Saving lives, saving money? The effect of a multisectoral suicide prevention program on a healthcare system

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Funding

This research was funded by a grant provided by the Paul Ramsay Foundation.

Key words

Suicide, self-harm, causal inference, healthcare costs, healthcare utilisation.

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PRELIMINARY DRAFT – PLEASE DO NOT CIRCULATE OR CITE WITHOUT PERMISSION

Abstract

The World Health Organization (WHO) made preventing suicide a global imperative in 2014, suggesting to governments they reduce their suicide rates by implementing a comprehensive multisectoral suicide prevention strategy. Some European governments have since implemented this strategy type, although evaluations of their effectiveness are hampered by small sample sizes, confounding factors and low data quality.

This study estimates the impact of a large, community based multisectoral suicide prevention intervention on healthcare resource use and costs in Australia. We exploit a stepped trial conducted between 2017 and 2020 and use a large linked state government administrative dataset with millions of observations from emergency department presentations, inpatient hospital care, primary care, allied health and medicine supply.

Patients from a population of one million people in four local health networks exposed to the suicide prevention intervention were matched to patients from local health networks that were not exposed, using entropy balancing. A multigroup, staggered difference-in-differences approach was employed to account for different intervention start dates and for potential heterogeneous effects across local health networks and time.

We present the Intention to Treat (ITT) causal effects of the intervention on healthcare resource use and costs. The effect is disaggregated across time and each treated local health network. Heterogeneity within each local health network is explored by separately estimating ITT on emergency department presentations, inpatient hospital care, health care delivered outside the hospital and pharmaceutical supply. Sensitivity analysis tested whether results are robust to an alternative estimator and whether results are sensitive to a placebo treatment period or placebo treatment group.

Our study provides valuable insights into the potential impact of large community based, multisectoral suicide prevention interventions on healthcare systems, to better understand the mechanisms of impact associated with these types of strategies. This could help other countries better design, implement and scale-up a comprehensive multisectoral suicide prevention strategy.

1. Introduction

Suicide remains a critical public health issue worldwide, with over 700,000 individuals dying by suicide annually. (World Health Organization, 2024) While the global suicide rate has declined since 2000, some high income countries have experienced increasing trends, highlighting the complexity and variability of the issue. (Ilic and Ilic, 2022)

Each suicide has a devastating and prolonged effect. The impact of each suicide is felt by up to 135 people, (Cerel et al., 2019) including families, friends, colleagues and first responders, many of whom themselves need clinical services and support to help cope with the loss. Social and economic factors associated with suicide include the nature and security of work, housing, education, and access to healthcare. (Pirkis et al., 2017) For instance, income shocks can contribute to increased stress, unmanageable debt and mental illness, leading to a higher risk of suicide. (Brainerd, 2001, Breuer, 2015, Christian et al., 2019) Unemployment, in particular, can cause social isolation, loss of social status and reduced self-confidence, potentially driving some individuals to view suicide as an escape. (Gathergood, 2013) Other risk factors are less modifiable by government, but remain highly relevant, such as social cohesion, loneliness, culture, racism and relationship breakdowns. (Huang, 1996)

In 2014 the World Health Organization (WHO) made preventing suicide a global imperative. It suggested to governments that suicide rates could be reduced by implementing a comprehensive multisectoral suicide prevention strategy. (World Health Organization, 2014) The WHO noted key effective interventions for suicide prevention included limiting access to the means of suicide, responsible media reporting of suicide, fostering socio-emotional life skills in adolescents and better management of people with suicidal behaviours, particularly those with a previous suicide attempt. (Mann et al., 2021, Zalsman et al., 2016) High income countries have started to explore multisectoral, multilevel and multistrategy suicide interventions to reduce suicide rates. (Platt et al., 2019) As of 2024, the Austrian best practice on suicide prevention (SUPRA) program was being piloted in 14 European countries, part of the EU funded Joint Action ImpleMENTAL program. (European Health and Digital Executive Agency (HaDEA), 2024)

Some national prevention interventions have reduced suicide and self-harm although results are mixed, (Matsubayashi and Ueda, 2011) impact age and gender differently, (Lewitzka et al., 2019) and establishing a causal relationship has been challenging. Evaluations have suffered from small sample sizes, limited access to data, low data quality, poor trial designs, and inadequate control for confounders. (De Leo and Evans, 2004, Ono et al., 2008, Matsubayashi and Ueda, 2011, Ono et al., 2013, Yarborough et al., 2019, Pearce et al., 2022) Similarly, the small number of studies on healthcare resource use and costs have found mixed results, finding either hospital cost reductions or no effect. (Park et al., 2018, Sale et al., 2022, Comtois et al., 2019)

The effectiveness of suicide prevention strategies remains a critical area of concern, with current evidence on their cost-effectiveness limited. (Zechmeister et al., 2008, Sinyor et al., 2024) While national strategies are deemed worthwhile, they continue to evolve with many less than a decade old. The evidence supporting their efficacy is often described as *promising* rather than *convincing*, underscoring the need for more robust research to establish causal impacts to inform the development, evaluation and

scaling up of effective interventions. (Sinyor et al., 2024, Martinez-Ales et al., 2020) Evidence of this nature will also justify commitment of resources to such programs.

Our study estimated the causal effect of a multisectoral suicide prevention intervention known as LifeSpan. (Shand et al., 2020) The program is trialled in four regions of New South Wales (NSW), Australia's largest state, and for two years each staggered across regions between 2017 - 2020. It contained nine strategies commonly found in national suicide prevention strategies, (Sinyor et al., 2024) implemented simultaneously using a 'stepped' approach across four local health networks (LHNs). LHNs are public, statutory organisations that manage a small group of public hospital services. Around 1.04 million people were potentially exposed to LifeSpan within the four LHNs, accounting for approximately 13 per cent of the NSW population. Implementation was coordinated across health, education, social care and local government organisations.

LifeSpan has shown promising results in reducing self-harm rates, with a 13.8% reduction in hospital-presenting self-harm rates after two years of implementation. (Shand et al., 2024) The focus of our study was to determine whether LifeSpan influenced healthcare service use and costs by estimating the Intention to Treat (ITT) coefficients. While a decrease in self-harm incidents is expected to lower healthcare utilisation and costs, heightened one's own suicidal thoughts and increased self-efficacy to identify other individuals at risk of suicide and connect them to healthcare might have led to increased healthcare demand, potentially raising costs. As LHNs were given one year within the two year trial period to establish all nine interventions, any impact would likely be gradual over time.

Our study is the first to explore the causal impact of a large multisectoral, multistrategy suicide prevention interventions on a healthcare system. We used a linked, high quality administrative government dataset to explore impacts on emergency department presentations, inpatient hospital care, primary care and pharmaceutical supply. Selection was controlled for by conditioning on observable variables to remove correlation between potential outcomes and treatment and balancing treated and control LHNs prior to estimation to support the realisation of parallel trends assumption. (Callaway and Sant'Anna, 2021, Damonte and Negri, 2023)

Our causal estimator derived from Borusyak et al. (2024) circumvented potential biased estimates associated with using a two way fixed effects (TWFE) estimator with staggered treatment and heterogeneous effects across groups. To our knowledge, we are the first to reveal heterogeneous periodic impacts of a multisectoral suicide prevention intervention highlighting lags in treatment effects and surrendering effects after the trial had finished. This has policy implications for government, suggesting investment in multisectoral suicide prevention programs may need to be ongoing to achieve a sustained reduction in suicide and self-harm rates.

Different communities have unique needs and risk factors. Multisectoral strategies can be tailored to address specific local contexts, making them more relevant and effective. Our results show multisectoral suicide prevention strategies can reduce healthcare system costs, and change the distribution of healthcare service use, in addition to saving lives. Our results are robust to two alternative estimators that circumvent limitations with TWFE, alternative control LHNs, a placebo test that shifts the intervention start date back two years and a negative control test that randomly labels one control LHN as the treatment group.

In the case of LifeSpan, more significant reductions in healthcare resource use and costs were found in primary care and pharmaceutical use compared to emergency department and inpatient hospital services, although these also declined. Impacts differed across LHNs most likely due to their different implementation approaches and starting positions. Estimated impacts were a function of how long LifeSpan had been implemented, suggesting any evaluation of a multisectoral suicide prevention strategy should consider the potential delay between investment and outcomes. Our results also suggest multisectoral suicide prevention programs have differing effects on individuals. LifeSpan was more effective in reducing healthcare costs for males, the non-Indigenous population and people aged 50 years and over, suggesting the potential for government to better target strategies to specific population groups that may respond more favourably.

