	1.55	0.956
Differential impacts in the number of deaths due to lung cancer in the target population between those living in IMD quintiles 2-5 and quintile 1	4.64	0.865

Null hypothesis: Differences between TLHC intervention and comparison areas are jointly equal to zero for all pre-TLHC periods.
Note: Rows with amber text indicate that the null hypothesis has been rejected at the 90% confidence level, providing weak evidence that the parallel trends assumption has been violated; Rows with red text indicate that the parallel trend assumption has been violated at the 95% confidence level.

5.3.3 Robustness checks

Robustness checks were utilised to test the validity of the results found in the main analysis. The robustness checks are set out below:

- **Placebo tests** - Run the DiD analysis on the non-target population (within the same intervention and comparison MSOAs), e.g., for individuals aged 40 – 54. Since the intervention only addressed 55–76 year-old individuals, statistically insignificant effects would be expected in the outcomes of interest on the younger groups. Failure to detect statistically significant results supports the robustness of the analysis by indicating that there are not wider systemic changes occurring that may lead to the results detected in the target population.

- **Assessing the definition of the intervention areas** – The sample was also split into two, a full intervention group and a partial intervention group. The analysis follows the overarching PSM-DiD approach discussed above, estimating the impact for each of the samples separately. Comparisons between the two model outputs can then be made to understand how the TLHC programme changes with the definition of the intervention areas.

5.4 Impact of the TLHC programme on cancer outcomes

This section presents the results for each of the key outcomes in turn: the number of lung cancers diagnosed in the target population; the number of lung cancers diagnosed at stage 1 or 2, stage 3 or 4 and not staged at diagnosis within the target population; and the number of deaths due to lung cancer within the target population. Within each of the outcomes, descriptive evidence is first presented. This compares the areas that are part of the TLHC programme (THLC intervention areas) and all MSOAs in England that did not participate in the TLHC programme (referred to as non-intervention areas). Note, descriptive statistics are not causal estimates of impact.

The descriptive evidence is followed by the results of the staggered DiD design for each of the key outcomes. The results of the staggered DiD can be interpreted as the causal impact of the TLHC programme, where any observed changes can be attributed to the programme rather than other factors. The results are presented in graphical form, using ‘event study’ graphs, which display the impact of the programme over time – presenting a measure of impact for each yeah following the introduction of the TLHC programme.

The event study chart can be interpreted in the following way:

- The event study chart presents a plot of the estimated difference in outcomes between TLHC intervention areas and comparison groups over time, for both pre- and post-intervention periods.
- Points to the left of year 0 represent pre-intervention periods – left of the red dotted line.
- The coefficients from the pre-intervention periods are interpreted with respect to the previous year (i.e. represent the incremental change in outcome measure compared to the year before).
- Points to the right of year 0 represent post-intervention periods – right of the red dotted line.
- The coefficients from the post-intervention periods are interpreted with respect to the year before the intervention started (which varies for each MSOA).

Overall, the results suggest that the TLHC programme has had a positive impact on the number of lung cancers diagnosed, with additional diagnoses at both an earlier and later stage. The analysis did not detect any significant effects of the TLHC programme on the mortality due to lung cancer within the target population. More detail can be found on each outcome in the sub-sections below.

5.4.1 Key findings

The analysis suggests that the TLHC programme had the following impacts:

- **The TLHC programme was effective in diagnosing additional lung cancers in pilot areas**. It is estimated that an additional 1,168 lung cancers were diagnosed in pilot areas between 2019 and 2022 that would otherwise would have been diagnosed at a later stage or not diagnosed at all.[60]

- **The TLHC programme was effective in meeting its objectives relating to the number and share of lung cancers diagnosed at an earlier stage.** It is estimated that an additional 781 lung cancers were diagnosed at stage 1 or 2 in pilot areas between 2019 and 2022 that would have otherwise been diagnosed at a later stage or not diagnosed at all. The programme also enabled the detection of an additional 341 lung cancers at stage 3 or 4. The share of total lung cancers diagnosed at stage 1 or 2 rose from 24 to 39 percent between 2019 and 2022 in pilot areas (with no clear improvement trajectory in non-pilot areas sharing similar characteristics). This is likely driven by the share of early-stage cancers diagnosed amongst those patients attending LHCs.

- **The introduction of the programme is likely to place additional short-term demands on NHS resources** by increasing the number of lung cancer diagnoses. This effect is likely to be temporary as the system reaches a new equilibrium in which a higher share of those with lung cancer are diagnosed at earlier stages, likely leading to a future reduction in demand for late-stage cancer treatment. Evidence from the evaluation indicates that the number of additional lung cancers diagnosed begins to fall three years following the introduction of the pilot. For the purposes of future capacity planning, it may be reasonable to expect that additional demand for diagnostic and treatment capacity will persist for at least four to five years. However, it should be noted that the programme was targeted at those areas with the highest lung cancer mortality rates, and the roll-out of a lung cancer screening service to other areas might reasonably be expected to produce smaller demands on NHS resources.

- **Earlier diagnostic staging has not yet led to improved lung cancer mortality outcomes over the timescale of the study.** This is in line with clinical expectations given the timescales required to observe improvements in mortality rates due to earlier diagnosis of lung cancer.

5.4.2 Descriptive trends

Lung cancer diagnosis volumes

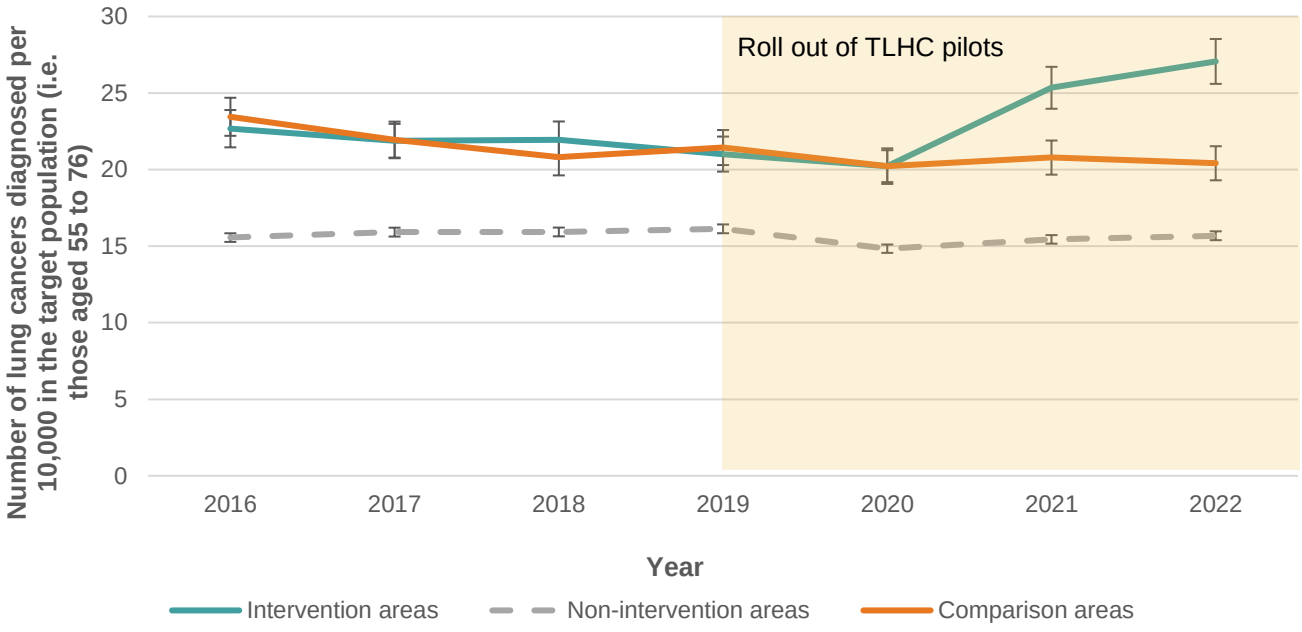
Figure 5.4 shows trends in the number of lung cancers diagnosed per 10,000 people aged 55 to 76 for intervention MSOAs and matched comparison areas between 2016 and 2022:

- **Pre-programme trends:** The number of individuals diagnosed with lung cancer per 10,000 residents aged 55 to 76 showed similar trends in pilot and comparison areas between 2016 and 2018 (around 22 per 10,000 residents over the period in both sets of areas).

[60] Note, the sum of additional stage 1 and 2, and stage 3 and 4 diagnoses does not equate to the sum of additional cancers. This is a form of 'aggregation bias', where the disaggregated data (i.e. considering each stage individually) does not perfectly match the aggregated data as each disaggregation has a different sample size, distribution, trend over time, leading to different model estimates.

- **Post-pilot trends:** Trends across the two areas began to diverge markedly in 2021, coinciding with mainstage delivery of the pilot programme. Lung cancer diagnosis rates increased notably in pilot areas (to 25 per 10,000 residents), while declining in comparison areas.

Figure 5.4: Trend in the number of lung cancers per 10,000 people for those aged 55-76 within the intervention and non-intervention areas between 2016 and 2022



Vertical bars represent the 95% confidence interval.
Source: Ipsos analysis of National Cancer Registration Dataset. Sample size: TLHC intervention areas, n=537; matched comparison areas, n = 537 non-intervention areas, n= 4,843. The number of lung cancers per 10,000 in the target population was computed as the number of individuals in the target population (55 to 76 years old) who received a lung cancer diagnosis divided by the total number of individuals in the target population (55 to 76 years old).

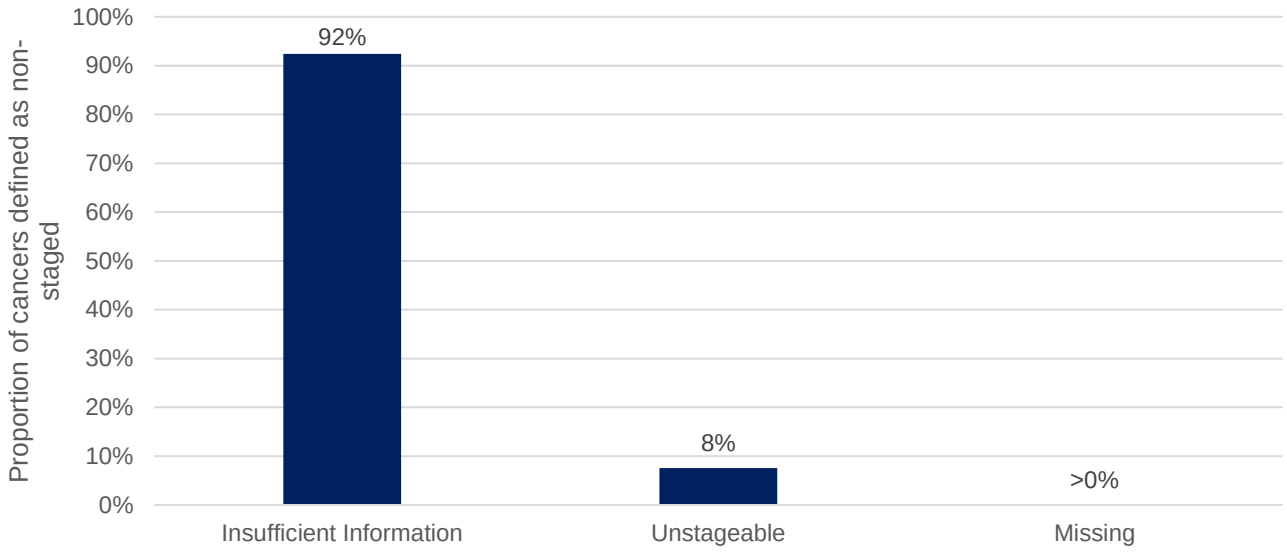
Diagnostic staging

The patient level data from the National Cancer Registration Dataset contains information on the stage at which lung cancers are diagnosed. However, within the records from 2016 to 2022, approximately 10 percent of all diagnoses were either not stageable, had insufficient information to stage or had missing values[61]. For the purposes of this analysis, not stageable and insufficient information to stage are referred to as 'non-staged cancers'. Insufficient information is the most common reason for not having a stage at diagnosis. Missing values were excluded from the analysis, however this is a negligible proportion of the population.

Given then 10 percent of all lung cancers of those aged 55-76 did not have a stage at diagnosis, this was included as one of the outcomes explored alongside the number of lung cancers diagnosed at stage 1 and 2, and stage 3 and 4. This will provide an assessment of how the TLHC programme impacted the number of non-staged lung cancers, and whether improvements in reporting brought about by the programme enabled better classification of these lung cancers.

[61] For the purpose of this analysis, missing values are instances where cell is empty, i.e. there is not value in the cell, opposed to a reason for the stage not being provided.

Figure 5.5: Reason for a non-staged lung cancer diagnosis recorded in 55-76 year old in both TLHC intervention and non-intervention areas for the target population over all recorded cases of lung cancer from 2019 – 2022.



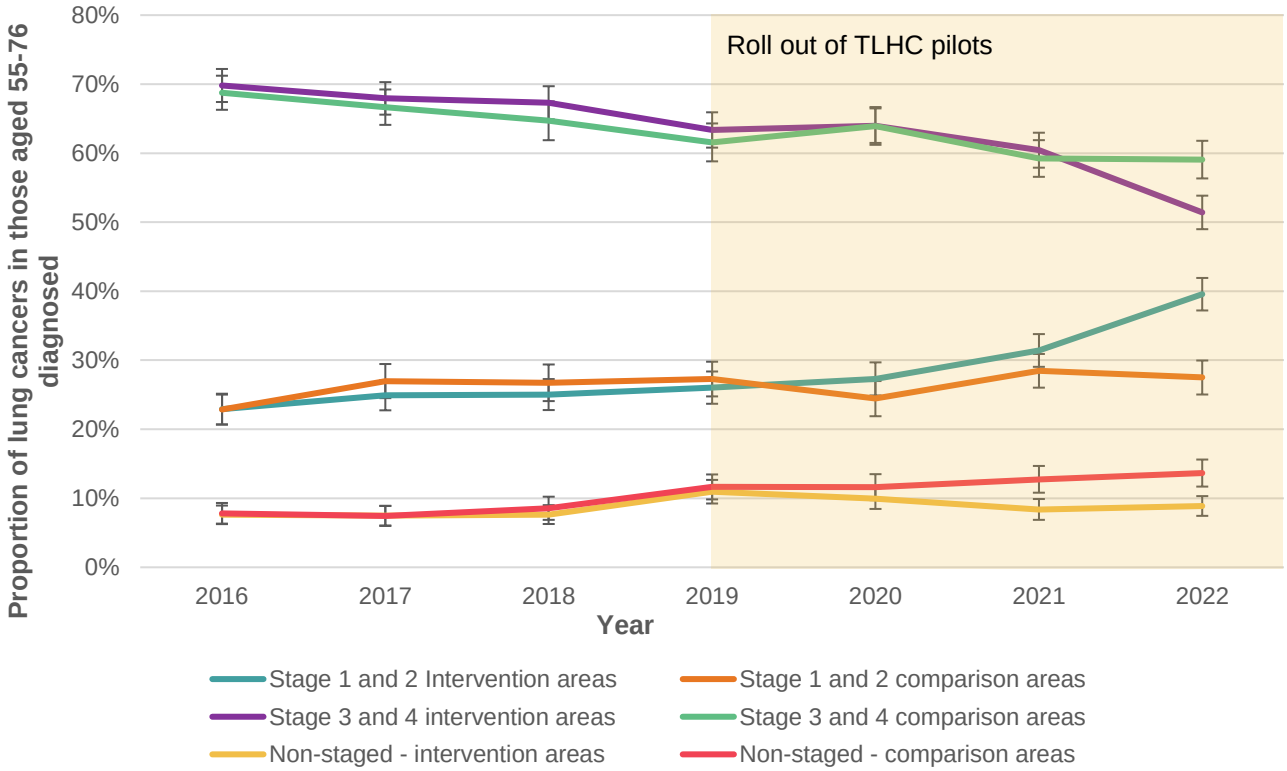
Source: Ipsos analysis of National Cancer Registration Dataset.
Note, missing values are instances where cell is empty, i.e. there is not value in the cell, opposed to a reason for the code not being provided.

Figure 5.6 provides descriptive evidence that TLHC pilot areas saw a shift in the stage at diagnosis. The chart suggests that the objectives of the programme to increase the share of lung cancers diagnosed were met:

- **Pilot areas:** The average share of lung cancers diagnosed at stage 1 or 2 in pilot areas rose from an average of 24 percent between 2016 and 2018 to just over 39 percent in 2022. The share of lung cancers diagnosed at stages 3 or 4 fell from an average of 67 percent prior to the programme to 51 percent in 2022. The share of non-staged cancers remained at a similar level across the evaluation period.

- **Matched comparison areas:** By contrast, matched comparison areas saw no improvement trajectory between 2016 and 2022 in terms of the share of lung cancers diagnosed at stage 1 and 2, or stage 3 and 4. The share of non-staged lung cancers increased from an average of 8 percent across 2016 to an average of 12 percent across 2019 to 2022.