2. Background

2.1 Suicide and self-harm

Australia experiences more than 3,000 suicides per year, while NSW experienced 940 suicide deaths in 2023. (Australian Institute of Health and Welfare (AIHW), 2024) For each suicide in Australia, there are approximately 11 times more hospitalisations as a result of intentional self-harm. (Harrison and Henley, 2014)

The true extent of non-fatal suicide and self-harm behaviours is unknown because some people do not receive medical treatment. Data on monthly ambulance attendances for suicidal ideation, and suicide and self-harm behaviours suggests there were around 34 visits per 100,000 people in NSW in 2021, equating to more than 33,000 visits per year. Crude rates were higher for females aged 15-29 years, which were nearly twice as much as their male counterparts. (Australian Institute for Health and Welfare (AIHW), 2024) Limitations with the National Ambulance Surveillance System means suicide and self-harm are likely underreported. (Lubman et al., 2020) Adjusting for underreporting within emergency department data suggests there are more than 50,000 annual presentations for suicide and self-harm in NSW. (Sara and Wu, 2023)

Contact with primary healthcare services prior to suicide is common, with around 80 per cent of people being in contact with primary health 12 months prior to suicide. People over the age of 50 years have even greater contact with primary care, with around 97 per cent using primary care, although this contact was not necessarily for mental health problems that may be responsible for their suicide actions. (Stene-Larsen and Reneflot, 2019)

Hospital contact prior to suicide is less common, with 50 per cent of people in Australia having a hospital contact for any reason 12 months prior to suicide and 9.9 per cent having hospital contact for intentional self-harm. Females aged 10–24 years and 25–49 years had 3.5 times and 2.4 times the odds of having hospital contact for intentional self-harm compared to males aged 25–49 years. (Clapperton et al., 2021) A systematic literature review found around 18 per cent of people who die by suicide after having contact with mental health inpatient services in the year before their death, and 26 per cent having contact with mental health outpatient services in the year before their death. (Walby et al., 2018)

2.2 Implementation of LifeSpan, a large suicide prevention program

LifeSpan was a multisectoral, multistrategy suicide prevention program developed by the Black Dog Institute, University of New South Wales (UNSW) and funded by the Paul Ramsay Foundation (a not-for-profit philanthropic organisation), based on evidence supporting the efficacy of multistrategy interventions in reducing suicidal behaviour. It consisted of 12 standalone, interventions implemented across the following nine strategic areas within education, community, and health settings. (Shand et al., 2020)

- Improving emergency and follow-up care for suicidal crisis.
- Using evidence-based treatment for suicidality.
- Equipping primary care to identify and support people in distress.
- Improving competency and confidence of frontline workers to deal with suicidal crisis.
- Training the community to recognise and respond to suicidality.
- Promoting help-seeking, mental health and resilience in schools.
- Engaging the community and providing opportunities to be part of the change.
- Encouraging safe and purposeful media reporting.
- Improving safety and reducing access to means of suicide.

While LifeSpan strategies are prevalent in many national suicide prevention strategies, (Sinyor et al., 2024) the program was designed to reflect available global evidence for suicide prevention intervention. Its primary objective was to reduce age standardised rates of suicide attempts. Four LHNs implemented LifeSpan over two years, (see Figure 1) starting within three distinct timepoints. Sites 1 and 2 started in August 2017, site 3 started in December 2017 and site 4 started in April 2018 (see Table 1).[1]

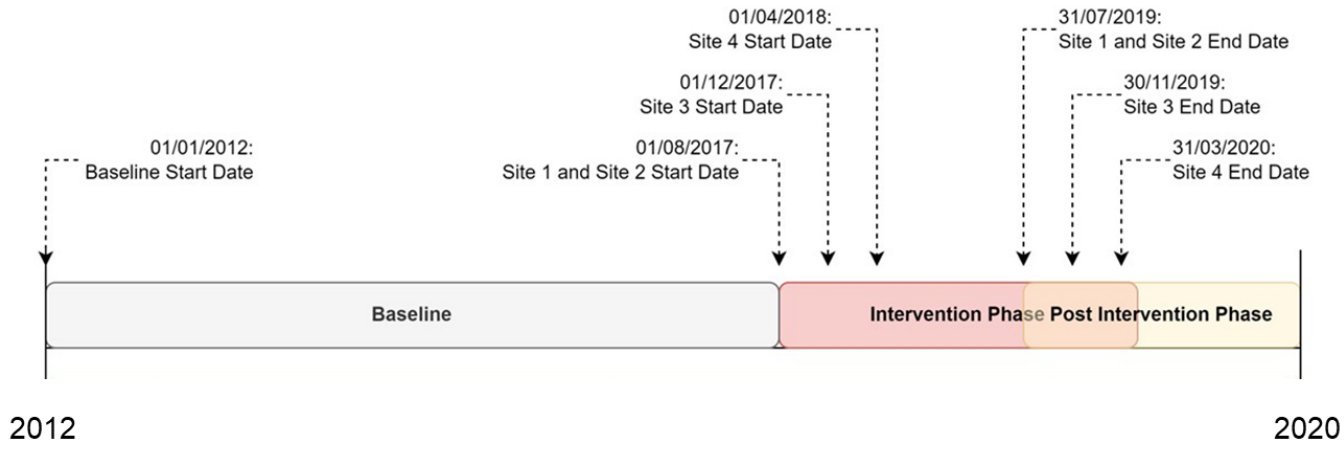
Each site had a designated six-month establishment phase followed by a two-year active intervention phase, where LHNs were responsible for implementing the 12 interventions. Within the establishment phase, site trial coordinators were employed, collaborations with key organisations working within suicide prevention and mental healthcare were established, and a local steering committee was created. LHNs were not considered fully exposed to LifeSpan within the first year of the trial. After the first 12 months of the intervention phase at each site, all nine strategies were expected to be operative with at least one intervention. LifeSpan's implementation phase ceased after the third distinct timepoint, with the final LHN completing their two year intervention period by 31 March 2020.

Sites were selected for LifeSpan based on an initial expression of interest sought from LHNs, PHNs or non government organisations. Each site was assessed against five criteria that represented the

[1] NSW has 15 geographically defined LHNs, six which cover the Sydney metropolitan region and nine cover rural and regional NSW (see Appendix A, Figure A.1). LHNs operate in accordance with the National Health Reform Agreement (NHRA), which outlines funding arrangements between state, territory and federal governments for all public emergency department services, all admitted and non-admitted services, and other outpatient, mental health, sub-acute services and other public hospital services.

organisations capacity to implement LifeSpan. Areas with high incidence of suicide mortality and/or non-fatal incidents were prioritised for site selection to better match LifeSpan with the greatest need for suicide prevention. (Shand et al., 2020) Trial sites received some funding from the Black Dog Institute to employ suicide prevention coordinators and implement interventions but were required to seek additional funding from the NSW Ministry of Health and elsewhere to implement resource intensive strategies, such as developing services to improve emergency and follow-up care for suicidal crisis.

Figure 1: Timeline of stepped intervention of LifeSpan across four LHNs



Note: Site 1= Hunter New England (Newcastle); Site 2 = Illawarra Shoalhaven; Site 3 = Central Coast; Site 4 = Murrumbidgee

Table 1: LHN characteristics

LHN	Start date	Trial duration	Location type	Resident population
Site1 - Newcastle	1 August 2017	2 years	Large regional city	155,411
Site 2- Illawarra Shoalhaven	1 August 2017	2 years	Coastal / rural	393,204
Site 3 - Central Coast	1 December 2017	2 years	Coastal / rural	327,736
Site 4 - Murrumbidgee	1 April 2018	2 years	Rural	164,364
Total				1,040,715
NSW population				8,166,000

3. Data and methods

3.1 Data

NSW government administration data was collected from 2012 to 2020. Datasets included the Emergency Department Data Collection (EDDC), the Admitted Patient Data Collection (APDC), which includes public and private hospitalisations, and NSW Ambulance. These three datasets were linked by the Centre for Health Record Linkage, an organisation managed by the NSW Ministry of Health, to federal Department of Health and Aged Care administrative data on services that received an MBS subsidy and administrative data from the Pharmaceutical Benefits Scheme (PBS), Australia's national subsidised medicines program. MBS funded services include anaesthetics, diagnostic imaging, GP

attendances, obstetrics, optometry and allied health including psychology services, pathology, specialist attendances including psychiatrists, and other services.

The aggregated linked dataset included administrative records of patient-level service use along with costs, fees charged by physicians and pharmacists, and co-payments made by patients. Individual patient healthcare use and cost data were used as the outcome variables and aggregated over three months. Incidents of self-harm were identified within the EDDC data using a binary free text field. Incidents of self-harm leading to an inpatient stay was identified using the International Classification of Diseases, tenth revision, Australian modification codes (ICD-10-AM Codes X60-X84, Y87.0) for intentional self-harm. As routinely collected ED and diagnosis and presenting problem codes significantly underestimate suicide and self-harm rates, these were adjusted using a purpose built algorithm developed by Sara and Wu (2023).

APDC and EDDC records were linked using the project-specific person number and episode start date time to ascertain the continuation of care from emergency departments to patient admission, resulting in a single recorded intentional self-harm episode. The self-harm linkage cohort comprised all intentional self-harm episodes in NSW between 1st January 2012 and 31st December 2020 for individuals aged 10 years or older, due to challenges in determining 'deliberate' from 'accidental' self-harm in young children.

Individual records were sourced from the cause of death unit record file (COD-URF) and the NSW Registry of Births and the Deaths and Marriages (RBDM) datasets and linked probabilistically by the Centre for Health Record Linkage to identify suicide deaths and patients who dropped off from the administrative datasets due to other causes of death. Cause of death was coded according to the International Classification of Disease 10th revision, Australian Modification (ICD-10-AM X60-X84, Y87.0). Suicides are modelled for missing data periods (January to March 2020) where we do not have confirmed suicide death data. Suicide death records in children aged less than 10 years were excluded, consistent with the self-harm linkage.

Each service delivered to patients was geocoded using longitude and latitude coordinates to a suburb using an Australian Bureau of Statistics (ABS) concordance. This allowed each service to be assigned to one of four local health networks that received LifeSpan, or one of local health networks that were used as controls. Less than 2 per cent of patients received emergency department or inpatient services in multiple local health networks and only 1 per cent of patients received these services in a treatment and control local health network. These patients were dropped from the analysis to reduce potential confounding.

3.2 Descriptive statistics on healthcare resource use

Healthcare use varied across each LHN, although each LHN experienced some increase in mean healthcare use and costs. Table 2 show mean utilisation and costs were similar across treated LHNs and the rest of NSW. While sites 1 and 2 experienced an increase in mean utilisation and costs for emergency department services and hospital inpatient services, site 3 experienced an increase in utilisation and a decrease in total costs for emergency department services and hospital inpatient services, suggesting hospital unit costs for these services decreased. The opposite was true for site 4. All sites experienced an

increase in MBS and PBS subsidised services, but a decrease in annual costs. Sites 1 and 4 experienced a decrease in annual cost for PBS subsidised scripts.

Table 2: Mean utilisation and cost across LHNs

LHN	Annual utilisation			Annual cost (AUD)		
	Before LifeSpan	During LifeSpan	% change	Before LifeSpan	During LifeSpan	% change
Emergency department						
Site1 - Newcastle	1.11	1.13	1.8	587.6	579.6	-1.4
Site 2- Illawarra Shoalhaven	1.14	1.11	-2.6	1,042.2	954.5	-8.4
Site 3 - Central Coast	1.23	1.25	1.6	565.9	522.1	-7.7
Site 4 - Murrumbidgee	1.20	1.15	-4.2	677.4	729.1	7.6
Rest of NSW	1.14	1.15	0.9	610.4	585.2	-4.1
Hospital inpatient						
Site1 - Newcastle	1.76	1.83	4.0	12,912.0	13,241.0	2.5
Site 2- Illawarra Shoalhaven	1.71	1.83	7.0	11,254.0	12,502.0	11.1
Site 3 - Central Coast	1.97	2.08	5.6	13,541.0	12,395.0	-8.5
Site 4 - Murrumbidgee	1.56	1.45	-7.1	12,329.0	13,998.0	13.5
Rest of NSW	1.85	2.04	10.3	12,534.0	12,406.0	-1.0
MBS subsidised services						
Site1 - Newcastle	11.99	12.18	1.6	457.4	445.3	-2.6
Site 2- Illawarra Shoalhaven	10.69	11.19	4.7	428.3	425.6	-0.6
Site 3 - Central Coast	10.80	11.13	3.1	421.1	398.0	-5.5
Site 4 - Murrumbidgee	9.85	10.49	6.5	398.8	388.3	-2.6
Rest of NSW	11.05	11.14	0.8	453.6	431.4	-4.9
PBS subsidised services						
Site1 - Newcastle	7.63	7.75	1.6	383.3	376.9	-1.7
Site 2- Illawarra Shoalhaven	7.61	7.71	1.3	391.3	416.5	6.4
Site 3 - Central Coast	7.34	7.41	1.0	383.8	321.3	-16.3
Site 4 - Murrumbidgee	7.11	7.46	4.9	344.8	381.8	10.7
Rest of NSW	7.18	7.29	1.5	412.9	375.3	-9.1

Note: The 'Before LifeSpan' period' was set from January 2015 to December 2016, while the 'During LifeSpan' period was set for each period of the two year trial for each LHN from August 2017

3.3 Econometric methods

LifeSpan was implemented across four LHNs at different times. Each LHN received Lifespan for two years. The staggered implementation meant LHNs that were control groups become treatment groups, hence treatment groups may have had different treatment effects, and treatment effects may have varied with the length of implementation time.

The standard two way fixed effect (TWFE) approach estimates effects for each period and then weights the effects. Regressions are commonly expressed as:

$$Y_{i,t} = \alpha_i + \emptyset_t + D_i\beta + X_{i,t}\delta + \epsilon_{i,t} \quad (1)$$

The outcome $Y_{i,t}$ depends on a group fixed effect α_i, a time fixed effect $\emptyset_t$, an interaction of a post-treatment indicator with treatment status D_i and a random effect $\epsilon_{i,t}$. Including covariates $X_{i,t}$ attempts to remove any correlation between outcomes and treatment. Leads and lags are often used within TWFE estimations to capture dynamic treatment effects for staggered treatment.

However, TWFE estimation will bias estimates with staggered treatment and heterogeneous effects across groups. (Callaway and Sant'Anna, 2021, de Chaisemartin and D'Haultfoeuille, 2023, Goodman-Bacon, 2021, Sun and Abraham, 2021, Roth et al., 2023) Limitations in using TWFE include confusing the control, (Goodman-Bacon, 2021) requiring homogenous treatment effects for parallel trends to hold, (Sun and Abraham, 2021) and inappropriately weighting units that could change the estimator sign. (de Chaisemartin and D'Haultfoeuille, 2023)

Our study sought to estimate a difference in difference (DD) model with dynamic treatment effects. The regression estimated was:

$$Y_{i,t} = \alpha_i + \emptyset_t + \sum_{m=-G}^{M} \beta_m z_{i,t-m} + X_{i,t}\delta + \epsilon_{i,t} \quad (2)$$

Dynamic effects are incorporated into the estimation through $\sum_{m=-G}^{M} \beta_m z_{i,t-m}$, where the effect is estimated at most M≥0 periods before *t* and at most G≥0 periods after *t*. The estimator reflects estimates of the cumulative effects which is summarized in an 'event study' plot that shows effects at different quarters. (Freyaldenhoven et al., 2021)

An estimator developed by Borusyak et al. (2024) was used to circumvent TWFE limitations. While other estimators also address TWFE limitations associated with multiple groups and staggered timing (Callaway and Sant'Anna, 2021, Sun and Abraham, 2021, de Chaisemartin and D'Haultfoeuille, 2023), there is not one best estimator, and performance depends on matching identifying assumptions with economic setting. (Freyaldenhoven et al., 2021) However, Borusyak et al. (2024) notes their estimator uses all pre-treatment periods for imputation, while alternative estimators are less efficient, using limited information within the pre-treatment period.