Figure 5.6: Proportion of lung cancers diagnosed at stage 1 or 2, and 3 or 4, for those aged 55-76 in TLHC intervention areas and matched comparison areas, 2016-2022

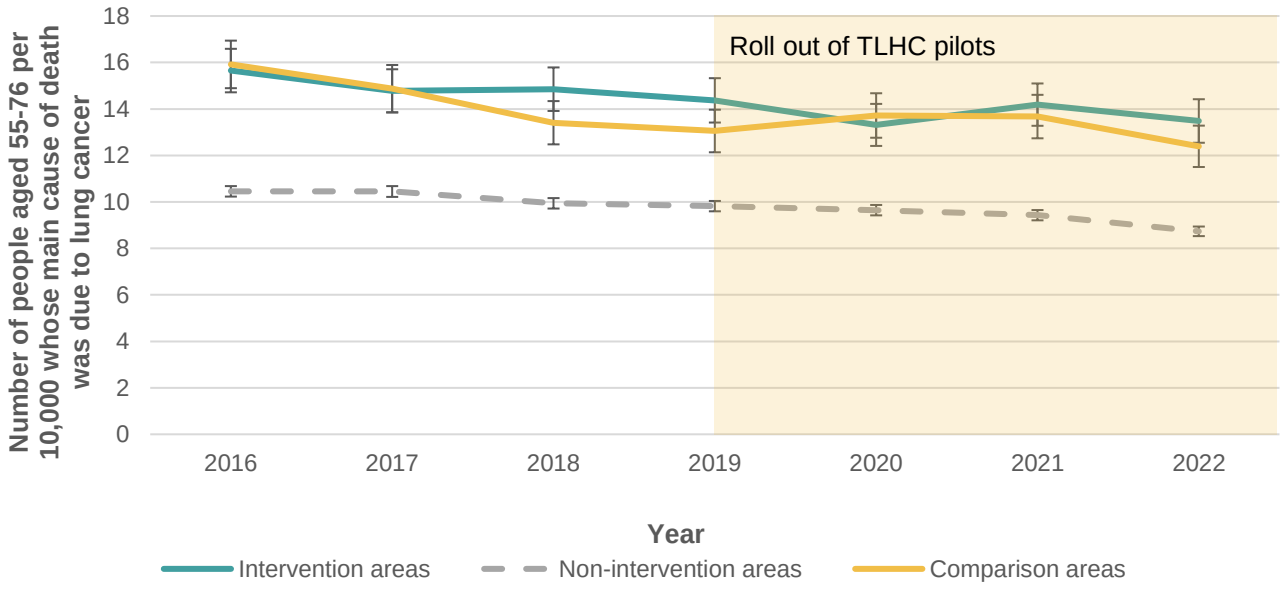


Source: Ipsos analysis of National Cancer Registration Dataset. Incidence by stage was computed as the number of individuals amongst the target population (55 to 76 years old) with a lung cancer diagnosed at; stage 1 or 2, stage 3 or 4, and non-staged, divided by the target population.
Sample size: TLHC intervention areas, n=537; matched comparison areas, n = 537

Lung cancer mortality rates

Figure 5.7 shows trends in the number of deaths due to lung cancer in the target population in pilot and matched comparison areas. Lung cancer mortality rates fell steadily in pilot areas between 2016 and 2022 (from 15.7 to 13.3 deaths per 10,000 residents aged 55 to 76). However, similar trends were observed both in the comparison areas as well as nationally.

Figure 5.7: Trend in the number people whose main cause of death was due to lung cancer per 10,000 people for those aged 55 – 76 within TLHC intervention and non-intervention areas between 2016 and 2022



Vertical bars represent the 95% confidence interval.
Source: Ipsos analysis of ONS Civil Registration – Deaths. Sample size: TLHC intervention areas, n=537; comparison areas = 537; non-intervention areas, n= 4,843. The mortality rate due to lung cancer was computed as the Number of individuals in the target population (55 to 76 years old) who have died with lung cancer recorded as the underlying cause of death divided by the total number of individuals in the target population (55 to 76 years old).

5.4.3 Causal impact analysis of TLHC pilots

Table 5.7 below presents the regression outputs for the staggered difference-in-differences used to estimate the causal impact of TLHC:

Table 5.7: Estimated impacts of the TLHC programme (statistically significant effects at the 95% confidence level highlighted in blue)

	Additional number of lung cancers diagnosed among those aged 55-76	Additional number of lung cancers diagnosed at stage 1 or 2 among those aged 55-76	Additional number of lung cancers diagnosed at stage 3 or 4 among those aged 55-76	Additional number of lung cancers not staged at diagnosis among those aged 55-76	Additional number of deaths whose primary cause of death was due to lung cancer among those age 55-76
	Coefficient (Standard error) [95% confidence interval]	Coefficient (Standard error) [95% confidence interval]	Coefficient (Standard error) [95% confidence interval]	Coefficient (Standard error) [95% confidence interval]	Coefficient (Standard error) [95% confidence interval]
Sample size	n=7,252	n=7,252	n=7,252	n=7,252	n=7,252
Pre-intervention period 4	0.736 (1.156) [-1.53 - 3.003]	-0.158 (0.574) [-1.284 - 0.968]	0.545 (0.931) [-1.28 - 2.369]	0.219 (0.324) [-0.417 - 0.855]	-0.232 (1.003) [-2.199 - 1.734]
Pre-intervention period 3	2.009* (1.072) [-0.091 - 4.11]	1.075* (0.563) [-0.028 - 2.178]	0.927 (0.873) [-0.784 - 2.637]	0.098 (0.298) [-0.485 - 0.682]	1.905** (0.924) [0.094 - 3.715]
Pre-intervention period 2	-1.447* (0.865) [-3.143 - 0.249]	-0.772* (0.452) [-1.658 - 0.114]	-0.594 (0.679) [-1.924 - 0.736]	-0.095 (0.248) [-0.58 - 0.39]	-0.09 (0.727) [-1.514 - 1.334]
Pre-intervention period 1	0.098 (0.823) [-1.515 - 1.712]	0.349 (0.404) [-0.442 - 1.141]	-0.017 (0.668) [-1.325 - 1.291]	-0.116 (0.257) [-0.619 - 0.388]	-0.832 (0.702) [-2.209 - 0.544]
Post-intervention period 0	2.657*** (0.864) [0.963 - 4.351]	0.980** (0.451) [0.095 - 1.864]	1.748** (0.681) [0.412 - 3.083]	-0.233 (0.262) [-0.747 - 0.28]	1.006 (0.701) [-0.369 - 2.38]
Post-intervention period 1	6.397*** (0.833) [4.765 - 8.029]	4.538*** (0.487) [3.583 - 5.494]	1.624*** (0.617) [0.415 - 2.832]	0.146 (0.250) [-0.343 - 0.636]	1.127* (0.68) [-0.206 - 2.461]
Post-intervention period 2	5.353*** (1.376) [2.656 - 8.051]	4.201*** (0.863) [2.509 - 5.893]	1.567 (1.025) [-0.442 - 3.575]	-0.520 (0.361) [-1.227 - 0.187]	-0.912 (1.034) [-2.939 - 1.115]
Post-intervention period 3	3.586** (1.405) [0.831 - 6.340]	3.777*** (0.832) [2.146 - 5.408]	-0.041 (1.063) [-2.124 - 2.042]	-0.351 (0.430) [-1.195 - 0.492]	-0.634 (1.204) [-2.993 - 1.725]

Average impact over first four post-intervention periods	4.523*** (0.696) [3.159 - 5.887]	3.088*** (0.380) [2.344 - 3.832]	1.451*** (0.549) [0.374 - 2.527]	-0.149 (0.214) [-0.569 - 0.271]	0.576 (0.603) [-0.605 - 1.758]

*** represents statistically significant difference at the 99% confidence level; ** represents statistically significant at the 95% confidence level; * represents statistically significant at the 90% confidence level, based on asymptotic standard errors clustered at the MSOA level.
Estimated using Callaway and Sant'anna (2021) doubly robust estimator. Number of observations = 7,252.
Source: Ipsos analysis of National Cancer Registration Dataset and ONS Civil Registration – Deaths.

When looking across the results across the outcomes:

- **Impacts across lung cancer diagnosis volumes:**
  - **The TLHC programme led to an increase in the number of lung cancers diagnosed within the target population in pilot areas between 2019 and 2022** (that would not have otherwise been diagnosed until a later date or not diagnosed at all). On average, it was estimated that the introduction of the TLHC programme led to an additional 4.5 cases of lung cancers being diagnosed per 10,000 people per annum in the target population (this result was significant at the 99% level of confidence).
  - This is equivalent to an additional estimated 1,168 (lower bound 675, upper bound 1,662) cases of lung cancer that otherwise would not have been detected over the period[62].
  - As illustrated in the second column of Table 4.1, the effects of the TLHC programme on overall numbers of lung cancer diagnoses appears to strengthen in the first two years following its introduction (peaking at an additional 6.4 lung cancers diagnosed per 10,000 residents aged 55 to 76). This effect begins to decline in the third year. This is consistent with expectations that the introduction of the TLHC programme would lead to a temporary increase in lung cancer diagnosis volumes before returning to a new equilibrium with a higher share of cancers diagnosed at earlier stages.
  - The findings confirm that the introduction of the TLHC programme will lead to an increase in demand for NHS diagnostic and treatment capacity. For the purposes of future capacity planning, it appears reasonable to anticipate that these additional demands will persist for at least four to five years following the introduction of screening. It should be noted that the programme was targeted at those areas with the highest lung cancer mortality rates, and the roll-out of a lung cancer screening service to other areas might be reasonably be expected to produce smaller demands on NHS resources.
  - It should be noted that a significant proportion of the additional lung cancers may never have caused harm to the patients and may never have been diagnosed. Determining the proportion of cancers which would be considered over-diagnosed typically requires long term follow-up that is beyond the scope of this evaluation. Results from the NLST suggest that 4.5 years post-screening overdiagnosis rates were at 18.5 percent, falling to 3 percent after 9 years.[63] Similar results were observed in the NELSON trial, where overdiagnosis rates were 19.7 percent 4.5 years post-screening.[64]

[62] This was estimated by multiplying the estimated additional cases of lung cancer per 10,000 by the number of people (in ten thousands) in participating CCGs for each of the four years of delivery– producing an annual additional number of lung cancer cases identified. The point at which each CCG began participating in TLHC was accounted for in this calculation. Population estimates of those aged 55-76 were obtained from the 2021 Census. The 95% confidence interval was used to provide a range of values in which there is 95% confidence that the true number of additional cancers lies between.

[63] Patz *et al.* (2014) Overdiagnosis in low-dose computed tomography screening for lung cancer, *JAMA Internal Medicine*, 174(2), 269-274.; Aberle *et al.* (2020) Lung Cancer Incidence and Mortality with Extended Follow-up in the National Lung Screening Trial, *Journal of Thoracic Oncology*, 14(10), 1732-1742

[64] de Koning *et al*. (2020) Reduced Lung-Cancer Mortality with Volume CT Screening in a Randomized Trail, *The New England Journal of Medicine*, 382(6), 503-513. Accessed 07/06/2024.

- **Impacts on staging at diagnosis:**

  - **The introduction of the TLHC programme led to the diagnosis of an average of 3.1 additional cases of lung cancer at stage 1 or 2 per 10,000 residents per annum** (i.e. cancers that would not have otherwise been diagnosed or would have otherwise been diagnosed at a later stage). This equates to an estimated 781 (lower bound 500, upper bound 1063) additional cancers diagnosed at stage 1 or 2 that would likely have been diagnosed at a later stage or may not have been diagnosed at all in the absence of the programme.[65]

    As illustrated in the third column of Table 4.1, the impact of the TLHC programme strengthened in the first two years following its introduction, identifying a comparatively large number of cancers in a previously unscreened population. These effects began to weaken in the third-year post roll-out, possibly as the size of the unscreened population beings to diminish and the intervention was rolled out to new cohorts that had aged into the target group (shown by the rate of increase beginning to fall in Figure 8.2) – although the degree to which a new long-term equilibrium had been reached by this stage is unclear.

  - **The introduction of the TLHC programme also led to a temporary increase in the number of lung cancers detected at stage 3 or 4, concentrated in the first two years post-roll-out.** This equates to an estimated 341 (lower bound 91, upper bound 599) additional cancers diagnosed at stage 3 or 4 that would not have otherwise been diagnosed over the four years of programme delivery.

  - No evidence was found to suggest that TLHC affected the volume of lung cancers not staged at diagnosis

  - The findings suggest that around 80 percent of the additional lung cancers detected were at stages 1 or 2. This indicates that the roll-out of the TLHC programme in uncontrolled healthcare settings has achieved levels of effectiveness at the upper end of the range implied by prior randomised control trials. The UK NSC 'Targeted screening for lung cancer in individuals at risk' report provides a meta-analysis of previous lung cancer screening Randomised Control Trials (RCTs) (including DANTE, DLCST, LSS, LUSI, MILD, NELSON and NLST) that shows that stage 1 and 2 cancers made up between 47 percent and 86 percent of lung cancers diagnosed (in the intervention arm).

- **Impacts on lung cancer mortality rates:**

  - The introduction of the TLHC programme had no statistically significant effect on the number of deaths due to lung cancer in the target group between 2019 and 2022.[66]

[65] Calculated by multiplying the number of MSOAs in each CCG by the estimated impact of the intervention on the number of stage 1 or 2 diagnoses to give an annual number of additional stage 1 or 2 diagnoses. This is then multiplied by the number of years that the CCG has been participating in the TLHC programme for to estimate the additional number of cancers across the programme.

[66] It should be noted that in year 1 (the second post-intervention period), a statistically significant impact (at the 95% confidence level) is detected. Additional analysis was undertaken to explore this result, including running the analysis using additional outcomes to delve deeper into mortality within the TLHC intervention areas: all-cause mortality in the target population, all deaths due to cancer and all deaths due to cancers of unknown origin within the target population. The results of the additional analysis did not suggest the total number of deaths in TLHC areas have increased with respect to the comparison areas. Therefore, the observed increase in the number of deaths due to lung cancer in the second post-intervention period cannot directly be attributed to the TLHC programme. This is further discussed in Appendix 5.

- There are two potential explanations why significant reductions in mortality due to lung cancer are not found within this analysis:

  1. Screening programmes often take several years before impacts on mortality are observed owing to lags associated with the progression of the disease and mortality outcomes. As such, a material effect on mortality may not be expected at this stage for clinical reasons. Evidence from three randomised control trials have demonstrated a longer-term reduction in lung cancer mortality with low dose computed tomography (LDCT) lung cancer screening: the National Lung Screening Trial (NLST)[67], NELSON[68], and MILD[69], indicating that these types of outcomes would be expected in the longer term.

  2. However, it is not possible to rule out the possibility that wider pressures on the NHS have limited the extent to which it has been possible to realise the clinical benefits of earlier diagnosis. As highlighted in later chapters (see Figure 8.11 and 8.12), performance against the 62-day waiting time target for treatment has deteriorated from 2020 onwards. It is possible that wider capacity pressures have delayed treatment for some patients receiving LHCs, eroding the potential benefits of an earlier diagnosis.

5.5 Differential impacts

Analysis across four sub-groups was undertaken to understand whether the TLHC programme contributed towards differences in the number of diagnoses and deaths due to lung cancer, between different demographics:

- **Gender:** Differences in the number of diagnoses and deaths due to lung cancer per 10,000 (of the target population) between male and female.
- **Ethnicity:** Differences in the number of diagnoses and deaths due to lung cancer per 10,000 (of the target population) between those that identify as white British and non-white British.
- **Age:** Differences in the number of diagnoses and deaths due to lung cancer per 10,000 (of the target population) between those that are aged 55 – 65 and 66 – 76.
- **Level of deprivation:** Differences in the number of diagnoses and deaths due to lung cancer per 10,000 (of the target population) between those that live in areas that are in Index of Multiple Deprivation (IMD) quintile 1 quintiles 2-5.

The causal impact analysis looks at differences in the number of diagnoses (including number of diagnoses by stage) and deaths due to lung cancer per 10,000 (in the target population) between the sub-groups, exploring how these differences change over time between intervention and comparison areas.

The findings are presented by sub-group, first presenting descriptive (non-causal) analysis, followed by causal impact analysis to explore the extent to which any detected impact can be attributed to the TLHC programme.

[67] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4356534/ [Accessed 08/02/2024]
[68] https://pubmed.ncbi.nlm.nih.gov/31995683/ [Accessed 08/02/2024]
[69] https://pubmed.ncbi.nlm.nih.gov/30937431/ [Accessed 08/02/2024]

5.5.1 Key findings

The analysis suggests that the TLHC programme had the following impacts:

- **The increased volumes of lung cancer diagnoses were predominantly concentrated among those individuals identifying as White British.** Within TLHC intervention areas, the number of lung cancers per 10,000 increased more within White British groups than in non-White British groups compared to comparison areas. Descriptive analysis indicates that the likely widening of this gap is due to increases in the number of lung cancers in White British groups, whilst the number of lung cancers in non-White British groups showed no deviation from prior trends. This raises some questions as to how all groups within the target population can be effectively engaged.

- **The programme did not lead to any other positive or adverse impacts across subgroups.** While there was a larger increase in the number of un-staged cancers diagnosed amongst those aged 66 to 76 than amongst those aged 55 to 65, this is likely largely attributable to higher prevalence amongst the older cohort.