Borusyak et al. (2024) fit unit and period effects by regressions using untreated observations only. These fixed effects are used to impute the untreated potential outcomes for the treated observations, to obtain an estimate of the treated effect for each treated observation.

$$\hat{\tau}_{i,t} = Y_{i,t} - \hat{\alpha}_i - \hat{\emptyset}_t \quad (3)$$

A weighted sum of the treatment effect estimates is taken, with weights corresponding to the estimation target. In essence, the estimator imputes unobserved potential effects for each LHN and period and weights these effects accordingly.

$$\beta_{post} = \sum_{i,t} \omega_{i,t}\hat{\tau}_{i,t} \quad (4)$$

Borusyak et al. (2024) rely on standard assumptions of event study designs. It assumes the event study design is appropriate, assumes parallel trends hold and assumes no anticipatory effects. We show parallel trends hold and anticipatory effects are unlikely, given LHNs were not engaged and coordinators were not employed before the implementation start date.

The outcome variables of interest were the natural log transformed quarterly aggregate patient-level healthcare use and costs. Taking the natural log reduced the skewness and brought the distribution closer to normal although this transformation results in long tails. While researchers tend to interpret resulting coefficients as average percentage change, this is not possible with our estimates as the data has a large amount of zeros. Chen and Roth (2024) show that if treatment affects the extensive margin, the size of the average treatment effect depends arbitrarily on the units of the outcome variable. The 'percentage' treatment effect is therefore not well defined for people who sought healthcare due to LifeSpan but had previously had zero healthcare. Our results focus on how the effects of LifeSpan change over time and make no comment on the size of the impact.

Eight quarters were used to establish the pre-treatment period to assess parallel trends, while 11 quarters were used to establish the post-treatment period. This meant sites 1 and 2 finished three quarters before the post treatment period finished, site 3 finished two quarters before, and site 4 finished in the last quarter. The coefficient of interest was the DD estimator β which captured the ITT on a quarterly basis, reflecting the cumulative effect of LifeSpan. Errors were clustered at the statistical level area 2 (SLA2) to account for spatial correlation of patient level healthcare decisions. SLA2s are medium-sized general purpose areas created by the Australian Bureau of Statistics to represent a community that interacts together socially and economically. (Australian Bureau of Statistics (ABS), 2024)

3.4 Spillovers and selection

While spillovers can occur with staggard adoption of health programs, (Elenev et al., 2021) they are problematic for a DD framework, as they can violate the parallel trend assumption, violate the stable unit treatment value (STUVA) assumption, and bias the DD estimate towards zero. (Roth et al., 2023) The four treatment LHNs were therefore compared to two control LHNs located in Sydney. While other LHNs were also available for comparison, the two chosen LHNs do not share any geographical border with any treatment LHN, whereas all other LHNs shared at least one border. This minimised any potential spillover of LifeSpan, which would have resulted in the controls no longer reflecting what the treatment LHNs would have experienced without the intervention.

Selection of treatment LHNs were based on five criteria that sought to identify sites most likely to experience a positive response from LifeSpan. Selection was controlled for by conditioning on observable variables to remove correlation between potential outcomes and treatment. Individual-level fixed effects and LHN-level fixed effects were included to remove any potential bias associated with unobservables. Treated LHNs were entropy balanced with control LHNs prior to estimation, (Athey and Imbens, 2017, Hainmueller, 2012, Hainmueller and Xu, 2013) using age, gender, marital status, concession card membership, Socio-Economic Indexes for Areas (SEIFA), private health insurance membership, and the Charlson comorbidity index. Entropy balancing can help improve parallel trends, (Callaway and Sant'Anna, 2021, Damonte and Negri, 2023) and outperforms other matching techniques. (Hainmueller, 2012)

3.5 Assessing treatment heterogeneity

Our detailed linked data allowed treatment effects to be estimated across sites and services, producing 50 treatment effect estimates, including 25 for healthcare resource use and 25 for costs for each quarter. We

first focused on whether LifeSpan impacted healthcare resource use and costs by aggregating all treated LHNs. Results were then disaggregated by site, first in aggregate across resource use and costs and then by each service type, including emergency department visits, hospital inpatient care, MBS subsidised services and PBS subsidised scripts. Results were also disaggregated across patient characteristics, including gender, Indigenous status and age. These characteristics correlate with suicide risk, suggesting the effects of LifeSpan may be different across these characteristics. It also provided additional insight on the potential mechanisms of impact.

3.6 Sensitivity analysis

Alternative estimators drawn from Sun and Abraham (2021) and de Chaisemartin and D'Haultfoeuille (2023) were applied to our baseline estimates. Alternative control LHNs were drawn from neighbouring LHNs rather than using the two control LHNs. A placebo test was undertaken using treatment period two years prior to the actual treatment period, to evaluate whether the observed relationship was truly causal or whether it could be explained by random events. Finally, a negative control test was undertaken by randomly designating one of two control LHNs as the treatment LHN, to test for potential confounding or bias in the estimates.

4. Results

The cumulative quarterly treatment effect of Lifespan on aggregated utilisation and cost across four treated LHNs are presented in Table 3. Effects are also presented in event study plots in Chart 1. They show statistically insignificant differences between the treatment and control LHNS in the pre-treatment period, which aligns with the quarterly pattern of healthcare use and costs (see Appendix B, Chart B.1). This provides evidence of parallel trends between the treated and control LHNs prior to LifeSpan being implemented. Parallel trends are the key identifying condition within DD frameworks, allowing us to assume that outcomes for the treatment group would have followed the same trend as the control group without the treatment.

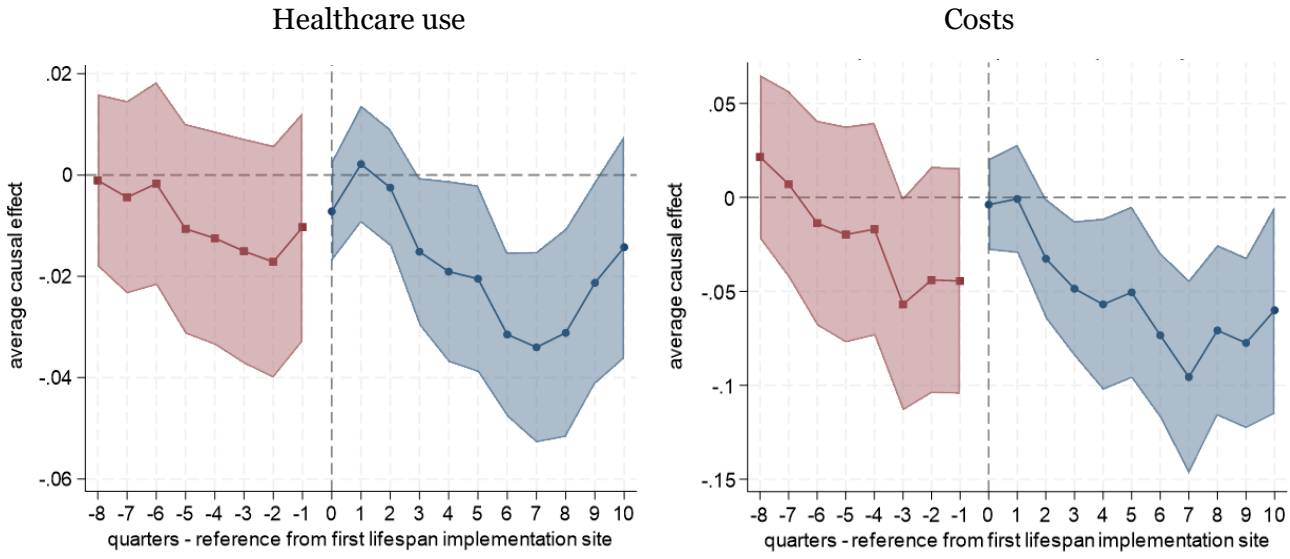
Table 3: Cumulative ITT effects on aggregate healthcare use and cost

Quarterly treatment effects (τ_{DiD})	Quarter	Utilisation	Cost
Sites 1 and 2 started	0 quarter	-0.0072	-0.0038
		(0.0050)	(0.0124)
Site 3 started	1 quarter	0.0022	-0.0008
		(0.0059)	(0.0147)
	2 quarters	-0.0025	-0.0326**
		(0.0059)	(0.0163)
Site 4 started	3 quarters	-0.0151**	-0.0486***
		(0.0074)	(0.0183)
	4 quarters	-0.0191**	-0.0569**
		(0.0091)	(0.0233)
	5 quarters	-0.0205**	-0.0505**

		(0.0094)	(0.0233)
	6 quarters	-0.0315***	-0.0734***
		(0.0083)	(0.0224)
Sites 1 and 2 finished	7 quarters	-0.0340***	-0.0956***
		(0.0096)	(0.0293)
Site 3 finished	8 quarter	-0.0311***	-0.0708***
		(0.0105)	(0.0232)
	9 quarter	-0.0213**	-0.0775***
		0.0102	(0.0232)
Site 4 finished	10 quarter	-0.0142	-0.0600**
		(0.0112)	(0.0282)
All Controls		YES	YES
Individual fixed effects		YES	YES
Year-quarter fixed effects		YES	YES
LHN fixed effects		YES	YES
Entropy balancing with selected covariates		YES	YES
SEs cluster at SA2 level		YES	YES
Observations		1,834,678	1,834,678

Notes: Results are aggregated across all four treated LHNs, for all healthcare resource use and costs. Costs were adjusted for quarterly inflationary trends using quarterly consumer price indices (CPI) obtained from the Australian Bureau of Statistics (ABS). Covariates used in the regressions include age, gender, Indigenous status, marital status, private health insurance status, compensation status, categories of country of birth and country of residence, Charlson comorbidity index, financial level and categories of SEIFA. *** p<0.01, ** p<0.05, * p<0.1.

Chart 1: Event study plot of cumulative ITT effects on aggregate healthcare use and cost



Notes: Results are aggregated across all four treated LHNs, for all healthcare resource use and costs. The shaded area represents a 95% confidence interval of estimated coefficients. The Y-axis presents estimated coefficients while the X-axis presents quarter periods. Quarter 0 represents the implementation of LifeSpan in sites 1 and 2.

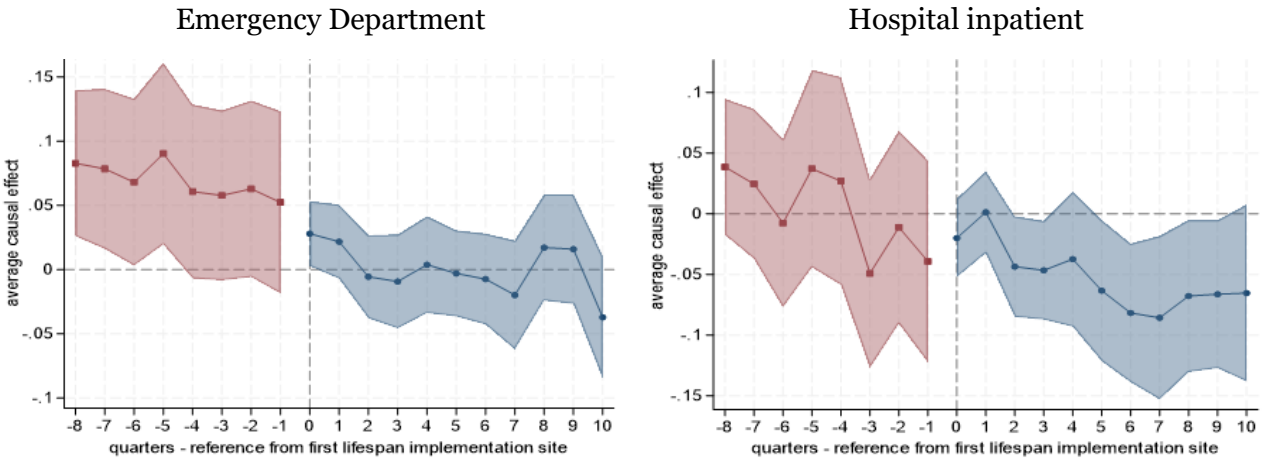
The results provide evidence of a decrease in healthcare resource use and costs. There is a slow and insignificant onset of impacts within the first three quarters for healthcare use and the first two quarters for costs. The decrease in healthcare use and costs becomes significant in quarter 4 and quarter 3 respectively, which remains significant and grows in magnitude as time progresses. Effects of LifeSpan start to dissipate for healthcare use and costs after nine quarters, continuing to dissipate until the end of the trial period. The decrease in healthcare use becomes insignificant in the last quarter, while the decrease in costs remains significant.

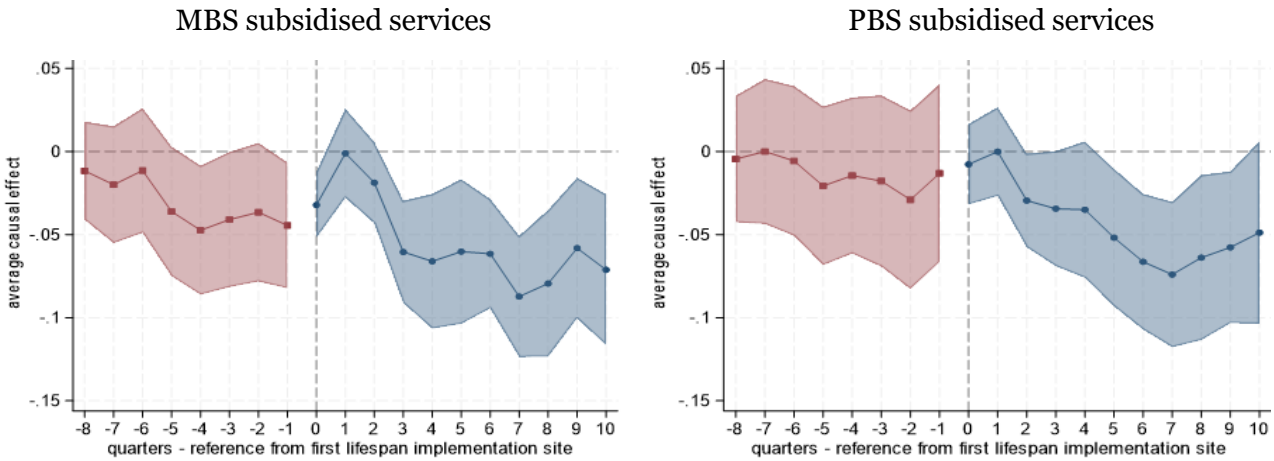
The U-shaped quarterly effects presented in Chart 1 suggest the cumulative effects deepen the longer LifeSpan was implemented. This aligns with LifeSpan's implementation design, including the first year dedicated to employing trial coordinators, establishing collaborations with key organisations, and creating a local steering committee. The staggard adoption of LifeSpan also seems to contribute to the U-shaped pattern. The only quarter where LifeSpan operated within all four LHNs for more than a year (i.e., maximum dose) was after eight quarters (i.e., Quarter 7 in Table 3 and Chart 1). This quarter experienced the greatest cumulative reduction in healthcare use and costs. The subsequent dissipation of effects after the eighth quarter reflects LifeSpan's staggered finish.

4.1 Results by healthcare type

Quarterly treatment effects of Lifespan on individual healthcare costs across four treated LHNs are presented in Chart 2. From here we focus on costs rather than healthcare resource use given costs incorporate impacts on utilisation and unit costs. Event study plots for healthcare resource use are presented in Appendix B, Chart B.2, which have similar patterns, suggesting most of the effects are associated with a reduction in healthcare use. This is expected given unit costs for MBS-subsidised services, and PBS-subsidised scripts are the same for all LHNs, being set by the federal government. However, there may still be some variation in effects for healthcare use and costs as LifeSpan could have resulted in a different mix of MBS subsidised services and PBS scripts.

Chart 2: Event study plot of cumulative ITT effects on healthcare costs





Note: MBS = Medicare Benefits Schedule; PBS = Pharmaceutical Benefits Schedule

While the results show a decline in costs resulting from LifeSpan, more significant effects occur in MBS subsidised services and PBS subsidised services, although our results do not indicate which type of MBS subsidised services was impacted the most. A reduction in PBS costs suggests there are fewer scripts filled in treated LHNs after LifeSpan was implemented.