5.5.2 Gender

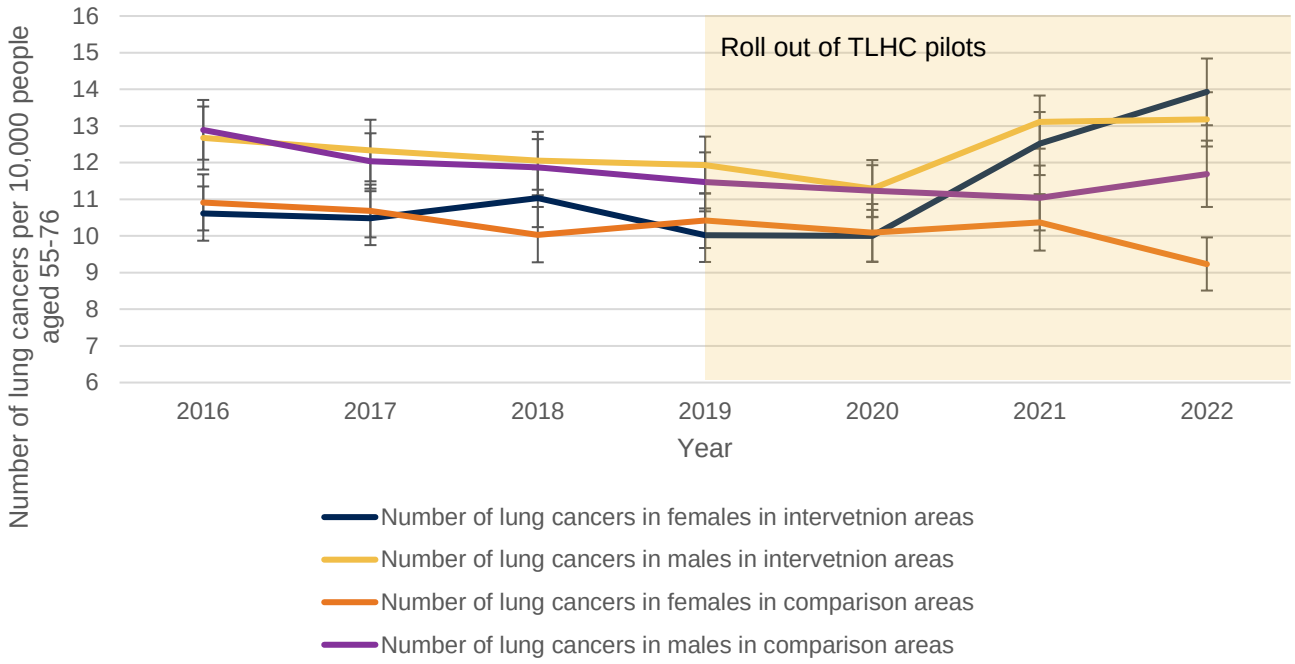
Descriptive Trends

Figure 5.8 presents the number of lung cancers per 10,000 people aged 55-76, disaggregated by gender, for both TLHC pilot and matched comparison areas:

- **Trends in THLC pilot areas:** The number of diagnoses falls between 2016 and 2019. From 2020, a sharp increase in diagnoses is seen in both males and females. The rate of increase in the volume of lung cancers diagnosed is larger in the female population, however notable increases are also observed among males.

- **Trends in comparison areas:** The number of diagnoses falls in both males and female groups up until 2022, where in the final period a divergence in trend is observed. However, the comparison areas do not exhibit a corresponding step change in 2020, as was observed in TLHC pilot areas.

Figure 5.8: Number of lung cancer diagnoses per 10,000 people aged 55-76, disaggregated by gender, in intervention and comparison areas, 2016 to 2022



Vertical bar represents the 95% confidence interval.
Source: Ipsos analysis of National Cancer Registration Dataset. Sample size: intervention, n=537; comparison areas, n= 537.

Causal Impact Analysis

Table 5.8 below presents the regression outputs for the staggered difference-in-differences used to estimate the extent to which there were differential impacts between males and females within TLHC pilot areas compared to comparison areas.

Table 5.8: Estimated effect of the TLHC programme – relative impacts by gender (statistically significant effects at the 95% confidence level highlighted in blue)

	Estimated number of additional lung cancers amongst males relative to females diagnosed per 10,000 people aged 55-76	**Estimated number of additional lung cancers amongst males relative to females diagnosed at stage 1 or 2 per 10,000 people aged 55-76**	**Estimated number of additional lung cancers amongst males relative to females diagnosed at stage 3 or 4 per 10,000 people aged 55-76**	**Estimated number of additional lung cancers amongst males relative to females not staged at diagnosis diagnosed per 10,000 people aged 55-76**	**Estimated number of additional deaths whose primary cause of death was due to lung cancer amongst males relative to females per 10,000 people aged 55-76**
	Coefficient (Standard error) [95% confidence interval]	Coefficient (Standard error) [95% confidence interval]	Coefficient (Standard error) [95% confidence interval]	Coefficient (Standard error) [95% confidence interval]	Coefficient (Standard error) [95% confidence interval]
Sample size	n=7,252	n=7,252	n=7,252	n=7,252	n=7,252
Pre-intervention period 4	1.008 (1.171) [-1.286 - 3.303]	1.883 (1.908) [-1.857 - 5.622]	-1.417 (1.105) [-3.583 - 0.749]	-1.025 (2.591) [-6.103 - 4.054]	-0.685 (1.132) [-2.903 - 1.533]
Pre-intervention period 3	-0.952 (1.139) [-3.185 - 1.28]	0.654 (1.678) [-2.634 - 3.943]	-1.282 (1.009) [-3.259 - 0.695]	4.64 (4.083) [-3.362 - 12.642]	1.237 (1.135) [-0.987 - 3.46]
Pre-intervention period 2	-0.265 (0.937) [-2.102 - 1.571]	0.348 (1.402) [-2.401 - 3.096]	1.038 (0.839) [-0.606 - 2.683]	1.995 (2.154) [-2.226 - 6.216]	0.13 (0.908) [-1.649 - 1.909]
Pre-intervention period 1	0.211 (0.918) [-1.587 - 2.009]	0.477 (1.234) [-1.941 - 2.896]	-1.136 (0.87) [-2.841 - 0.569]	-3.488 (3.344) [-10.043 - 3.067]	-0.228 (0.843) [-1.881 - 1.425]
Post-intervention period 0	0.651 (0.89) [-1.093 - 2.395]	-0.397 (1.044) [-2.444 - 1.649]	0.852 (0.838) [-0.79 - 2.495]	-1.542 (2.189) [-5.833 - 2.749]	1.262 (0.909) [-0.519 - 3.043]
Post-intervention period 1	-1.845** (0.863) [-3.536 - -0.153]	-1.765 (1.103) [-3.926 - 0.397]	0.266 (0.849) [-1.398 - 1.93]	-0.812 (1.995) [-4.722 - 3.098]	1.281 (0.789) [-0.265 - 2.826]

Post-intervention period 2	1.645 (1.4) [-1.099 - 4.39]	-2.136 (1.797) [-5.657 - 1.386]	1.399 (1.357) [-1.261 - 4.059]	10.938** (5.576) [0.009 - 21.867]	2.097 (1.383) [-0.613 - 4.807]
Post-intervention period 3	-1.946 (1.448) [-4.785 - 0.893]	-1.842 (1.551) [-4.882 - 1.199]	-2.8* (1.474) [-5.689 - 0.088]	-2.388 (3.735) [-9.709 - 4.933]	0.736 (1.35) [-1.911 - 3.382]
Average impact over first four post-intervention periods	-0.453 (0.728) [-1.881 - 0.974]	-1.41* (0.803) [-2.984 - 0.165]	0.198 (0.694) [-1.162 - 1.559]	-0.774 (1.574) [-3.859 - 2.311]	1.324* (0.738) [-0.123 - 2.771]

*** represents statistically significant difference at the 99% confidence level; ** represents statistically significant at the 95% confidence level; * represents statistically significant at the 90% confidence level, based on asymptotic standard errors clustered at the MSOA level.
Note: Rows with amber text indicate that the null hypothesis has been rejected at the 90% confidence level, providing weak evidence that the parallel trends assumption has been violated; Rows with red text indicate that the parallel trend assumption has been violated at the 95% confidence level.
Estimated using Callaway and Sant'anna (2021) doubly robust estimator. Number of observations = 7,252.
Source: Ipsos analysis of National Cancer Registration Dataset and ONS Civil Registration – Deaths.

The sub-group analysis indicates that the impacts of TLHC were equitable across males and females:

- No differences between males and females were observed across the overall outcome measures (final row of Table 5.8) at the 95% confidence level. The analysis also failed to identify statistically significant year-by-year effects in most instances, further supporting the notion of the equitable distribution of impacts across genders.

  There is tentative evidence to suggest that overall, the number of lung cancers diagnosed in females increased by 1.4 cases per 10,000 people relative to male diagnoses in TLHC pilot areas. However, this is only statistically significant at the 90% confidence level.

  There is also week evidence to suggest that the number of deaths due to lung cancer increased among males relative to females in TLHC intervention areas. This is significant the 90% confidence level.

- The analysis found that in post-intervention period two, there were 10.9 more lung cancers not staged at diagnosis among males in TLHC areas relative to female diagnoses. The magnitude of this coefficient is considerably higher that all other reported coefficients, and is anticipated to largely be driven by random noise.

5.5.3 Ethnicity

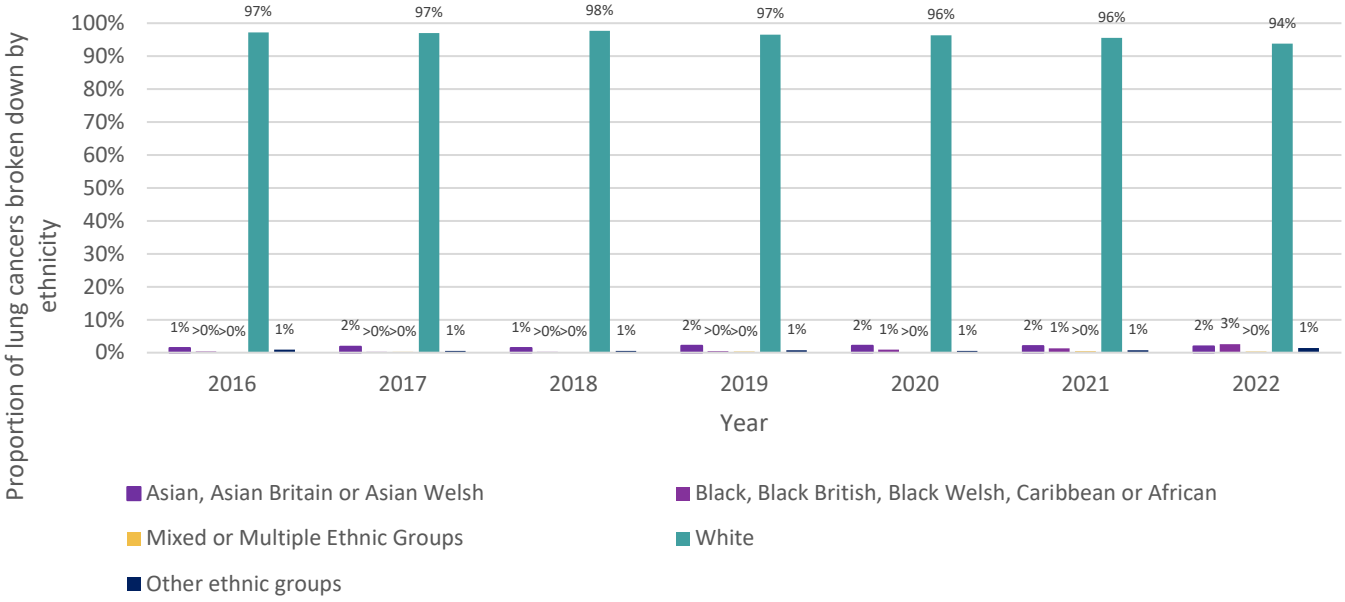
Descriptive trends

Within TLHC intervention areas, most of the target population diagnosed with lung cancer was classified as white (using ONS ethnic group classification) (See Figure 5.9).[70] Given the notable difference in the proportion of the eligible population with lung cancer who are identified as white compared to other ethnicities, for the purpose of this sub-group analysis, differences are compared between the number of diagnoses of those identifying as white British and non-white British (i.e. pooling all other ethnicities).[71]

[70] Ethnic group classification 6a: https://www.ons.gov.uk/census/census2021dictionary/variablesbytopic/ethnicgroupnationalidentitylanguageandreligionvariablescensus2021/ethnicgroup/classifications

[71] For the purposes of this analysis, it is not possible to further disaggregate ethnicity sub-groups as the sample sizes are too small.

Figure 5.9: Proportion of total lung cancers of those aged 55-76 within TLHC intervention areas broken down by ethnicity over time.



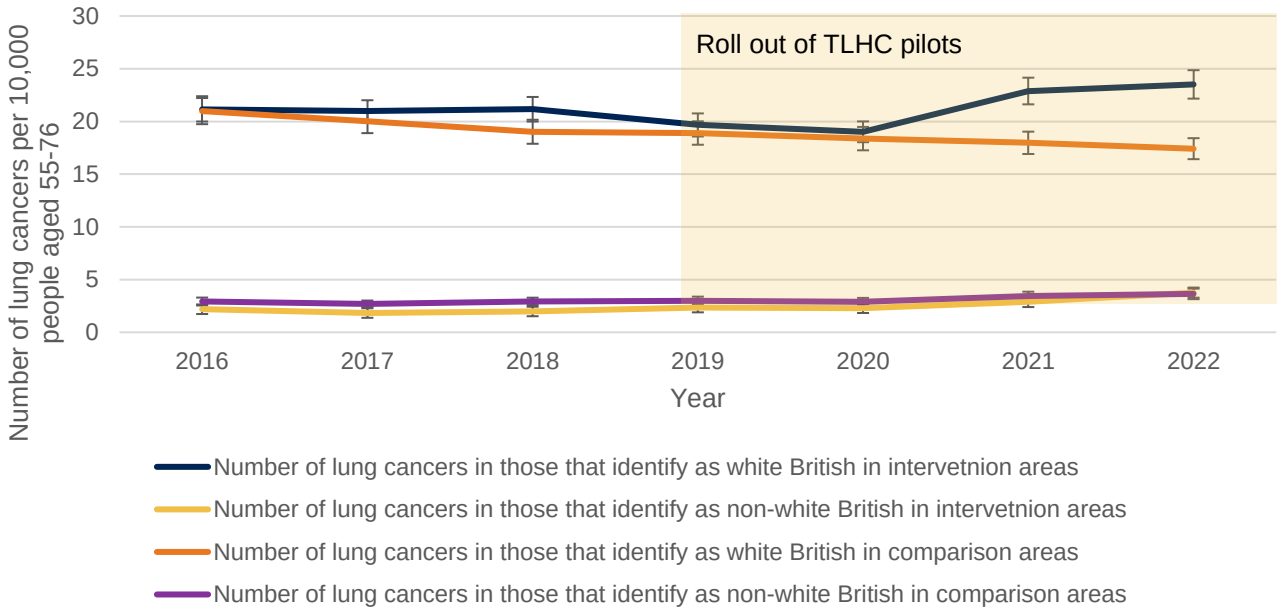
Note: missing values (i.e. patient level records that did not contain information on the patients ethnicity) are excluded.
Source: Ipsos analysis of National Cancer Registration Dataset. Sample size, n=537 intervention areas; The incidence rate was computed as the number of individuals in the target population (55 to 76 years old) receiving a lung cancer diagnosis divided by the total number of individuals in the target population (55 to 76 years old).

The trends in lung cancer diagnosis volumes, separated by white British and non-white British groups, in TLHC pilot and comparison areas is presented in Figure 5.3:

- **Pre-pilot trends:** TLHC pilot areas and comparison areas exhibit approximately the same volumes of white British lung cancers per 10,000 people in the target population. Likewise, similar volumes of non-white British lung cancers are exhibited in pilot and comparison areas. In both areas, the volume of lung cancers is almost 10 times higher among white British groups compared to non-white British groups.

- **Post pilot trends:** A notable increase in the number of lung cancer diagnoses within the white British group is seen in 2021, whilst no corresponding increase is seen in the non-white British group (or within both groups in the comparison areas). This suggests that the overall increase in lung cancers diagnosed associated with the introduction of the TLHC programme appears to be almost entirely driven by an increase in the number of diagnoses among those identifying as white British.

Figure 5.10: Number of lung cancer diagnoses per 10,000 people aged 55-76 who identify as white British or non-white British in intervention and comparison areas, 2016 to 2022



Vertical bar represents the 95% confidence interval.
Source: Ipsos analysis of National Cancer Registration Dataset. Sample size: intervention, n=537; comparison areas, n= 537.

Causal Impact Analysis

Table 5.9 below presents the regression outputs for the staggered difference-in-differences used to estimate the extent to which there were differential impacts between white British and non-white British groups within TLHC pilot areas compared to comparison areas.