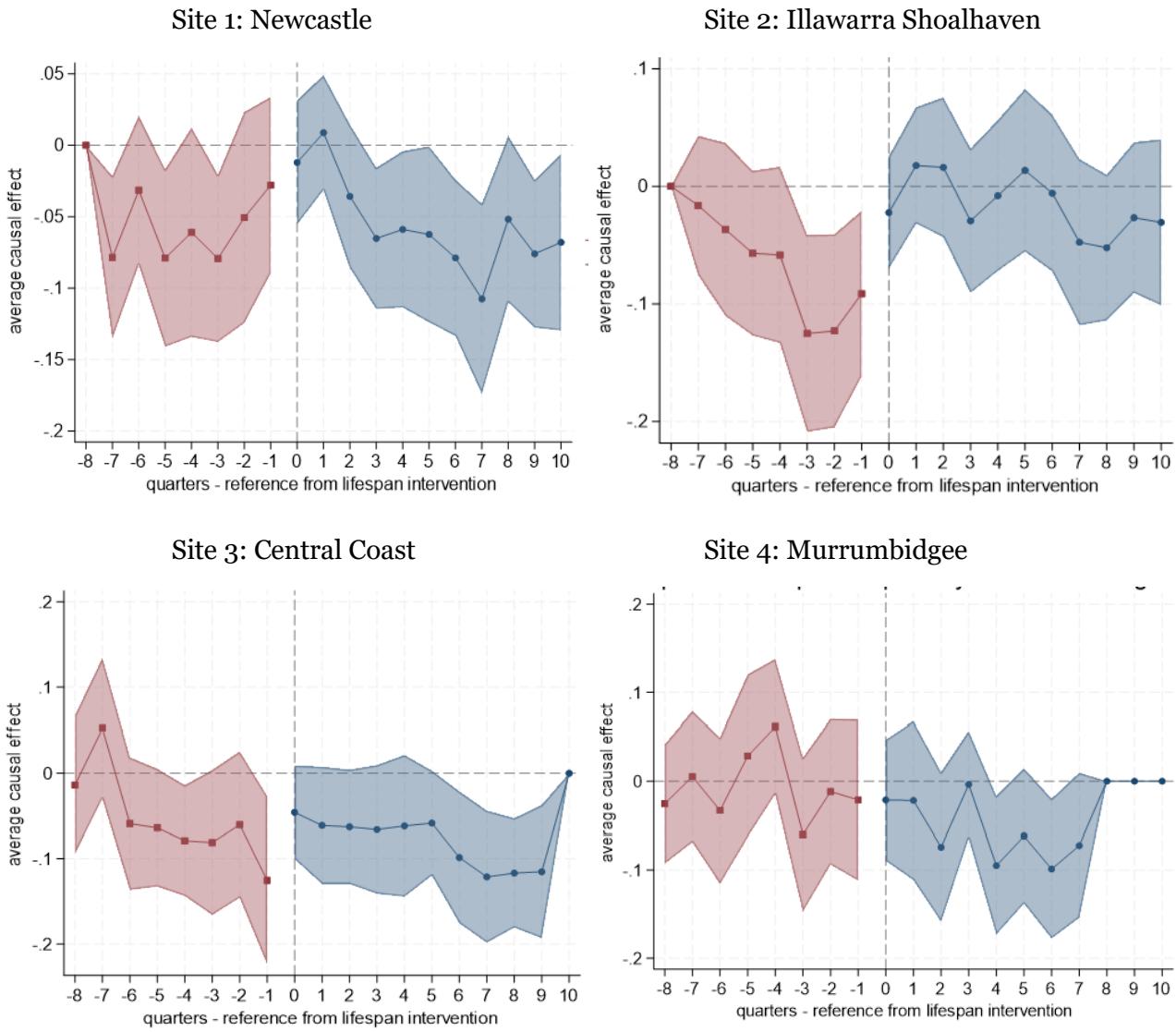
Chart 2 shows analogous patterns of effects associated with aggregate cost estimates presented in Chart 1. The reduction in costs becomes larger for hospital inpatient, MBS subsidised services and PBS subsidised services the longer LifeSpan has been implemented until the point where LifeSpan finishes in sites 1 and 2. MBS subsidised services is the only service type where the effect remains statistically significant from zero at the end of the trial period.

4.2 Results across sites

The impacts of LifeSpan on costs across sites are presented in Chart 3. It shows LifeSpan had a heterogeneous impact on LHNs. Site 1 has the most significant decline in costs associated with LifeSpan, whereas the impact on site 2 is not significantly different from zero in any quarter. Site 3 experienced a decrease in costs, although the effects become significant only halfway through the second year of implementation. A similar pattern was experienced by site 4. Unlike the event study plot pattern in Chart 1, the effects on each treatment LHN do not follow a U-shaped pattern, lending support to the claim that the aggregate effects presented in Chart 1 dissipate because trials finish within LHNs.

Differences in sites may reflect differences in LifeSpan implementation and patient access to healthcare services within LHNs. Each LHN was afforded the flexibility to implement LifeSpan to meet local circumstances, with each site employing their own coordinator and producing their own implementation plan. Each LHN had varying degrees of access to resources to implement LifeSpan strategies, and each LHN faced differing circumstances regarding access to mental healthcare services and experiences in implementing public health programs in the past.

Chart 3: Event study plot of cumulative ITT effects across treatment LHNs



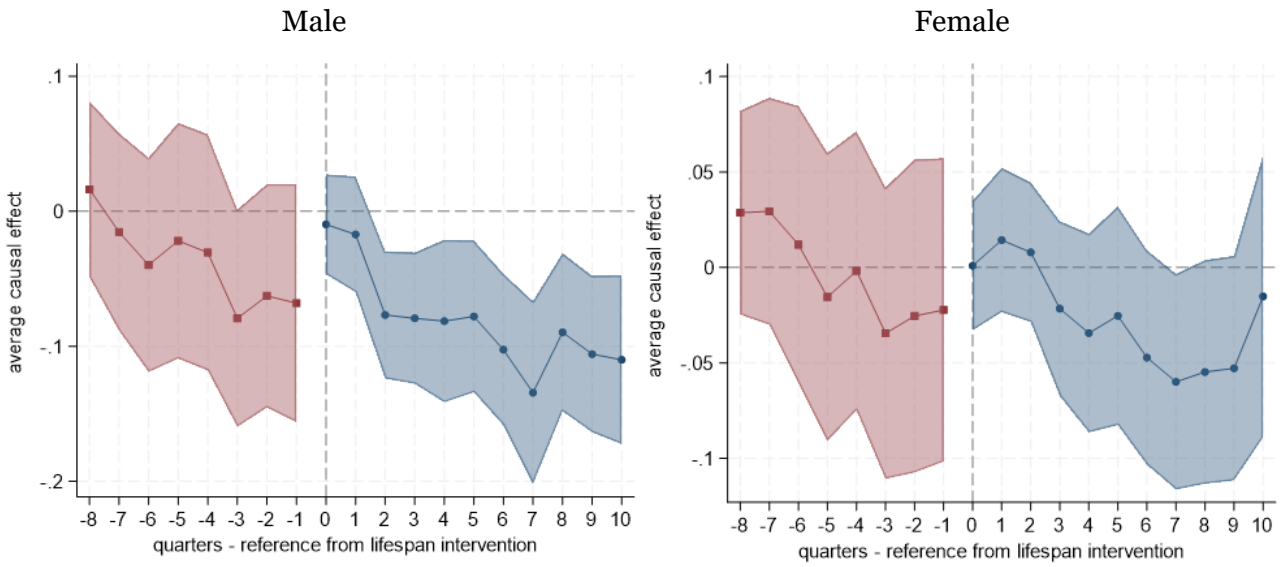
Note: The effects for the 11th quarter for site 3 and the 9th to 11th quarter for site 4 are zero as these two sites started later and therefore do not have 11 quarters of data after LifeSpan implementation.

4.3 Results by individual characteristics

Gender

The impacts of LifeSpan on costs across gender are presented in Chart 4. It shows LifeSpan reduced costs mostly for males, with statistically significant reductions after three quarters. The effects become larger until the eighth quarter where they dissipate for the following quarter but remain statistically different from zero for the remainder of the trial period. Conversely, while costs for females also decline after LifeSpan was implemented, and the effects of LifeSpan follow a similar structure as presented in Chart 1, they are not statistically different from zero.