Table 5.9: Estimated effect of the TLHC programme – relative impacts by ethnicity (statistically significant effects at the 95% confidence level highlighted in blue)

	Estimated number of additional lung cancers amongst white British groups relative to non-white British groups diagnosed per 10,000 people aged 55-76	Estimated number of additional lung cancers amongst white British groups relative to non- white British groups diagnosed at stage 1 or 2 per 10,000 people aged 55-76	Estimated number of additional lung cancers amongst white British groups relative to non-white British groups diagnosed at stage 3 or 4 per 10,000 people aged 55-76	Estimated number of additional lung cancers amongst white British groups relative to non-white British groups not staged at diagnosis diagnosed per 10,000 people aged 55-76	Estimated number of additional deaths whose primary cause of death was due to lung cancer amongst white British groups relative to non-white British groups per 10,000 people aged 55-76
	Coefficient (Standard error) [95% confidence interval]	Coefficient (Standard error) [95% confidence interval]	Coefficient (Standard error) [95% confidence interval]	Coefficient (Standard error) [95% confidence interval]	Coefficient (Standard error) [95% confidence interval]
Sample size	n=7,252	n=7,252	n=7,252	n=7,252	n=7,252
Pre-intervention period 4	1.094 (1.169) [-1.198 - 3.387]	0.017 (0.799) [-1.548 - 1.582]	-0.569 (0.699) [-1.94 - 0.801]	-0.682 (1.233) [-3.099 - 1.734]	-1.874* (1.117) [-4.063 - 0.316]
Pre-intervention period 3	2.236** (1.127) [0.026 - 4.445]	-0.623 (0.659) [-1.914 - 0.668]	0.677 (0.707) [-0.708 - 2.062]	-0.472 (1.722) [-3.847 - 2.902]	4.078*** (1.01) [2.098 - 6.057]
Pre-intervention period 2	-1.682* (0.938) [-3.521 - 0.157]	0.013 (0.58) [-1.123 - 1.15]	-1.276** (0.538) [-2.332 - -0.221]	0.418 (1.042) [-1.624 - 2.461]	-2.259*** (0.855) [-3.934 - -0.583]
Pre-intervention period 1	-0.043 (0.878) [-1.765 - 1.678]	-0.186 (0.55) [-1.265 - 0.893]	0.722 (0.541) [-0.337 - 1.782]	-0.097 (0.944) [-1.946 - 1.753]	1.372* (0.833) [-0.261 - 3.005]
Post-intervention period 0	3.012*** (0.914) [1.222 - 4.803]	1.394** (0.58) [0.257 - 2.53]	1.148** (0.55) [0.07 - 2.227]	0.189 (1.094) [-1.955 - 2.333]	-0.372 (0.816) [-1.972 - 1.227]
Post-intervention period 1	5.59*** (0.884) [3.857 - 7.322]	3.534*** (0.715) [2.132 - 4.935]	1.77*** (0.597) [0.601 - 2.939]	1.301 (1.206) [-1.062 - 3.665]	0.251 (0.806) [-1.33 - 1.832]

Post-intervention period 2	4.651*** (1.414) [1.88 - 7.422]	2.284** (1.001) [0.323 - 4.246]	0.711 (0.879) [-1.012 - 2.434]	1.112 (1.946) [-2.702 - 4.926]	0.427 (1.26) [-2.043 - 2.897]
Post-intervention period 3	0.87 (1.561) [-2.19 - 3.93]	2.541** (1.158) [0.271 - 4.811]	0.236 (1.034) [-1.791 - 2.262]	1.064 (1.829) [-2.521 - 4.649]	0.327 (1.369) [-2.357 - 3.011]
Average impact over first four post-intervention periods	3.933*** (0.745) [2.473 - 5.394]	2.496*** (0.491) [1.534 - 3.458]	1.2** (0.482) [0.255 - 2.145]	0.823 (0.769) [-0.684 - 2.331]	0.059 (0.69) [-1.292 - 1.411]

*** represents statistically significant difference at the 99% confidence level; ** represents statistically significant at the 95% confidence level; * represents statistically significant at the 90% confidence level, based on asymptotic standard errors clustered at the MSOA level.
Note: Rows with amber text indicate that the null hypothesis has been rejected at the 90% confidence level, providing weak evidence that the parallel trends assumption has been violated; Rows with red text indicate that the parallel trend assumption has been violated at the 95% confidence level.
Estimated using Callaway and Sant'anna (2021) doubly robust estimator. Number of observations = 7,252.
Source: Ipsos analysis of National Cancer Registration Dataset and ONS Civil Registration – Deaths.

The sub-group analysis shows that the number of lung cancers increased more in white British groups compared to non-white British groups:

- The analysis estimates that there was an increase in 3.9 lung cancers diagnosed in white British groups relative to non-white British groups in TLHC pilot areas, statistically significant at the 99% confidence level. The analysis indicates that the lung cancers diagnosed were found at an early stage as well as at a later stage. Triangulation of the results of the DiD and the descriptive analysis in Figure 5.9 suggests that the impacts of the programme were predominantly concentrated amongst those identifying as white British (as opposed to other ethnic groups).[72]

- There is weak evidence to suggest that the parallel trends assumption is violated when looking at overall lung caner diagnoses, and diagnoses at stage 3 and 4. However, the findings align with the findings when looking at differential impacts for stage 1 and 2 (where the parallel trends assumption is not violated).

- This result is partly explained by differences in the prevalence of lung cancer across the two groups (non-white ethnic minority groups display a lower lung cancer incidence rate compared to those that are white-British[73], while Arnold *et al.* (2010) suggest that those that identify as white British are more likely to engage in unhealthy behaviours such as smoking, poor diet and carrying excess bodyweight[74]). Additionally, those that identify as white British exhibit greater LHC uptake rates compared to those that identify as non-white British (64% compares to 31%), suggesting greater engagement with the TLHC pilots (Section 6.9.5 in the Main Report). Section 6.9.5 of the Main Report also identifies that lung cancer conversion is higher for those that are white (1.73%) compared to those that are not white (0.68%). This therefore raises some questions as to how all groups of the target population can be effectively engaged.

5.5.4 Age

Descriptive trends

Figure 8.1 shows trends in the number of lung cancers diagnosed per 10,000 people aged 55 to 76 for intervention MSOAs and matched comparison areas between 2016 and 2022:

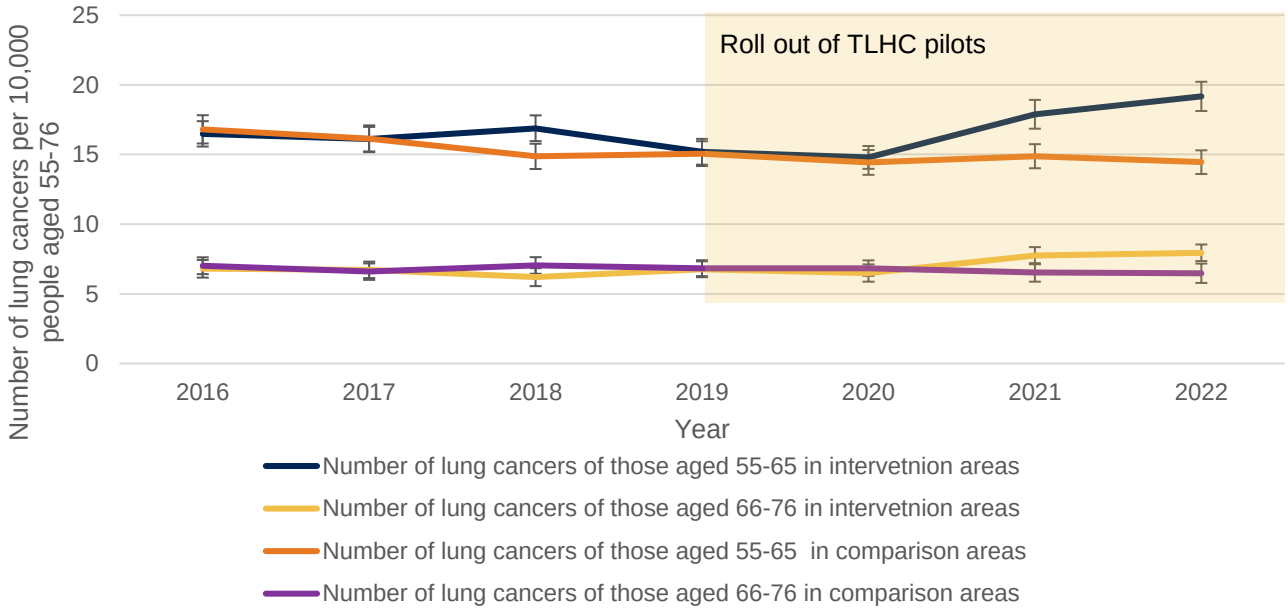
Trends for those aged 55-65: In the pre-intervention periods, TLHC pilot and comparison areas exhibit broadly similar volumes of lung cancers among those aged 55-65. This trend persists until 2021 where there is a small increase of approximately 1 lung cancer diagnosis per 10,000 in TLHC pilot areas, and no corresponding increase seen in comparison areas

Trends for those aged 66-76: Similar volumes of lung cancer diagnoses were observed in 2016 and 2017, however there is a divergence in trend in 2018. Volumes return to similar levels in 2019 and 2020 before an increase in diagnosis volumes is seen in TLHC pilot areas and no corresponding increase observed in comparison areas.

[72] A binary white British, non-white British classification was adopted as more granular ethnic classifications of the non-white British group contained a significant amount of zero values. Therefore other ethnic groups were pooled together to create a 'non-white British group'
[73] Delon, C. *et al.* (2022) Differences in cancer incidence by broad ethnic group in England, 2013 – 2017. *British Journal of Cancer*, 126, 1765 – 1773. [accessed: 30/05/2024]
[74] Arnold. M., Razum. O. and Coebergh, J.W. (2010) Cancer risk diversity in non-western migrants to Europe: An overview of the literature, *European Journal of Cancer*, 46,14,2647-2659. [accessed: 30/05/2024].

The descriptive evidence suggests that the number of lung cancers grew faster among those aged 66-76 compared to those aged 55-65.

Figure 5.11: Number of lung cancer diagnoses per 10,000 people aged 55-65 and 66-76 in intervention and comparison areas, 2016 to 2022



Vertical bar represents the 95% confidence interval.
Source: Ipsos analysis of National Cancer Registration Dataset. Sample size: intervention, n=537; comparison areas, n= 537.

Causal Impact Analysis

Table 5.10 below presents the regression outputs for the staggered difference-in-differences used to estimate the extent to which there were differential impacts between those aged 66-76 and those aged 55-65 within TLHC pilot areas compared to comparison areas.

Table 5.10: Estimated effect of the TLHC programme – relative impacts by age (statistically significant effects at the 95% confidence level highlighted in blue)

	Estimated number of additional lung cancers diagnosed amongst those aged 66-76 relative to those aged 55-65	**Estimated number of additional lung cancers diagnosed at stage 1 or 2 amongst those aged 66-76 relative to those aged 55-65**	**Estimated number of additional lung cancers diagnosed at stage 3 or 4 amongst those aged 66-76 relative to those aged 55-65**	**Estimated number of additional lung cancers not staged at diagnosis amongst those aged 66-76 relative to those aged 55-65**	**Estimated number of additional deaths whose primary cause of death was due to lung cancer amongst those aged 66-76 relative to those aged 55-65**
	Coefficient (Standard error) [95% confidence interval]	Coefficient (Standard error) [95% confidence interval]	Coefficient (Standard error) [95% confidence interval]	Coefficient (Standard error) [95% confidence interval]	Coefficient (Standard error) [95% confidence interval]
Sample size	n=7,252	n=7,252	n=7,252	n=7,252	n=7,252
Pre-intervention period 4	-0.769 (1.19) [-3.102 - 1.563]	-0.375 (0.765) [-1.875 - 1.126]	-1.007 (0.674) [-2.329 - 0.314]	0.011 (1.277) [-2.492 - 2.513]	-0.312 (1.079) [-2.426 - 1.803]
Pre-intervention period 3	4.491*** (1.13) [2.277 - 6.706]	1.213* (0.719) [-0.197 - 2.622]	1.051* (0.617) [-0.158 - 2.26]	0.718 (1.751) [-2.713 - 4.15]	2.293** (1.089) [0.159 - 4.427]
Pre-intervention period 2	-2.464*** (0.914) [-4.256 - -0.672]	-0.167 (0.617) [-1.375 - 1.042]	-0.297 (0.489) [-1.255 - 0.661]	-0.502 (0.885) [-2.237 - 1.233]	0.121 (0.907) [-1.656 - 1.898]
Pre-intervention period 1	0.559 (0.839) [-1.085 - 2.202]	-0.148 (0.582) [-1.288 - 0.993]	0.269 (0.486) [-0.683 - 1.222]	0.257 (0.869) [-1.446 - 1.96]	-0.649 (0.902) [-2.416 - 1.118]
Post-intervention period 0	0.554 (0.863) [-1.137 - 2.246]	0.281 (0.527) [-0.752 - 1.313]	0.292 (0.517) [-0.722 - 1.306]	-1.124 (1.052) [-3.185 - 0.938]	1.495* (0.901) [-0.272 - 3.262]
Post-intervention period 1	2.562*** (0.827) [0.94 - 4.183]	2.104*** (0.696) [0.74 - 3.468]	0.171 (0.538) [-0.883 - 1.226]	0.95 (0.995) [-1 - 2.9]	-0.427 (0.821) [-2.037 - 1.183]

Post-intervention period 2	1.562 (1.387) [-1.158 - 4.281]	1.988* (1.089) [-0.147 - 4.123]	-0.178 (0.784) [-1.714 - 1.359]	1.981 (1.621) [-1.197 - 5.159]	0.109 (1.379) [-2.593 - 2.811]
Post-intervention period 3	1.276 (1.498) [-1.659 - 4.212]	1.555 (1.186) [-0.769 - 3.879]	-0.073 (1.048) [-2.128 - 1.981]	4.054** (1.926) [0.278 - 7.829]	-0.869 (1.512) [-3.832 - 2.094]
Average impact over first four post-intervention periods	1.53** (0.72) [0.118 - 2.942]	1.398*** (0.504) [0.41 - 2.386]	0.134 (0.437) [-0.723 - 0.991]	0.503 (0.725) [-0.918 - 1.925]	0.293 (0.756) [-1.188 - 1.775]

*** represents statistically significant difference at the 99% confidence level; ** represents statistically significant at the 95% confidence level; * represents statistically significant at the 90% confidence level, based on asymptotic standard errors clustered at the MSOA level.
Note: Rows with amber text indicate that the null hypothesis has been rejected at the 90% confidence level, providing weak evidence that the parallel trends assumption has been violated; Rows with red text indicate that the parallel trend assumption has been violated at the 95% confidence level.
Estimated using Callaway and Sant'anna (2021) doubly robust estimator. Number of observations = 7,252.
Source: Ipsos analysis of National Cancer Registration Dataset and ONS Civil Registration – Deaths.

The sub-group analysis shows that the number of lung cancers diagnosed at an earlier stage increased more in those aged 66-76 compared to those aged 55-65 in TLHC pilot areas:

- The findings indicated that the introduction of the TLHC programme led to the diagnosis of 1.4 more lung cancers at stage 1 or 2 per 10,000 individuals amongst those aged 66-76 than amongst those aged 55-65, statistically significant at the 99% confidence level. This result is likely to reflect higher rates of prevalence amongst older populations.[75]

- A statistically significant increase in the number of non-staged lung cancers of those aged 66-76 relative to 55-65 is observed in the final post intervention period. This effect is not observed in periods prior to this.

- The total volume of lung cancers (column two of Table 5.10) grew fast among those aged 66-76 relative to 55-65. However the parallel trends outcome is violated for this outcome, meaning differences cannot be confidently attributed to TLHC.

5.5.5 Level of Deprivation

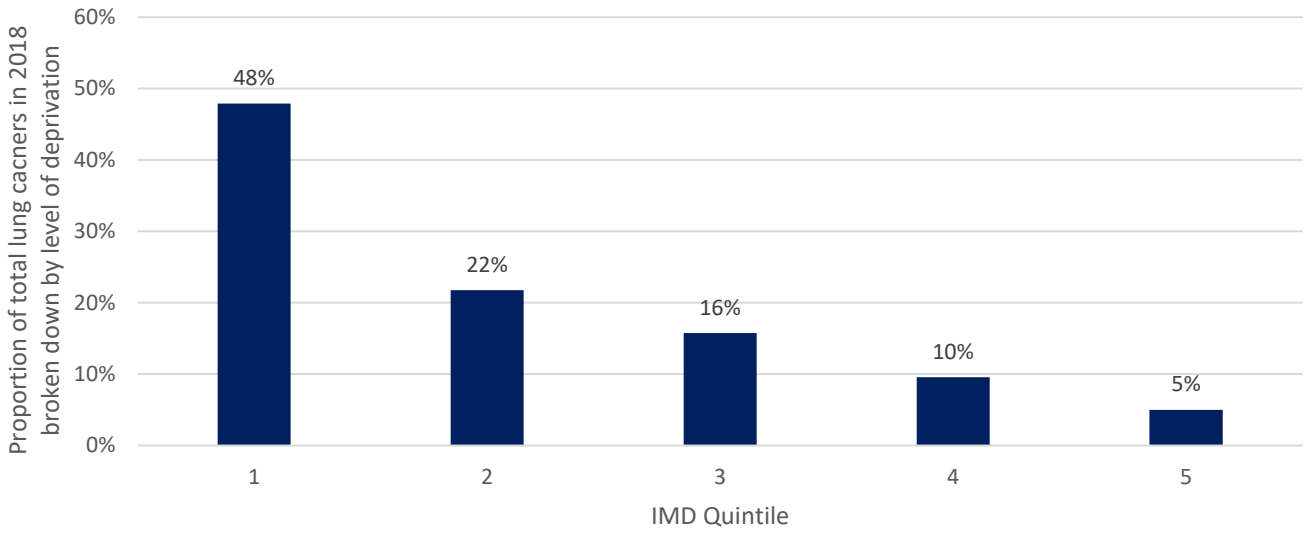
Descriptive trends

Within the TLHC intervention areas, just under half of individuals with lung cancer lived in the most deprived areas (IMD quintile 1) (see Figure 5.12).[76] For the purposes of this analysis, the outcomes of those in IMD quintiles 2-5 are compared with those in IMD quintile 1 to understand the extent of the differential effects across these two groups.

[75] Di Girolamo.C *et al*. (2018) Characteristics of patients with missing information on stage: a population based study of patients diagnosed with colon, lung or breast cancer in England in 2013, *BMC Cancer*, 18,482. [Accessed 31/05/2024)

[76] Noting that the TLHC programme specifically targeted more deprived areas.

Figure 5.12: Proportion of total lung cancers of those aged 55-76 within TLHC intervention areas in 2018 broken down by IMD quintile.



IMD quintile 1 = most deprived areas; IMD quintile 5 = least deprived areas.

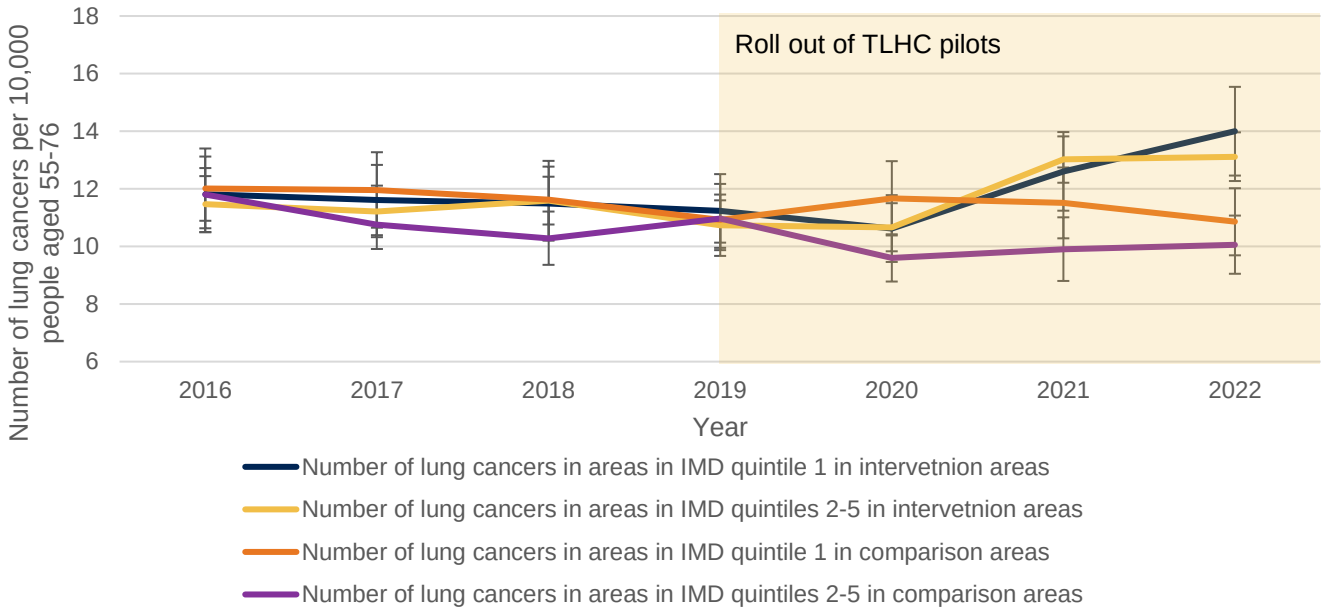
Source: Ipsos analysis of National Cancer Registration Dataset. Sample size, n=537 intervention areas; The incidence rate was computed as the number of individuals in the target population (55 to 76 years old) receiving a lung cancer diagnosis divided by the total number of individuals in the target population (55 to 76 years old).

Figure 5.13 below presents differences in the number of lung cancer diagnoses per 10,000 in the eligible population, split by areas in IMD quintile 1 and quintiles 2-5 for both TLHC intervention areas and non-intervention areas:

- **TLHC pilot areas:** The volumes of lung cancers diagnosed in areas in IMD quintile 1 and quintiles 2-5 are broadly similar across the evaluation period. An increase in the volume of diagnoses is seen in 2020, with both groups exhibiting increases of approximately the same magnitude, suggesting TLHC was equally effective cross the two groups.

- **Matched comparison areas:** across the pre-intervention periods, more deprived areas typically exhibit greater volumes of lung cancer compared to less deprived areas. From 2020, the volumes begin to converge: driven by small increases in diagnostic volumes in areas in IMD quintile 2-5, and small decreases in diagnostic volumes in areas in IMD quintile 1.

Figure 5.13: Number of lung cancer diagnoses per 10,000 people aged 55-76 in IMD quintile 1 and quintiles 2-5 in intervention and comparison areas, 2016 to 2022



Vertical bar represents the 95% confidence interval.
Source: Ipsos analysis of National Cancer Registration Dataset. Sample size: intervention, n=537; comparison areas, n= 537.

Causal Impact Analysis

Table 5.11 below presents the regression outputs for the staggered difference-in-differences used to estimate the extent to which there were differential impacts between areas in IMD quintile 1 and quintiles 2-5, in TLHC pilot areas compared to comparison areas.

Table 5.11: Estimated effect of the TLHC programme – relative impacts by IMD quintile (statistically significant effects at the 95% confidence level highlighted in blue)

	Estimated number of additional lung cancers amongst areas in IMD quintile 1 relative to areas in IMD quintile 2-5 diagnosed per 10,000 people aged 55-76	**Estimated number of additional lung cancers amongst areas in IMD quintile 1 relative to areas in IMD quintile 2-5 diagnosed at stage 1 or 2 per 10,000 people aged 55-76**	**Estimated number of additional lung cancers amongst areas in IMD quintile 1 relative to areas in IMD quintile 2-5 diagnosed at stage 3 or 4 per 10,000 people aged 55-76**	**Estimated number of additional lung cancers areas in IMD quintile 1 relative to areas in IMD quintile 2-5 not staged at diagnosis diagnosed per 10,000 people aged 55-76**	**Estimated number of additional deaths whose primary cause of death was due to lung cancer amongst areas in IMD quintile 1 relative to areas in IMD quintile 2-5 per 10,000 people aged 55-76**
	Coefficient (Standard error) [95% confidence interval]	Coefficient (Standard error) [95% confidence interval]	Coefficient (Standard error) [95% confidence interval]	Coefficient (Standard error) [95% confidence interval]	Coefficient (Standard error) [95% confidence interval]
Sample size	n=7,252	n=7,252	n=7,252	n=7,252	n=7,252
Pre-intervention period 4	0.934 (1.16) [-1.339 - 3.208]	-0.736 (0.791) [-2.286 - 0.814]	0.114 (0.702) [-1.262 - 1.489]	-1.165 (1.325) [-3.762 - 1.433]	-0.447 (1.092) [-2.587 - 1.693]
Pre-intervention period 3	0.043 (1.136) [-2.183 - 2.269]	0.096 (0.655) [-1.188 - 1.38]	0.209 (0.71) [-1.182 - 1.6]	-0.423 (1.429) [-3.225 - 2.378]	-0.236 (1.036) [-2.267 - 1.794]
Pre-intervention period 2	-1.336 (0.891) [-3.083 - 0.41]	-1.143** (0.57) [-2.261 - -0.025]	-0.057 (0.519) [-1.074 - 0.959]	-0.268 (0.927) [-2.084 - 1.549]	-0.873 (0.877) [-2.592 - 0.846]
Pre-intervention period 1	1.906** (0.85) [0.24 - 3.572]	-0.098 (0.575) [-1.226 - 1.029]	-0.039 (0.518) [-1.053 - 0.976]	0.072 (0.856) [-1.605 - 1.749]	1.445* (0.867) [-0.254 - 3.145]
Post-intervention period 0	-1.088 (0.895) [-2.842 - 0.666]	0.759 (0.603) [-0.423 - 1.942]	0.121 (0.543) [-0.943 - 1.184]	-1.357 (0.871) [-3.065 - 0.351]	1.404* (0.845) [-0.253 - 3.061]

Post-intervention period 1	-1.496* (0.886) [-3.233 - 0.242]	1.173 (0.768) [-0.332 - 2.677]	-0.136 (0.626) [-1.364 - 1.091]	0.212 (0.897) [-1.547 - 1.97]	-1.358* (0.754) [-2.835 - 0.12]
Post-intervention period 2	1.359 (1.464) [-1.51 - 4.228]	2.282** (1.081) [0.164 - 4.401]	0.288 (0.937) [-1.549 - 2.125]	-0.11 (1.524) [-3.098 - 2.878]	-0.294 (1.238) [-2.72 - 2.132]
Post-intervention period 3	-1.065 (1.414) [-3.836 - 1.706]	-0.348 (1.289) [-2.875 - 2.179]	-0.54 (0.974) [-2.448 - 1.368]	-2.993 (2.236) [-7.376 - 1.39]	0.907 (1.302) [-1.645 - 3.46]
Average impact over first four post-intervention periods	-0.887 (0.753) [-2.364 - 0.59]	0.986* (0.541) [-0.074 - 2.046]	-0.032 (0.49) [-0.993 - 0.928]	-0.668 (0.653) [-1.948 - 0.611]	0.083 (0.675) [-1.24 - 1.406]

*** represents statistically significant difference at the 99% confidence level; ** represents statistically significant at the 95% confidence level; * represents statistically significant at the 90% confidence level, based on asymptotic standard errors clustered at the MSOA level.
Note: Rows with amber text indicate that the null hypothesis has been rejected at the 90% confidence level, providing weak evidence that the parallel trends assumption has been violated; Rows with red text indicate that the parallel trend assumption has been violated at the 95% confidence level.
Estimated using Callaway and Sant'anna (2021) doubly robust estimator. Number of observations = 7,252.
Source: Ipsos analysis of National Cancer Registration Dataset and ONS Civil Registration – Deaths.

5.6 Robustness Checks

This section presents the robustness checks for the PSM-DiD analysis. The purpose of these checks are to validate the reliability of the impact evaluation findings and ensure that findings are not a product of model specification or wider systematic changes simultaneously occurring. This crucial step reinforces the robustness of the results, instilling greater confidence that the impacts identified in Section 4 can be attributed to the TLHC programme.

Within this section of the report, robustness checks are undertaken on the main outcomes of interest: the number of lung cancers diagnosed in those aged 55-76 (including stage at diagnosis) and the number of deaths due to lung cancer in those aged 55-76; as well as instances in the sub-group analysis where statistically significant results are identified.

This section utilises regression tables, opposed to event study charts to better convey statistical significance of the variables of interest.

5.6.1 Key Findings

Overall, the robustness checks provide additional confidence in the validity of the PSM-DiD analysis, helping to strengthen the claims that the observed impacts can be attributed to the TLHC programme.

Placebo tests were utilised to understand whether there are wider systematic changes in the intervention areas which may have instead been driving changes in outcome variables. The Placebo tests failed to identify statistically significant impacts on the non-eligible population (40-54 year olds). Providing more certainty that the TLHC programme caused the observed impacts.

Analysis was also undertaken to understand the validity of the definition of the MSOAs within the CCGs which partially rolled out the TLHC programme. Separate PSM-DID analyses were ran for i) full intervention areas, and ii) partial intervention areas. The results indicated that there were not drastic differences in the estimated impacts between full and partial intervention areas. This therefore suggests that the classification of MSOAs that made up the CCGs where TLHC was partially rolled out (in which some Phase 2 projects did not have patient level data) did not induce spurious results of threaten the robustness of the analysis.

5.6.2 Placebo tests

Methodology

A placebo test applies the staggered DiD methodology to a group of individuals who were not eligible to participate in the TLHC programme, i.e. 40-54 year old who were below the minimum age required to be invited for a LHC.

Initially the matched comparison areas from the main analysis were used, however several outcomes failed the parallel trends tests, suggesting that meaningful inference could not be made from the results.

To overcome this, a new matched sample was selected, replacing outcomes for those aged 55-76 with outcomes for those aged 40-54 in the matching variables used. This better enabled a selection of MSOAs that shared similar characteristics before the introduction of TLHC in the MSOAs. Despite not utilising the original matched sample, this will still in principle provide a credible assessment of the causal impact analysis undertaken as the TLHC intervention areas are the same.

It would be expected that there are no statistically significant effects detected across outcome measures. The identification of statistically significant effects may suggest that there are wider systematic changes within the TLHC intervention areas that could be inducing a change in the outcomes - where this could have inadvertently been attributed to the TLHC programmes in the main analysis.

Results

The results of the placebo tests for the main outcomes of interest are presented below.

Table 5.12: Placebo Tests – estimated differences in key outcomes between TLHC intervention and comparison areas

	Additional number of lung cancers diagnosed among those aged 40-54	Additional number of lung cancers diagnosed at stage 1 or 2 among those aged 40-54	Additional number of lung cancers diagnosed at stage 3 or 4 among those aged 40-54	Additional number of lung cancers not staged at diagnosis among those aged 40-54	Additional number of deaths whose primary cause of death was due to lung cancer among those age 40-54
	Coefficient (Standard error) [95% confidence interval]	Coefficient (Standard error) [95% confidence interval]	Coefficient (Standard error) [95% confidence interval]	Coefficient (Standard error) [95% confidence interval]	Coefficient (Standard error) [95% confidence interval]
Sample size	n=7,252	n=7,252	n=7,252	n=7,252	n=7,252
Pre-intervention period 4	0.068 (0.283) [-0.818 – 0.953]	-0.115 (0.176) [-0.461 – 0.230]	0.118 (0.393) [-0.652 – 0.887]	0.039 (0.119) [-0.193 – 0.272]	0.594* (0.324) [-0.040 – 1.228]
Pre-intervention period 3	-0.331 (0.452) [-1.152 – 0.491]	-0.155 (0.182) [-0.511 – 0.202]	-0.209 (0.346) [-0.888 – 0.470]	0.069 (0.099) [-0.126 – 0.264]	-0.124 (0.270) [-0.653 – 0.404]
Pre-intervention period 2	0.417 (0.339) [-0.248 – 1.082]	0.187 (0.152) [-0.111 – 0.484]	0.169 (0.287) [-0.393 – 0.732]	0.040 (0.096) [-0.149 – 0.229]	-0.152 (0.210) [-0.563 – 0.259]
Pre-intervention period 1	-0.165 (0.354) [-0.859 – 0.528]	-0.117 (0.156) [-0.423 – 0.189]	0.094 (0.303) [-0.500 – 0.688]	-0.116 (0.095) [-0.303 – 0.071]	-0.094 (0.207) [-0.500 – 0.313]
Post-intervention period 0	-0.044 (0.345) [-0.720 – 0.633]	-0.039 (0.145) [-0.323 – 0.245]	-0.034 (0.302) [-0.626 – 0.558]	0.031 (0.103) [-0.171 – 0.233]	0.122 (0.201) [-0.272 – 0.516]
Post-intervention period 1	-0.013 (0.304) [-0.609 – 0.584]	0.113 (0.144) [-0.168 – 0.395	-0.195 (0.253) [-0.690 – 0.301]	0.091 (0.102) [-0.109 – 0.290]	0.240 (0.180) [-0.113 – 0.593]
Post-intervention period 2	-0.466 (0.510) [-1.466 – 0.533]	0.086 (0.270) [-0.444 – 0.615]	-0.462 (0.416) [-1.279 – 0.354]	-0.101 (0.168) [-0.430 – 0.228]	-0.098 (0.323) [-0.731 – 0.535]

Post-intervention period 3	-0.189 (0.527) [-1.222 – 0.845]	-0.029 (0.242) [-0.503 – 0.444]	-0.050 (0.439) [-0.909 – 0.810]	-0.113 (0.172) [-0.449 – 0.224]	0.010 (0.317) [-0.610 – 0.631]
Average impact over first four post-intervention periods	-0.111 (0.283) [-0.666 – 0.455]	0.035 (0.138) [-0.235 – 0.306]	-0.155 (0.240) [-0.626 – 0.315]	0.016 (0.084) [-0.149 – 0.181]	0.120 (0.166) [-0.205 – 0.445]

Note: *** denotes statistical significance at the 99% confidence level; ** denotes statistical significance at the 95% confidence level; and * denotes statistical significance at the 90% confidence level, based on asymptotic standard errors clustered at the MSOA level. Asymptotic standard error presented under central estimate in parentheses. Amber text indicates the parallel trend assumption is violated at the 90% confidence level; Red text indicates that there is evidence to suggest that parallel trends assumption does not hold at the 95% confidence level.

The placebo analysis presents no evidence that undermines the credibility of the main impact evaluation results presented in Section 4. Across all five outcomes measures, all post-intervention periods (as well as the average impact across all post-intervention periods) exhibit statistically insignificant effects. This suggests that there are no statistical differences in outcomes measures between TLHC intervention areas and the comparison areas for those aged 40-54. This therefore increases the confidence in which the observed impacts can be attributed to the TLHC programme.

Placebo tests are also undertaken in instances where the sub-group analysis yielded statistically significant results at the 95% confidence level. Given the placebo tests use age as the definition of the non-target group, it was not possible to perform sensitivity analysis on the finding that the number of non-staged lung cancers increased more among those aged 66-76 than 55-65 in TLHC intervention areas. The results are presented in Table 5.13 below.