Chart 4: Event study plot of cumulative ITT effects on costs across gender



It is unclear why males experienced a statistically significant decline in costs from LifeSpan while females did not. For males, self-harm was reduced by 10·2% over the intervention period, while for females, self-harm was reduced 14·8%. (Shand et al., 2024) However, a reduction in self-harm may not necessarily lead to a reduction in healthcare use. If the reduction in self-harm resulted from receiving more healthcare services, for example by seeking ongoing mental healthcare services from a GP or psychologist, then an increase in healthcare use could result.

Given males are less likely to seek mental healthcare prior to suicide and self-harm compared to females, the effects for males may reflect a reduction in healthcare use from lower self-harm events, while the effects for females may reflect a reduction in healthcare use from lower self-harm events and more help seeking behaviour. This would suggest the mechanism of impact may differ between males and females, with males benefiting more from community based suicide prevention activities, such as increased openness to communicating and expressing emotions to partners and friends, (Stas et al., 2024) and females benefiting more from additional healthcare services.

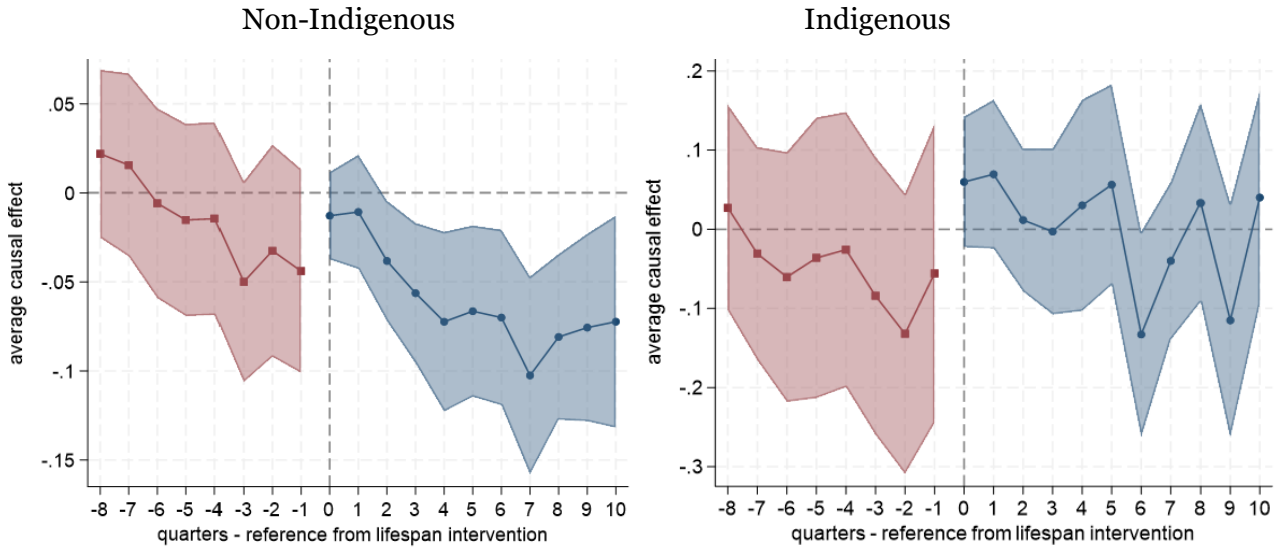
Indigenous status

The impacts of LifeSpan on costs across Indigenous status are presented in Chart 5. It shows LifeSpan reduced costs mostly for non Indigenous patients, with statistically significant reductions after three quarters. The effects become larger until the eighth quarter where they dissipate for the remaining quarters but are statistically different from zero at the end of the trial period. Conversely, there is no discernible statistically significant change in costs for Indigenous (Aboriginal and Torres Strait Islander) patients.

Differences in the effect across Indigenous status may reflect that LifeSpan did not specifically target the Indigenous population. Suicide prevention programs among Indigenous populations are often required to address specific cultural contexts and a sense of community to be successful. A systematic literature review of Indigenous approaches within targeted suicide prevention interventions suggested engaging culture and strengthening connectedness, integrating Indigenous knowledge, ensuring Indigenous self

determination and employing decolonial approaches to contribute positively to suicide prevention outcomes. (Sjoblom et al., 2022)

Chart 5: Event study plot of cumulative ITT effects on costs across Indigenous status



Age

The impacts of LifeSpan across age are presented in Chart 6. It shows LifeSpan had a heterogeneous effect across age. Patients between 10-18 years were relatively unimpacted by LifeSpan until the last quarter where there was a significant increase in costs. Trends suggest costs for those 19-35 years and 36-49 years decreased, although several quarters were not statistically different from zero for 19-35 year olds, or for any quarter for 36-49 year olds.

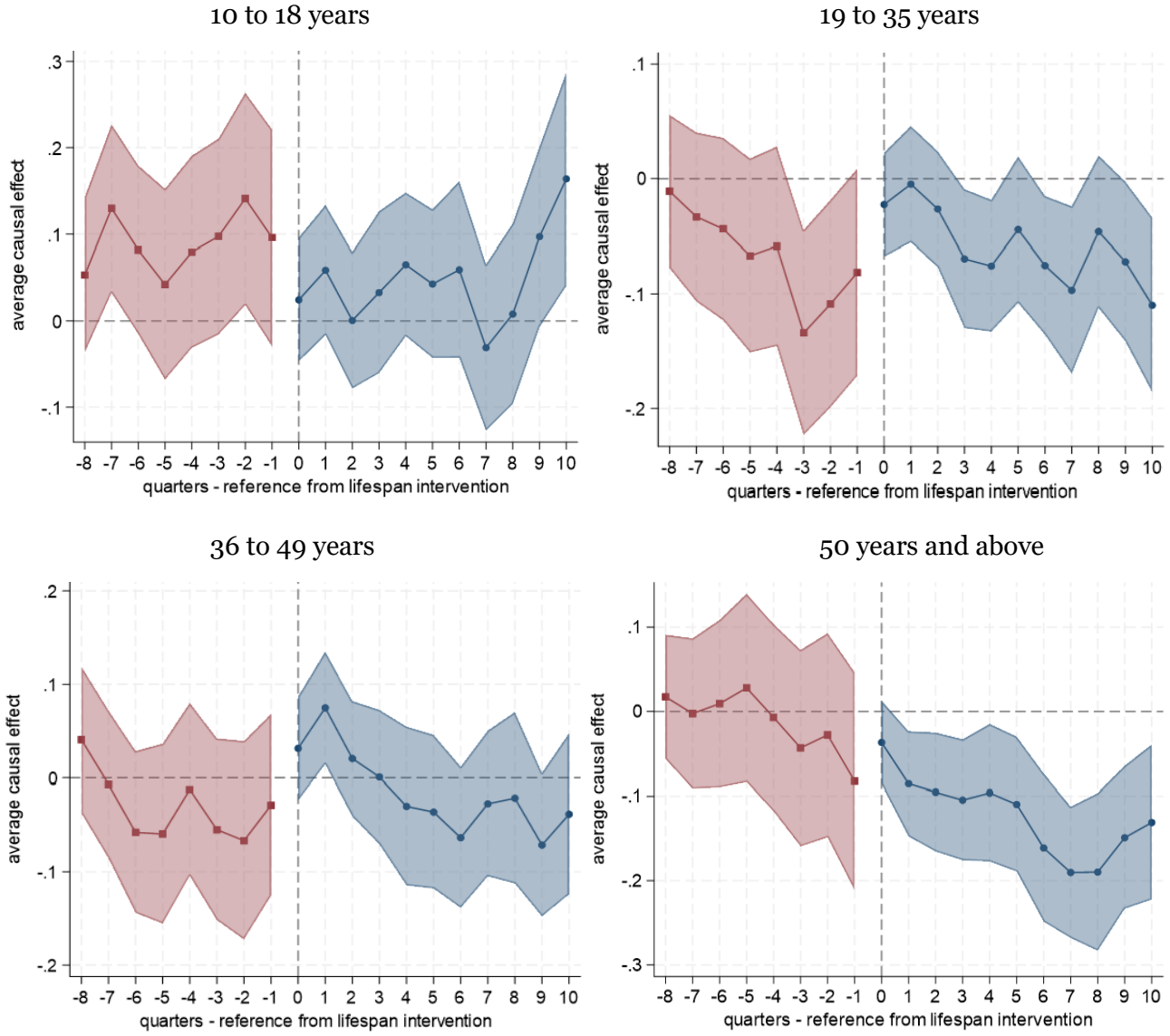
The largest and most significant impact was for patients aged 50 years and over, experiencing a statistically significant decrease in the second quarter that continued to decline until after eight quarters, when the cumulative effect starts to dissipate. The cumulative effect is significant at the end of the trial period, with the pattern of effects for those 50 years and older aligning with Chart 1. This effective pattern of LifeSpan in this age group is consistent with evidence showing that suicide attempts is predominant among the aged population (De Leo, 2022).