Table 5.13: Placebo tests - estimated differential in key outcomes by sub-groups between TLHC intervention and comparison areas

	Estimated differences in the number of lung cancers diagnosed per 10,000 between those that identify as white British and those that identify as non-white British, aged 55-76, between TLHC intervention and comparison areas	Estimated differences in the number of lung cancers diagnosed at stage 1 or 2 per 10,000 between those that identify as white British and those that identify as non-white British, aged 55-76, between TLHC intervention and comparison areas	Estimated differences in the number of lung cancers diagnosed at stage 3 or 4 per 10,000 between those that identify as white British and those that identify as non-white British, aged 55-76, between TLHC intervention and comparison areas
	Coefficient (Standard error) [95% confidence interval]	Coefficient (Standard error) [95% confidence interval]	Coefficient (Standard error) [95% confidence interval]
Sample size	n=7,252	n=7,252	n=7,252
Pre-intervention period 4	-0.168 (2.175) [-4.432 – 4.096]	4.699*** (1.780) [1.210 – 8.188]	-0.734 (1.901) [-4.459 – 2.991]
Pre-intervention period 3	3.595** (1.734) [0.196 – 6.994]	Coefficient not estimated	1.477 (1.979) [-2.402 – 5.355]
Pre-intervention period 2	-1.422 (1.430) [-4.226 – 1.381]	-2.781 (6.923) [-16.349 – 10.787]	-0.635 (1.408) [-3.395 – 2.124]
Pre-intervention period 1	0.118 (1.243) [-2.320 – 2.555]	-9.868*** (1.245) [-12.308 - -7.427]	-1.386 (1.334) [-3.999 – 1.228]
Post-intervention period 0	-1.345 (1.413) [-4.114 – 1.424]	-5.962** (2.657) [-11.169 – 5.936]	0.953 (1.278) [-1.552 – 3.458]
Post-intervention period 1	-1.783 (1.422) [-4.570 – 1.004]	-0.270 (3.167) [-6.477 – 5.936]	-1.813 (1.930) [-5.597 – 1.971]
Post-intervention period 2	-0.624	-0.710	2.887

	(1.504) [-3.573 – 2.325]	(5.748) [-11.977 – 10.556]	(2.204) [-1.432 – 7.206]
Post-intervention period 3	0.704 (2.648) [-4.486 – 5.893]	Coefficient not estimated	0.460 (2.863) [-5.151 – 6.070]
Average impact over first four post-intervention periods	-1.143 (0.941) [-2.987 – 0.701]	-1.147 (2.942) [-6.914 – 4.620]	0.043 (1.709) [-2.073 – 2.158]

Note: *** denotes statistical significance at the 99% confidence level; ** denotes statistical significance at the 95% confidence level; and * denotes statistical significance at the 90% confidence level, based on asymptotic standard errors clustered at the MSOA level. Asymptotic standard error presented under central estimate in parentheses.
Red values indicate that there is evidence to suggest that parallel trends assumption does not hold at the 99% confidence level.

The results suggest that:

- **There is little evidence to undermine the credibility of the impact evaluation results presented in Section 4**. Across the placebo outcomes, there are no statistically significant effects detected across the outcomes – suggesting that the differentials across the sub-groups of ineligible populations remained relatively stable between TLHC-intervention and comparison areas. This provides supporting evidence that the change in impacts observed in Section 5 can be attributed to TLHC.

  However, it should be noted that the parallel trends assumption is violated for across two of the placebo tests. This suggests that there may be underlying differences between the two areas causing a difference in trend over time in the absence of the TLHC programme. However, the lack of statistically significant effect is nonetheless a reassuring sign that there no significant changes in outcome measures over time for groups not eligible for the TLHC programme.

5.6.3 Assessing the definition of the intervention areas

As discussed in Section 2, the TLHC intervention areas were defined using the following rules:

- **For CCGs where TLHC was fully rolled out:** Any MSOA within a fully participating CCG in which all GP practices were able to invite patients.

- **For CCGs where TLHC was partially rolled out:** Information on GP practices that invited patients was used to determine which parts of the CCGs were participating or not. The assumption here is to consider the MSOA of the GP practice as part of the intervention if at least one patient attended a lung health check (noting that patients invited to the checks might not live in the same MSOA of the GP practice).

Given that patient-level data was only available for Phase 1 and a subset of Phase 2 projects, it was not possible to precisely identify the MSOAs within the CCGs in phase 2 which partially rolled out the TLHC programme.

The remainder of this Section seeks to understand the extent to which the uncertainty in definition of these partial intervention areas in Phase 2 poses a risk to the robustness of the analysis.

Methodology

The analysis follows the overarching PSM-DiD approach. To undertake this sensitivity analysis, the analysis was ran twice: Once using only MSOAs from CCGs which fully engaged with the TLHC programme; and once using only MSOAs from CCGs which partially engaged with the TLHC programme. Comparisons between the two model outputs can then be made to understand how the TLHC programme changes with the definition of the intervention areas.

Results

The results are presented in the following tables. The first table restricts the intervention group to areas that fully rolled out TLHC, whilst the second table restricts the intervention group to areas which partially rolled out TLHC.

Table 5.14: Estimated differences in key outcomes between full intervention areas and comparison areas (statistically significant effects at the 95% confidence level highlighted in blue)

	Additional number of lung cancers diagnosed among those aged 55-76 in full intervention areas	Additional number of lung cancers diagnosed at stage 1 or 2 among those aged 55-76 in full intervention areas	Additional number of lung cancers diagnosed at stage 3 or 4 among those aged 55-76 in full intervention areas	Additional number of lung cancers not staged at diagnosis among those aged 55-76 in full intervention areas	Additional number of deaths whose primary cause of death was due to lung cancer among those age 55-76 in full intervention areas
	Coefficient (Standard error) [95% confidence interval]	Coefficient (Standard error) [95% confidence interval]	Coefficient (Standard error) [95% confidence interval]	Coefficient (Standard error) [95% confidence interval]	Coefficient (Standard error) [95% confidence interval]
Sample size	n=6,146	n=6,146	n=6,146	n=6,146	n=6,146
Pre-intervention period 4	1.163 (1.257) [-1.301 - 3.627]	0.060 (0.629) [-1.173 - 1.294]	0.392 (1.019) [-1.606 - 2.390]	0.502 (0.374) [-0.231 - 1.236]	-0.231 (1.086) [-2.359 - 1.897]
Pre-intervention period 3	2.151* (1.213) [-0.226 - 4.528]	0.965 (0.632) [-0.273 - 2.203]	1.356 (0.962) [-0.529 - 3.241]	0.000 (0.353) [-0.691 - 0.691]	1.941* (1.02) [-0.058 - 3.94]
Pre-intervention period 2	-1.518 (0.984) [-3.446 - 0.41]	-0.940* (0.516) [-1.951 - 0.071]	-0.509 (0.763) [-2.003 - 0.986]	-0.148 (0.28) [-0.698 - 0.401]	0.035 (0.808) [-1.55 - 1.619]
Pre-intervention period 1	-0.217 (0.946) [-2.071 - 1.638]	0.233 (0.458) [-0.664 - 1.13]	-0.474 (0.746) [-1.935 - 0.987]	0.196 (0.291) [-0.375 - 0.767]	-0.720 (0.801) [-2.291 - 0.85]
Post-intervention period 0	2.751*** (0.993) [0.805 - 4.698]	1.305*** (0.506) [0.314 - 2.296]	1.917** (0.772) [0.403 - 3.431]	-0.567* (0.294) [-1.143 - 0.01]	1.278 (0.798) [-0.286 - 2.842]
Post-intervention period 1	6.476*** (0.968) [4.578 - 8.373]	4.665*** (0.556) [3.576 - 5.754]	2.022*** (0.700) [0.65 - 3.394]	-0.338 (0.277) [-0.882 - 0.205]	1.368* (0.789) [-0.179 - 2.914]

Post-intervention period 2	5.821*** (1.587) [2.71 - 8.932]	5.536*** (1.025) [3.527 - 7.545]	0.865 (1.170) [-1.429 - 3.159]	-0.641 (0.413) [-1.451 - 0.169]	-1.086 (1.168) [-3.376 - 1.204]
Post-intervention period 3	4.149** (1.662) [0.893 - 7.406]	5.007*** (0.987) [3.072 - 6.942]	0.069 (1.224) [-2.331 - 2.469]	-1.153** (0.456) [-2.047 - -0.258]	-1.898 (1.380) [-4.603 - 0.808]
Average impact over first four post-intervention periods	4.733*** (0.807) [3.151 - 6.314]	3.630*** (0.427) [2.794 - 4.467]	1.555** (0.629) [0.322 - 2.789]	-0.572** (0.243) [-1.050 - -0.095]	0.541 (0.700) [-0.831 - 1.914]

*** represents statistically significant difference at the 99% confidence level; ** represents statistically significant at the 95% confidence level; * represents statistically significant at the 90% confidence level, based on asymptotic standard errors clustered at the MSOA level.
Note: Rows with amber text indicate that the null hypothesis has been rejected at the 90% confidence level, providing weak evidence that the parallel trends assumption has been violated; Rows with red text indicate that the parallel trend assumption has been violated at the 95% confidence level.
Estimated using Callaway and Sant'anna (2021) doubly robust estimator.
Source: Ipsos analysis of National Cancer Registration Dataset and ONS Civil Registration – Deaths.

Table 5.15: Estimated differences in key outcomes between partial intervention areas and comparison areas (statistically significant effects at the 95% confidence level highlighted in blue)

	Additional number of lung cancers diagnosed among those aged 55-76 in partial intervention areas	Additional number of lung cancers diagnosed at stage 1 or 2 among those aged 55-76 in partial intervention areas	Additional number of lung cancers diagnosed at stage 3 or 4 among those aged 55-76 in partial intervention areas	Additional number of lung cancers not staged at diagnosis among those aged 55-76 in partial intervention areas	Additional number of deaths whose primary cause of death was due to lung cancer among those age 55-76 in partial intervention areas
	Coefficient (Standard error) [95% confidence interval]	Coefficient (Standard error) [95% confidence interval]	Coefficient (Standard error) [95% confidence interval]	Coefficient (Standard error) [95% confidence interval]	Coefficient (Standard error) [95% confidence interval]
Sample size	n=4,732	n=4,732	n=4,732	n=4,732	n=4,732
Pre-intervention period 4	-0.094 (1.803) [-3.628 - 3.44]	-0.696 (0.854) [-2.369 - 0.978]	0.829 (1.399) [-1.913 - 3.571]	-0.21 (0.480) [-1.15 - 0.73]	-0.256 (1.589) [-3.37 - 2.858]
Pre-intervention period 3	2.078 (1.654) [-1.165 - 5.32]	1.539* (0.904) [-0.233 - 3.311]	0.271 (1.370) [-2.414 - 2.957]	0.194 (0.431) [-0.651 - 1.039]	1.794 (1.425) [-0.999 - 4.588]
Pre-intervention period 2	-1.488 (1.404) [-4.241 - 1.264]	-0.423 (0.707) [-1.809 - 0.963]	-0.947 (1.093) [-3.088 - 1.195]	0.016 (0.382) [-0.733 - 0.764]	-0.294 (1.219) [-2.684 - 2.095]
Pre-intervention period 1	0.984 (1.290) [-1.543 - 3.512]	0.567 (0.612) [-0.633 - 1.767]	1.192 (1.098) [-0.961 - 3.345]	-0.780** (0.378) [-1.52 - -0.04]	-1.120 (1.107) [-3.289 - 1.049]
Post-intervention period 0	2.239 (1.369) [-0.445 - 4.922]	0.236 (0.715) [-1.166 - 1.637]	1.206 (1.089) [-0.928 - 3.34]	0.484 (0.385) [-0.271 - 1.239]	0.393 (1.102) [-1.766 - 2.552]
Post-intervention period 1	5.921*** (1.394) [3.189 - 8.653]	4.256*** (0.869) [2.552 - 5.959]	0.465 (1.057) [-1.606 - 2.536]	1.200*** (0.424) [0.368 - 2.032]	0.539 (1.124) [-1.663 - 2.741]

Post-intervention period 2	3.86* (2.252) [-0.554 - 8.275]	-0.059 (1.032) [-2.083 - 1.964]	3.807** (1.655) [0.564 - 7.05]	-0.134 (0.517) [-1.147 - 0.879]	-0.357 (1.774) [-3.834 - 3.12]
Post-intervention period 3	2.002 (2.039) [-1.995 - 6]	0.322 (1.128) [-1.888 - 2.532]	-0.349 (1.642) [-3.568 - 2.87]	1.900** (0.789) [0.354 - 3.445]	2.916 (1.934) [-0.874 - 6.706]
Average impact over first four post-intervention periods	3.819*** (1.075) [1.711 - 5.927]	1.766*** (0.604) [0.581 - 2.95]	1.038 (0.863) [-0.654 - 2.73]	0.851*** (0.307) [0.25 - 1.452]	0.651 (0.925) [-1.163 - 2.464]

*** represents statistically significant difference at the 99% confidence level; ** represents statistically significant at the 95% confidence level; * represents statistically significant at the 90% confidence level, based on asymptotic standard errors clustered at the MSOA level.
Note: Rows with amber text indicate that the null hypothesis has been rejected at the 90% confidence level, providing weak evidence that the parallel trends assumption has been violated; Rows with red text indicate that the parallel trend assumption has been violated at the 95% confidence level.
Estimated using Callaway and Sant'anna (2021) doubly robust estimator.
Source: Ipsos analysis of National Cancer Registration Dataset and ONS Civil Registration – Deaths.

The above results tables suggest that:

- **More prominent effects are identified within CCGs which fully rolled out the TLHC programme.** In areas where CCGs fully rolled out the TLHC programme, more of the dynamic year-by year effects are statistically significant, and also of a greater magnitude compared to the areas where CCGs partially rolled out the TLHC programme.

- **The estimated impacts for both full and partial intervention CCGs provides reassurances that the approach to defining intervention and excluded areas was appropriate.** Despite seeing results of a smaller magnitude the results generally support the narrative of the core impact findings presented in Section 4 – particularly that the TLHC programme enabled the detection of additional lung cancers, including those at an earlier stage, which otherwise would have not happened.

  This therefore suggests that the classification of MSOAs that made up the CCGs where TLHC was partially rolled out (in which some Phase 2 projects did not have patient level data) did not induce spurious results or threaten the robustness of the analysis.

5.7 Rejected Design: Geographical Regression Discontinuity Design

The feasibility of a technically more robust Geographic Regression Discontinuity Design (GRDD) approach was also considered to complement the PSM-DiD analysis. However, imbalances in MSOAs either side of the CCG boundary suggested that this approach would not be able to produce unbiased estimates of the impact of the TLHC programme – so this design was ultimately rejected. The below sub-section sets out the feasibility analysis of the GRDD approach.

A Regression Discontinuity Design (RDD) exploits the fact that participation in an intervention or programme is determined based on the value of a 'score' or 'running variable', such that only observations above / below a given cut-off of the running variable are eligible to participate.

In the context of the TLHC programme, an RDD design could be applied by exploiting the geographical distribution of the intervention. As some CCGs were assigned to the programme, and some neighbouring CCGs were not, MSOAs on one side on the administrative boundary were included in the programme, whilst MSOAs on the other side of the administrative boundary were not included in the programme. The distance from the centroid of the MSOA to the CCG boundary could therefore be used as running variable, and the 2019 CCG administrative boundary as cut-off. This application is called Geographic Regression Discontinuity Design (GRDD).

A GRDD assumes that areas 'just inside' the project boundary (the 2019 CCG boundaries that define the intervention areas) could be considered similar in all aspects to areas 'just outside' the project boundary, except for their eligibility for the programme. A comparison of these two groups around the boundary would therefore provide an assessment of the impact of the project.

It is worth noting that results of an RDD are less generalisable than the ones from the PSM-DiD approach as they are estimated using observations around the boundary, which may differ from observations located further away from the boundary.

The main identifying assumption for the RDD design is the **continuity assumption**. This assumption states that at the cut-off, outcomes for TLHC intervention and comparison areas are assumed to have followed a continuous pattern in the absence of the intervention. An implication of this assumption is that observations around the cut-off should be found to be similar across important covariates determining

both selection into the TLHC programme and outcome of interest. To assess the validity of the continuity assumption, balance tests were undertaken, similar to those conducted for PSM, to assess the validity of the continuity assumption.

There are two main types of RDDs:

- A **sharp RDD** would be applicable if no patients outside the project boundaries invited for a LHC. In this case, the proportions of eligible patients invited in the programme would be zero outside the project boundary and would jump to one for all MSOAs within the project boundaries. In sharp RDDs, the geographic treatment assignment would perfectly correspond to being part of (i.e., invited to) the intervention. In other words, there would be *perfect compliance*.

- A fuzzy **RDD** accounts for *imperfect compliance* with participation in the intervention. In the TLHC context, imperfect compliance occured because patients outside intervention MSOAs were invited into the programme. In addition, not all patients within the boundaries were invited, resulting in the proportion of eligible patients invited to the programme not being equal to one. In a fuzzy RDD, it would be expected that intervention assignment would predict the proportion of invited patients imperfectly, i.e. a non-zero proportion of invited patients outside the project boundaries, and a much larger (although not equal to one) proportion inside the boundaries could be observed.

The contamination analysis (Section 5.3) has shown that there is a considerable degree of non-compliance around the intervention areas, which rules out a sharp RDD design. However, a fuzzy geographic RDD design is in principle possible if robust evidence can be found in support of its identifying assumptions.

As outlined at the beginning of the section, the GRDD would seek to estimate the ITT effects, i.e., the effect of intervention assignment on outcomes of interest. A fuzzy RDD estimates the ITT effect through the following equation:

$$Y_i = \alpha_i + \tau T_i + f(RV_i) + e_i \qquad (3)$$

Where Y_i is the outcome of interest for MSOA i; α is a constant; T_i is a dummy variable indicating assignment into the THLC programme (i.e., equal to 1 if an MSOA is inside a project boundary and 0 otherwise); RV_i is the distance between MSOA i's centroids and the project boundary; $f()$ an n-th order polynomial of the running variable; and e_i is the error term, which captures unexplained variability in the data that is not accounted for by the independent variables. The model can also be augmented to include year fixed effects and other covariates. The coefficient of interest in equation (3) is τ, the intention to treat effect.

5.7.1 Proportion of invited patients at both sides of the project boundaries

The feasibility analysis for understanding the validity of a Fuzzy GRDD requires inspecting whether there is a discontinuity in the proportion of eligible patients invited to the programme at each side of the project boundaries.

Figures 5.14 to 5.17 plot the proportion of the eligible population invited to TLHC against the distance from their respective MSOAs centroids to project boundaries. This is done for MSOAs within four different distances either side of the boundary: 10km, 5km, 3km and 1km. Only MSOAs that are within the respective 10km, 5km, 3km and 1km distances are included within the analysis. In all cases, a

polynomial of order one (i.e. a linear fit) is used to estimate the proportion of invited patients. Table 5.16 illustrates the sample sizes (the number of MSOAs) on which a potential RDD would be based, since samples sizes for these estimations vary. As distance from the boundary decreases, so does the number of MSOAs that could used in the analysis.

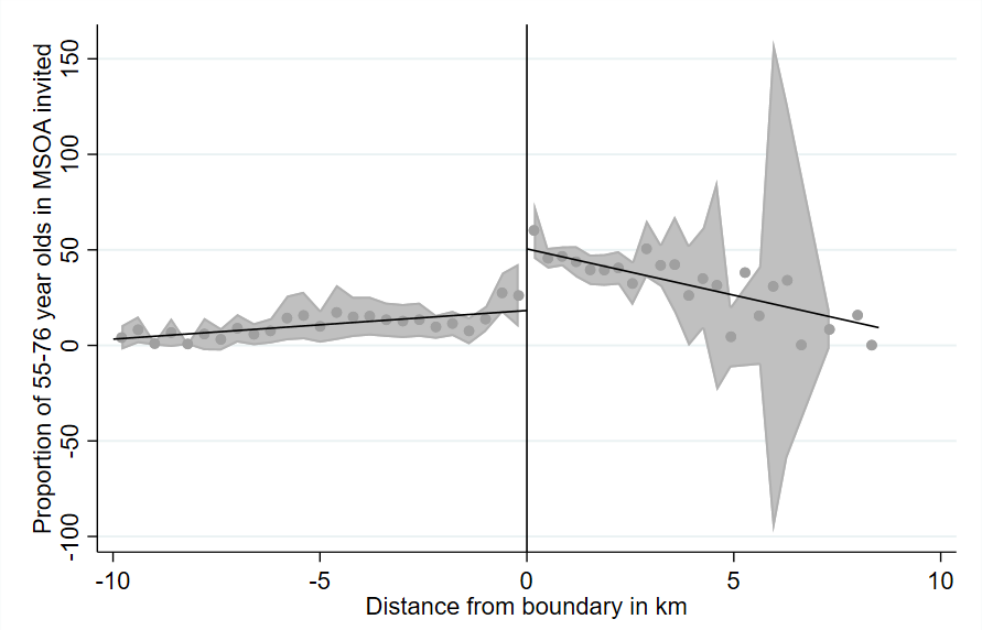
Table 5.16: Number of MSOAs around different boundaries

Distance to Boundary	Sample size of treated MSOAs	Sample size of comparison MSOAs	Total Sample size
10km	424	739	1,163
5km	403	401	804
3km	366	240	606
1km	170	61	231

Source: Ipsos analysis of programme data

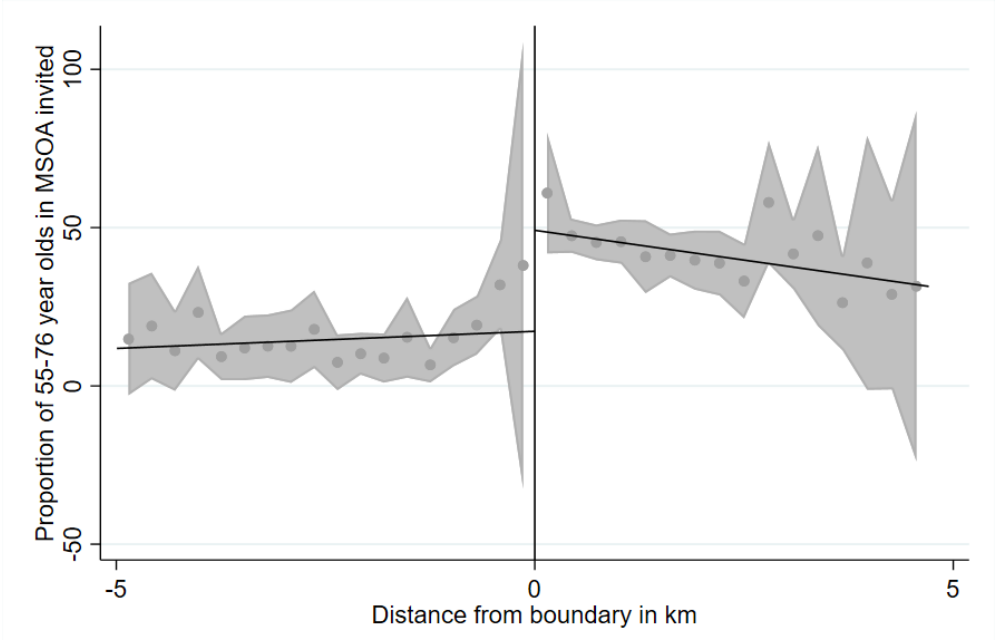
The Figures below show that there may exist a discontinuity in the probability of treatment either side of the project boundary, motivating the use of a fuzzy RDD.

Figure 5.14: Discontinuity in the probability of treatment in MSOAs within 10km of the project boundary.



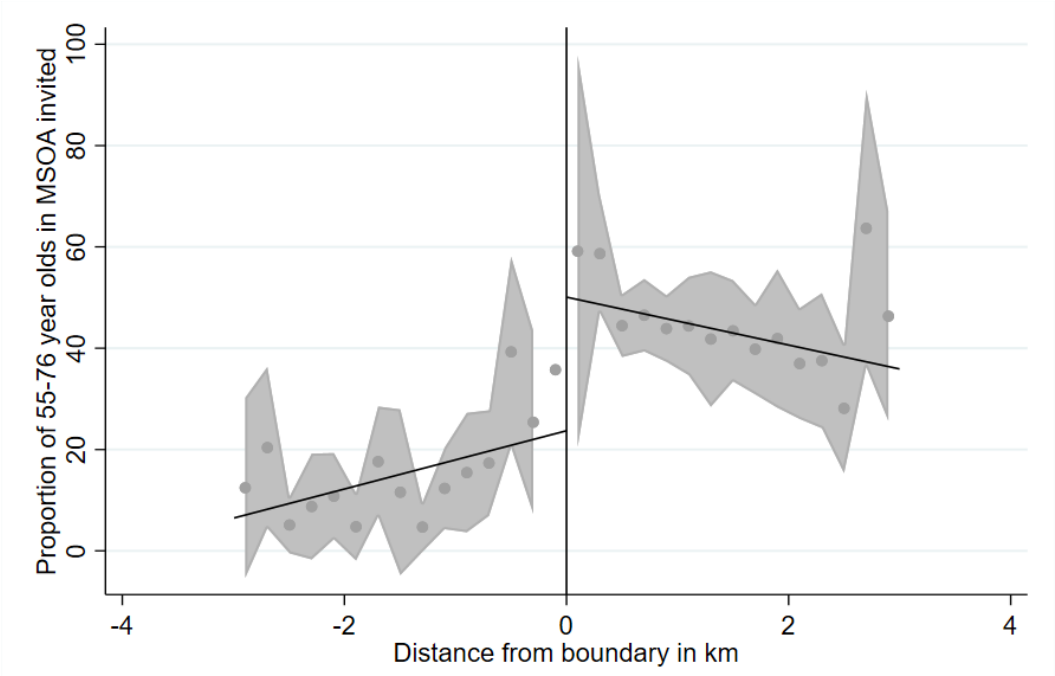
Note: Points represent the average proportion of the eligible population invited for each corresponding distance.
The grey shading represents the 95% confidence interval of the predicted probability for each bin.
Source: Ipsos analysis of programme data

Figure 5.15: Discontinuity in the probability of treatment in MSOAs within 5km of the project boundary.



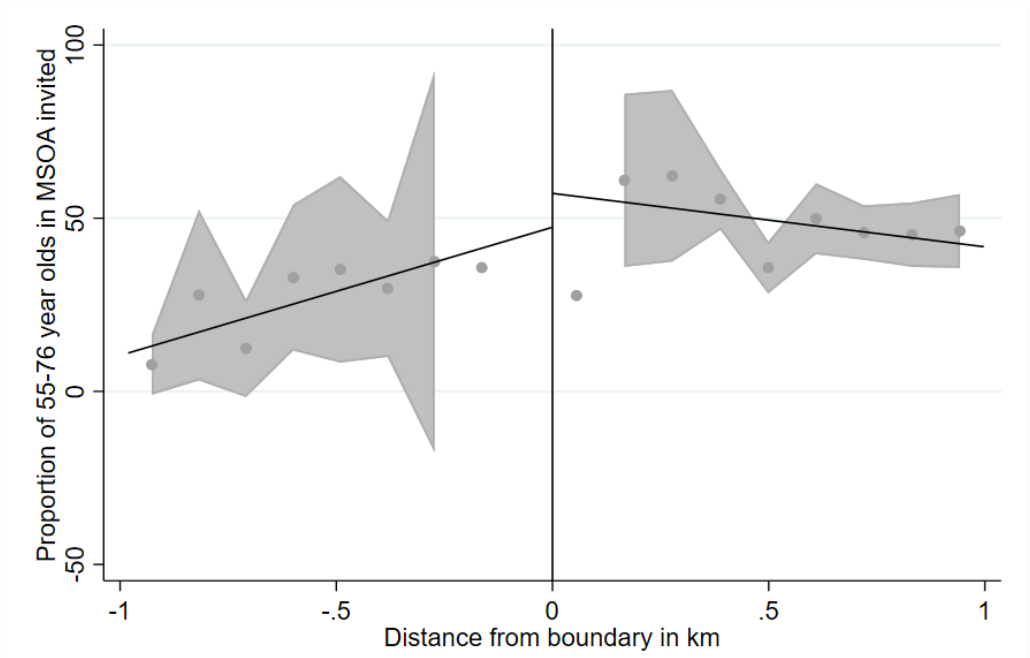
Note: Points represent the average proportion of the eligible population invited for each corresponding distance.
The grey shading represents the 95% confidence interval of the predicted probability for each bin.
Source: Ipsos analysis of programme data

Figure 5.16: Discontinuity in the probability of treatment in MSOAs within 3km of the boundary.



Note: Points represent the average proportion of the eligible population invited for each corresponding distance.
The grey shading represents the 95% confidence interval of the predicted probability for each bin.
Source: Ipsos analysis of programme data

Figure 5.17: Discontinuity in the probability of treatment in MSOAs within 1km of the boundary.



Note: Points represent the average proportion of the eligible population invited for each corresponding distance.
The grey shading represents the 95% confidence interval of the predicted probability for each bin.
Source: Ipsos analysis of programme data

Balance tests at both sides of the border

As previously discussed, one way of providing evidence for the continuity assumption in the GRDD model is to test differences in important covariates of the MSOAs on either side of the boundary.

Similarly to the PSM analysis, balance tests are carried out on the outcomes of interest, as well as key covariates, using SMDs to compare differences either side of the boarder.

The results are presented in the tables below. In general, it appears that there is an imbalance in most observable characteristics between TLHC intervention and non-intervention MSOAs across the various distances to the boundaries. The lack of covariate balance may indicate important pre-intervention differences that could confound the impacts of the programme. In particular, the level of deprivation exhibits an SMD greater than 0.1 across all distances to the boundary. This is important as deprivation is correlated with smoking status, and smoking status is correlated with all outcomes of interest, including selection into the programme. Therefore, differences in the level of deprivation may indicate pre-existing trends that may bias the results of the impact evaluation.

The imbalances in MSOAs either side of the CCG boundary suggested that this approach would not be able to produce unbiased casual estimates of the impact of the TLHC programme, and as such was rejected as a viable methodology.

Table 5.17: Covariate balance of MSOAs 10km from CCG boundary

Variable	Treatment Mean	Control Mean	SMD	Treatment Sample Size	Control Sample Size	Total Sample Size
IMD 2019	31.41	24.62	0.46	424	739	1163
Population of 55–76-year-olds in 2018	1,815.24	1,852.07	-0.08	424	739	1163
Total GPs in MSOA	1.06	1.16	-0.09	424	739	1163
Number of lung cancers per 10,000 in 2016	25.53	21.65	0.25	424	739	1163
Number of lung cancers per 10,000 in 2017	24.07	20.81	0.24	424	739	1163
Number of lung cancers per 10,000 in 2017	23.65	20.45	0.22	424	739	1163
Number of deaths due to lung cancer per 10,000 in 2016	19.55	15.05	0.39	424	739	1163
Number of deaths due to lung cancer per 10,000 in 2017	18.07	15.28	0.23	424	739	1163
Number of deaths due to lung cancer per 10,000 in 2018	17.74	14.68	0.26	424	739	1163

Source: Ipsos analysis of National Cancer Registration Dataset and ONS Civil Registration – Deaths

Table 5.18: Covariate balance of MSOAs 5km from CCG boundary

Variable	Treatment Mean	Control Mean	SMD	Treatment Sample Size	Control Sample Size	Total Sample Size
IMD 2019	31.58	25.59	0.40	424	739	1163
Population of 55–76-year-olds in 2018	1,804.16	1,864.45	-0.13	424	739	1163
Total GPs in MSOA	1.06	1.34	-0.23	424	739	1163
Number of lung cancers per 10,000 in 2016	26.01	23.66	0.15	424	739	1163
Number of lung cancers per 10,000 in 2017	24.14	22.09	0.15	424	739	1163
Number of lung cancers per 10,000 in 2017	24.05	21.38	0.18	424	739	1163
Number of deaths due to lung cancer per 10,000 in 2016	19.85	15.50	0.36	424	739	1163
Number of deaths due to lung cancer per 10,000 in 2017	18.29	16.85	0.11	424	739	1163
Number of deaths due to lung cancer per 10,000 in 2018	18.03	15.05	0.25	424	739	1163

Source: Ipsos analysis of National Cancer Registration Dataset and ONS Civil Registration – Deaths

Table 5.19: Covariate balance of MSOAs 3km from CCG boundary

Variable	Treatment Mean	Control Mean	SMD	Treatment Sample Size	Control Sample Size	Total Sample Size
IMD 2019	31.37	27.67	0.24	424	739	1163
Population of 55–76-year-olds in 2018	1,808.13	1,835.12	-0.06	424	739	1163
Total GPs in MSOA	1.04	1.47	-0.36	424	739	1163
Number of lung cancers per 10,000 in 2016	25.95	23.84	0.13	424	739	1163
Number of lung cancers per 10,000 in 2017	24.09	23.66	0.03	424	739	1163
Number of lung cancers per 10,000 in 2017	24.48	23.86	0.04	424	739	1163
Number of deaths due to lung cancer per 10,000 in 2016	19.81	16.03	0.31	424	739	1163
Number of deaths due to lung cancer per 10,000 in 2017	18.67	17.58	0.09	424	739	1163

Number of deaths due to lung cancer per 10,000 in 2018	17.92	15.90	0.17	424	739	1163

Source: Ipsos analysis of National Cancer Registration Dataset and ONS Civil Registration – Deaths

Table 5.20: Covariate balance of MSOAs 1km from CCG boundary

Variable	Treatment Mean	Control Mean	SMD	Treatment Sample Size	Control Sample Size	Total Sample Size
IMD 2019	34.14	18.15	0.98	424	739	1163
Population of 55–76-year-olds in 2018	1,730.15	2,182.67	-1.09	424	739	1163
Total GPs in MSOA	1.02	1.50	-0.42	424	739	1163
Number of lung cancers per 10,000 in 2016	28.16	16.71	0.68	424	739	1163
Number of lung cancers per 10,000 in 2017	25.40	16.80	0.60	424	739	1163
Number of lung cancers per 10,000 in 2017	25.77	20.84	0.32	424	739	1163
Number of deaths due to lung cancer per 10,000 in 2016	20.71	10.96	0.73	424	739	1163
Number of deaths due to lung cancer per 10,000 in 2017	20.20	18.45	0.13	424	739	1163
Number of deaths due to lung cancer per 10,000 in 2018	18.72	13.59	0.41	424	739	1163

Source: Ipsos analysis of National Cancer Registration Dataset and ONS Civil Registration – Deaths

6 Appendix Six: Patient-level analysis standalone PowerPoint report

Please see the standalone PowerPoint document.

7 Appendix Seven: Project breakdown by datasets and strands of the evaluation

Code	Project	Phase	Initial invites sent	Lung Health Checks attended	Initial LDCT scan performed	Main report						Patient Level Analysis	Impact analysis	Economic analysis[3]
						Chapter 4[2] - programme delivery analysis	Chapter 6 - implementation model analysis	Chapter 6 - demographic analysis	Chapter 8 - Impact analysis	Chapter 8 - Incidental Findings	Chapter 9 - Economics			
00Q	Blackburn Darwen and Blackpool	Original	37,578	13,403	7,485	Yes	Yes	Yes	Yes	Yes	-	Yes	Yes	-
03V	Corby	Original	11,254	3,405	2,036	Yes	Yes	Yes	Yes	Yes	-	Yes	Yes	-
04E	Mansfield and Ashfield	Original	23,648	16,523	7,168	Yes	Yes	Yes	Yes	Yes	-	Yes	Yes	-
06P	Luton	Original	40,560	12,680	6,865	Yes	Yes	Yes	Yes	Yes	-	Yes	Yes	-
07G	Thurrock	Original	50,825	9,863	4,736	Yes	Yes	Yes	Yes	Yes	-	Yes	Yes	-
02X	Doncaster	Original	46,813	17,168	8,960	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
03F	Hull	Original	38,990	17,389	9,962	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
13T	Newcastle Gateshead	Original	46,809	25,168	10,280	Yes	Yes	Yes	Yes	Yes	-	Yes	Yes	-
03J	North Kirklees	Original	17,662	10,391	4,263	Yes	Yes	Yes	Yes	Yes	-	Yes	Yes	-
10X	Southampton	Original	21,598	8,510	6,474	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
01Y	Tameside and Glossop	Original	34,825	22,176	9,947	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
RBQ00	Cheshire and Merseyside	Original and Onboarded[1]	124,555	55,979	34,726	Yes	Yes	Yes	Partial	Yes	-	Yes	Partial	-
36J	Bradford District and Craven	Onboarded	18,374	9,079	3,712	Yes	Yes	Yes	No	Yes	-	Yes	No	-
05A	Coventry and Warwickshire	Onboarded	40,255	28,018	11,248	Yes	Yes	No	No	Yes	-	No	No	-
14L	Manchester	Onboarded	31,993	12,548	5,560	Yes	Yes	No	No	Yes	-	No	No	-
01G	Salford	Onboarded	28,456	14,029	6,553	Yes	Yes	No	No	Yes	-	No	No	-
05W	Stoke on Trent	Onboarded	56,476	31,655	16,094	Yes	Yes	No	No	Yes	Yes	No	No	Yes
08C	Hammersmith and Fulham	Onboarded	21,482	3,903	1,879	Yes	Yes	No	No	Yes	-	No	No	-
08G	Hillingdon	Onboarded	25,341	6,336	2,893	Yes	Yes	No	No	Yes	-	No	No	-
08T	Sutton	Onboarded	17,558	5,698	2,129	Yes	Yes	No	No	Yes	-	No	No	-

Notes

[1] Halton and Knowsley were original projects and Liverpool was onboarded; Halton and Knowsley were included in the impact evaluation, but Liverpool was excluded due to pre-2019 activity which affected the analysis of the pre-intervention period.

[2] Cancer diagnosis rate by scanning round is only available for the projects used in the patient level analysis

[3] The following phase 3 sites provided set-costs for the economic analysis East Lancashire, St Helens & South Sefton, Sunderland & South Tyneside, Tees Valley, Rotherham, Barnsley, Bassetlaw (S Yorkshire Bassetlaw) (SYB), Nottingham, Sandwell & West Birmingham, North East Essex, Great Yarmouth (Norfolk & Waveney), Southend, BSW CCG (Swindon), East Kent, Portsmouth, Whole Alliance (SWAG), Kernow, North Central London, NE London (NEL) and SE London (SEL)

8 Appendix Eight: Summary write up of participant experience workstream

8.1 Background

Understanding participants' experiences of the TLHC programme was a key part of the evaluation. The aim was to test the anticipated outcomes outlined in the Theory of Change – firstly, that participants have a positive experience of the programme (likely to be a positive predictor of adherence to guidance provided to them during the LHC), and secondly that participants would demonstrate improved awareness of lung health issues as a result of engaging in the programme.

In order to achieve this, survey data was collected from participants who attended both a LHC and a CT scan. In addition, the evaluation design incorporated qualitative interviews with participants to provide a depth of understanding difficult to achieve with quantitative data alone.

8.2 Originally agreed approach

In January 2020[77], an approach to collecting participant experience was co-designed with the 10 projects and agreed with NHSE – outlined in table 1.2. Since this is a service evaluation, full HRA ethical approval was not required (as agreed with NHSE). All research materials and the proposed approach were reviewed by the Ipsos internal ethics committee against robust HRA ethical standards.

This original approach was designed to minimise burden to projects, both in distributing the survey and corresponding information governance requirements. Using this approach, participants' personal data would not need to be shared between projects and Ipsos, avoiding the need to establish Data Processing Agreements between Ipsos and each of the (then) 23 CCGs (17 projects) taking part. This would be a time-consuming process and would also require projects to collate and securely send us on a regular basis the details of all participants who have had an LHC/CT scan, so that we could then distribute the surveys directly.

[77] An extended collaborative session was held at the January 2020 TLHC Collaboration Event. Hosted by NHSE. These events bring all projects together to collaboratively design, trouble shoot and share learning.

Table 9.1: Originally agreed approach to collecting participant experience

Participant experience element	Participant group	Original proposed approach
Survey of attendees of the LHC service	Participants who attend an LHC (including those who are referred for a low dose CT scan)	Ipsos to provide survey packs to projects (containing survey, cover letter, pre-paid envelope for completed survey to be returned to Ipsos). Attendees to an LHC/LDCT scan given a survey pack by staff at their appointment. Survey posted back to Ipsos, or handed back to staff, who would then return in the post.
Follow-up survey	Participants who agreed to be re-contacted at the initial LHC attendee survey	Follow up survey sent 3-4 months after the LHC appointment. The survey would use a mixed methods approach (online and postal) at the preference of participants.
Qualitative interviews with participants	Participants who agreed to be re-contacted at the initial LHC attendee survey	A subset of participants who agreed to be re-contacted in the LHC attendee survey would be invited to participate in a 45-60 minute interview about their experience of the programme. These were to be conducted face-to-face where possible. Interviewees would receive £30 as a thank-you for their time.

8.3 Amendments to the originally agreed approach

As a consequence of the transition to virtual delivery required by the addendum to the TLHC Standard Protocol, in light of restrictions imposed due to the COVID-19 pandemic, the approach was revised from face-to-face survey distribution.

8.3.1 Attendee and follow up survey changes

For the attendee and follow up survey, this meant that the survey distribution was amended to be both postal and face-to-face. It was agreed that surveys would be sent out via post for those that received an LHC, but those that attended a CT scan would have it handed to them at the CT scan appointment. This allowed projects to have the greatest flexibility to select an approach best suited to local service and resourcing configurations.

The questionnaire itself, also had to be revised to remove questions about attending appointments in-person and explore experiences of the virtual LHC.

The distribution method for the follow up survey was unchanged (i.e. postal or online with those agreeing to be re-contacted).

8.3.2 Qualitative interview changes

For the qualitative interviews, the decision was taken, in agreement with NHS England, that all interviews would be conducted by telephone or online. The recruitment approach was unchanged (i.e. based on those agreeing to be re-contacted): a sub-group of participants was selected from the overall list of those who agreed to be recontacted, and a specialist qualitative recruiter used this list to contact participants by email or post to invite them to take part in an interview.

Quotas were used to ensure the sample for each wave included interviewees from all seven regions, and with a range of demographic and attitudinal characteristics. While interviews are not intended to be representative in the same way as a survey, these quotas helped to ensure that a wide range of views were obtained from the interviews.

Participants were offered £30 following the interview, as a thank-you for taking part. This helped to incentivise the interviews and secure participation. Participants were sent this £30 by bank transfer, cheque, or in shopping vouchers, at their preference.

8.4 Attendee and follow-up surveys

Participants were invited to complete the initial attendees' survey shortly after attending either a Lung Health Check or lung CT scan appointment. If participants agreed to be re-contacted, they were invited to complete a follow-up survey three to four months after their Lung Health Check or lung CT scan appointment. Both surveys were mixed-mode; administered using both online and postal methods.

Findings from the attendees' survey are based on 11,979 responses received between 22 June 2021 and 17 May 2022 from 21 CCG areas covering 14 projects participating in the programme. It is not possible to provide a response rate for the attendees' survey, because projects do not record the number of times a survey has been offered. For example, when handing out surveys face-to-face, a participant may decline to take part in the survey, but this would not be recorded. Likewise, projects do not record and share with Ipsos the number of email or text invitations that are sent.

Data from the follow-up survey is based on 2,296 responses received between 30 November 2021 and 14 September 2022. For the follow-up survey (distributed by Ipsos) the response rate was 23%.

8.4.1 Questionnaire content

The attendee questionnaire was designed to explore the participants' experience throughout the LHC process. It captured information on the following areas:

- Take up of the LHC – reasons for attendance and how this might differ by demographics or certain groups of participants;
- The effectiveness of different recruitment strategies;
- Experience of the service;
- Suggested improvements to the service;
- Engagement with advice provided through the programme (such as on keeping lungs healthy) and any subsequent behaviour change; and,
- Engagement with smoking cessation services and any subsequent behaviour change.

The attendee follow-up survey allowed NHSE to capture information on what participants had done since their initial Lung Health Check appointment. It was asked to those that agreed to be recontacted at the end of the attendee survey.

This survey captured information on the following areas:

- Next steps following their LHC
- Length of time between LHC and any follow up conversations
- Experience of next steps
- Current smoking habits
- Experience of being referred to a smoking cessation service

8.5 Qualitative interviews

Qualitative fieldwork with LHC attendees took place over four separate waves, with each wave consisting of 25 interviews. Wave one took place in October 2021; wave two in January-February 2022; wave three in April 2022; and wave four in June 2022. Interviewees were recruited from participants who had completed the attendees' survey and agreed to be re-contacted. Interviews took place via telephone or online and lasted up to 60 minutes.

Detailed notes were captured during participant interviews and then coded in NVivo.

8.5.1 Interview content

The interviews were designed to qualitatively explore participants' experiences, providing richer findings, and exploring findings from the surveys in more detail. The discussion guide for interviews with attendees was reviewed in two stages by the national programme team and Patient and Public Voice (PPV) group – once in mid-2020, and again closer to the start of fieldwork, in August and September 2021. The overall proposed approach and discussion guide were also reviewed by ethical experts within Ipsos in September 2021.

The discussion guide covered the following topics:

- Background information and context;
- Experience of the invitation to the service;
- Experience of the LHC appointment itself;
- Experience of smoking cessation advice/ services (if relevant);
- Experience of lung CT scan (if relevant);
- If participants have changed their behaviour in any way, since attending the LHC;
- Overall experience of the service; and
- Experience of referrals to other services.

8.5.2 Qualitative interview Profile of participants

The table below outlines the profile of the 100 achieved interviews, by the quotas set.

Characteristics:	Quota:	Number of interviews achieved			
		Wave 1 (Q4 2021)	Wave 2 (Q1 2022)	Wave 3 (Q2 2022)	Wave 4 (Q3 2022)
Age	At least 5x aged 55-59	6	6	5	6
	At least 5x aged 60-64	6	7	7	7
	At least 5x aged 65-69	7	6	7	6
	At least 5x aged 70-74	6	6	6	6
Sex	At least 10x males	13	13	13	12
	At least 10x females	12	12	12	13
Smoking status	At least 5x who smoked cigarettes in the week they completed the survey	9	8	12	6
	Did not smoke in the week they completed the survey	16	17	13	19
Have had a lung scan	At least 10x who have had a lung scan after their Lung Health Check	17	16	8	14
	Did not have a lung scan	8	9	17	11
CCG area	At least 1 participant from each of the CCGs who took part in the survey this quarter:				
	Blackburn with Darwen		3	2	
	Blackpool		2	1	2
	Corby	2	2	1	1
	Coventry & Rugby	3	1	1	1
	Doncaster	2	2	1	2
	Halton			1	2
	Hammersmith & Fulham	1	1	1	1
	Hillingdon	1	1	2	1
	Hull		1	1	
	Knowsley			2	1
	Liverpool	3	1	1	2
	Luton	2	1	1	1
	Mansfield & Ashfield		1	1	1
	Newcastle Gateshead	2	1	1	1
	North Kirklees		1	1	1
	Salford	2	2	1	1
	Southampton	1	1	1	
	Stoke	2	1	1	2
	Sutton	2	1	1	2
	Tameside and Glossop		1	2	2
	Thurrock	2	1	1	1
	At least 3x whose overall experience of the Lung Health	5	6	3	3

Views of the Lung Health Check	Check was 'Neither good nor poor', 'Poor' or 'Very poor'				
	Those whose overall experience of the Lung Health Check was 'Good' or 'Very good'	20	19	22	22
Ethnicity	At least 3x from a minority ethnic background	4	6	5	3
	White	21	19	20	22

8.6 Methodological limitations

8.6.1 Attendees' survey

Not all projects began distributing surveys at the start of the first survey quarter. Some started in the second and third survey quarters, which may contribute to differences between quarters. As projects distributed the survey themselves, rather than invitations being sent centrally by Ipsos, there is some variation in the methodology. This limits the comparability of the survey results. Projects could choose whether to distribute the survey online, by post, or in person at CT scan appointments. The amount of time between a participant's LHC and when they receive the survey varies by project. To maximise response, and minimise burden on projects, it was necessary to provide this flexibility to projects in how they choose to distribute the survey. Also, for practical reasons, projects were asked to survey a proportion of their participants rather than all participants. Some projects may have distributed all their surveys more quickly than others, depending on their throughput of attendees.

Similarly, there is over-representation in the survey of participants who have received a CT scan, averaging 54% over survey quarters one to four, compared to an average of 46% of participants over this same period in the MDS[78]. With the improvements made to data quality assurance and processes, we have added confidence that there is over-representation in the data which requires consideration whilst interpreting the data. It is possible this is because participants who have a CT scan tend to complete a paper survey face-to-face, compared to most receiving the survey digitally/via post, if completing it after their LHC.

8.6.2 Qualitative follow up interviews

Because fieldwork took place between October 2021 and June 2022, the findings may not reflect any changes in participant experience since then. Quotas were used to ensure an adequate distribution of participant characteristics, though the sample is not representative of all TLHC participants.

[78] Fieldwork for the attendees' survey was between June 2021 – May 2022. The MI average figure is also for this same time period.

9 Appendix Nine: Definitions of implementation model variations

This Appendix complements **Chapter 6, Section 1.28** within the main evaluation report by providing definitions to each implementation model variation.

Table 9.1: Definition of implementation model variations

Model	Variation (number of projects following variation)	Definition
Invitation model	Opt-in (9)	Where individuals are invited to participate, e.g. a letter offering the service and asking the individual to respond.
	Opt-out (4)	Where individuals are assumed to take part unless they state otherwise, e.g. a pre-booked appointment or an unscheduled telephone call.
	Combined (10)	Sending opt-out invitations to individuals recorded as ever-smokers along with a generic opt-in invitation to all other individuals in the age range.
Admin (Invites / Bookings etc)	In-house (16)	This process is all conducted by the responsible provider.
	Outsourced (7)	This process is all conducted by contractor.
LHC delivery model	Virtual (18)	The LHC is conducted remotely, most often via telephone but could include video conferencing appointments.
	Face-to-face (2)	An in-person appointment between the individual and the person completing the LHC.
	Both (3)	The project offers participants the option of a virtual or face-to-face LHC, with projects typically offering the virtual option first.
Triage (before LHC risk assessment)	Yes (6)	Where the individual is assessed for eligibility (age and smoking status) prior to the LHC.[79]
	No (17)	Where the GP practice details are assumed to be correct, and the individual is presumed to be eligible.
CT scanner location	Acute (3)	The CT scanner where the participant receives their LDCT scan is based within a fixed site in the acute Trust.

[79] This does not cover the 'telephone triage' approach observed in some projects whereby the LHC risk assessment is conducted by a Health Care Assistant, then, if the participant meets the risk threshold, will speak with a LHC nurse.

	Community (17)	The CT scanner where the participant receives their LDCT scan is in a mobile unit based within a community location, such as a supermarket car park.
	Both (3)	The TLHC project has both acute- and community-based CT scanners available. Sometimes initial and follow-up scans happen in different settings.
CT scan delivery	In-house (4)	The LDCT scans are conducted by staff employed by the Trust.
	Outsourced (15)	The LDCT scans are commissioned to a third party and are conducted by third party staff not employed by the Trust.
	Mixed (4)	The TLHC project has both CT scans conducted in-house by Trust staff and by third-party staff commissioned to deliver CT scans.
Smoking cessation referrals	Referral (17)	The participant is formally referred to a local smoking cessation service during their LHC.
	Signpost (3)	The participant is signposted to a service / organisation that can provide smoking cessation support (which could be a specific smoking cessation service or a pharmacy, area dependent) during their LHC.
	Mixed (3)	The TLHC project makes both formal referrals and signposts participants to support, likely due to different geographies having different local arrangements.
Smoking cessation opt-in / opt-out	Opt-in	The participant is asked during the LHC to consent to their contact details being shared with a smoking cessation service.
	Opt-out	The participant's contact details are shared with the smoking cessation service unless the participant requests they are not.