The relatively low impact of LifeSpan on 10-18 year olds may reflect limited exposure to LifeSpan for younger people. For example, the Youth Aware of Mental Health (YAM) program within LifeSpan was a school program delivered to year 9 students only, who are typically aged between 13-14 years. Given less use of healthcare resources, younger people would have also been less exposed to other LifeSpan strategies, such as equipping primary care to identify and support people in distress and improving competency and confidence of frontline workers to deal with suicidal crisis. The greater exposure to GP services among older people for other ailments may have provided a greater opportunity for LifeSpan to impact help seeking behaviours and for GPs to use their LifeSpan training.

The literature suggest multisectoral suicide prevention strategies may have limited impacts on changing help seeking behaviour for youth. A systematic review that assessed interventions like those delivered in LifeSpan, including psychoeducational curricula, gatekeeper training, and public service messaging,

suggested there was little evidence showing universal prevention efforts positively affect youth help-seeking attitudes and behaviours, and in some cases may have induced suicidal thoughts and behaviours. (Klimes-Dougan et al., 2013) Another review found psychoeducational curricula, gatekeeper training and competence programs positively impact adolescent knowledge and attitudes towards suicide but have little effect on suicidal behaviours. (York et al., 2013)

Chart 6: Event study plot of cumulative ITT effects on costs across age



5. Robustness checks

5.1 Alternative specifications

The model was estimated without controls using aggregated data across services and LHNs and was estimated with LHN-specific time (quarter) trends. Both alternative specifications did not substantially impact the treatment effects. The model was also estimated without entropy balancing the treatment and

control groups prior to estimation, resulting in a negligible impact on pre-treatment trends. This was expected as the four treated LHNs and the two control LHNs have similar patient characteristics and similar impacts from macro events on outcomes.

5.2 Placebo test

A placebo test was undertaken by moving LifeSpan start dates back two years, using data that only represents the pre-treatment period (Q2 2013 to Q2 2017). LifeSpan was assumed to start in Q1 2015 for sites 1 and 2, Q2 2015 for site 3 and Q3 2015 for Site 4. These were compared to the same two control LHNs. The event-study plot shows parallel trends within the placebo pre-treatment period for healthcare use and costs, and no statistically significant impact from LifeSpan in the post-treatment period (see Appendix B, Chart B.3). This suggests that the observed treatment effect found within our primary results is potentially due to the treatment and not due to spurious correlations.

5.3 Negative control test

A negative control test was undertaken by randomly selecting one control LHN and labelling it as treated, while retaining the other control LHN. All four treated LHNs were removed from the analysis. The proxy treated LHN was assumed to start LifeSpan in the same quarter as the first two sites, using the same pre-treatment and post treatment periods. The event study plot shows parallel trends within the pre-treatment period for healthcare use and costs, and no statistically significant impact from LifeSpan in the post-treatment period (see Appendix B, Chart B.4). This provides further evidence that the causal pathway from LifeSpan to healthcare use and costs is correctly identified, limiting the potential for confounding or bias.

6. Discussion

Suicide and self-harm incidents result in substantial healthcare costs, including emergency department visits, inpatient hospital stays, and ongoing mental health treatment through psychotherapy and pharmacotherapy interventions. (Kinchin et al., 2017) Our study found a multisectoral multilevel suicide intervention such as LifeSpan can reduce these costs, although the effects on costs differed across LHNs, healthcare service types, and individual characteristics.

Heterogeneous effects found within our study concord with the literature. Lewitzka et al. (2019) applied a segmented regression analysis of uninterrupted time series analysis comparing four countries (Finland, Norway, Sweden, and Australia) with a national multisectoral suicide prevention programs with four similar control countries (Canada, Austria, Switzerland and Denmark). They found that national suicide prevention strategies were effective but effects vary by age and gender. The largest reductions in suicide rates were found for males and for people aged 25 to 44 years and 45 to 64 years.

Matsubayashi and Ueda (2011) also found heterogenous effects for national multisectoral suicide prevention strategies, although their results contrasted Lewitzka et al. (2019) in respect to age. The authors implemented a fixed effect model to assess the relationship between suicide rates and the presence of a prevention program across 21 OECD countries. They found effects were greatest for males and the elderly population (aged 65 years and over). These results align directly with our study.

Matsubayashi and Ueda (2011) also found that prevention programs also reduced suicide rates for people aged less than 24 years, and while our results suggest costs were not significantly impacted by LifeSpan for people aged 10-18 years, this does not preclude a reduction in suicide rates for this age group.

Differences in effects on health care utilisation and costs across LHNs suggest implementation processes and the way program strategies are coordinated, can significantly impact success. Multisectoral suicide prevention strategies are necessarily complex, needing to address the complex, interactive risk factors associated with suicide and self-harm. Barriers and enablers will vary across settings, which should be identified prior to implementation and managed throughout, with regular monitoring of progress. Implementation plans should be tailored to local settings and culture. (Reifels et al., 2022)

Experiences in the US suggest multisectoral suicide prevention strategies must be implemented comprehensively, noting the need for investment in community level suicide prevention infrastructure, and the need to ensure a coordinated suicide prevention effort. (Office of the Surgeon General, Substance Abuse and Mental Health Services Administration (SAMHSA), 2017) An evaluation of the Optimizing Suicide Prevention Programs and Their Implementation in Europe project, implemented in Ireland, Portugal, Hungary, and Germany, also showed implementation mattered for success, particularly building social capital into the program. (Harris et al., 2013)

Even though evidence on effects of LifeSpan on self-harm rate persists, (SHAND, 2024) our study suggests that health care cost effects from multisectoral suicide prevention programs may dissipate once investment stops. Stakeholders may lose interest, communication and coordination slows or stops, leadership wanes, and access to resources disappears. (Sinyor et al., 2024) Multisectoral suicide prevention strategies require coordination built on community relationships, which can weaken if not continually nurtured. (King et al., 2022) Investment in workplace relationships must also be ongoing as those initially organising and delivering services within a multisectoral prevention strategy may focus on new initiatives, move roles or change organisations.

The limitation of our study primarily rests in our reliance on parallel trends between the treated and control LHNs. While our event study plots suggested no trend in outcome differences between the treatment and control, Roth (2022) suggests conventional pre-tests have low power to reject the hypothesis of no trends. This is particularly the case when parallel trends are non-linear. As event study plots investigate linear differences in outcomes, bias in treatment effects found within our study may remain. Adding more pre-treatment periods would be unhelpful if the counterfactual is driven only by periods close to treatment and could make the bias worse.

Roth (2022) provides a way forward for assessing the power of conventional pretests against hypothesised non linear trends, while Blinsky and Hatfield (2018) propose alternative approaches to pretesting that examine what magnitude of the pre-trend can be rejected. Other estimators allow for some divergence from parallel trends. (Freyaldenhoven et al., 2019, Rambachan and Roth, 2023) While these alternative approaches could be employed within our study, they too require restrictions and do not completely remove the potential for failing to reject parallel trends when they do not exist.

The strength of our study rests in our identification strategy. It was based on similar LHNs with a mix of socioeconomic status that face the same population health challenges. Each LHN is governed by the

NSW Ministry of Health, while MBS subsidised services and PBS subsidised services are governed within LHNs by the federal government. This macro governance structure of LHNs, and the location of all LHNs within the same state are expected to reduce the risk of external shocks derived from differing government policy and different macroeconomic conditions. This lends support to the assumption that parallel trends for healthcare use and costs conceptually exist between the four treated LHNs and the two control LHNs.

A further strength of our study was access to a large linked government administrative dataset that follows individuals over time across emergency department and inpatient hospital services, primary care, specialist and allied health services, and pharmaceuticals. It allowed for the staggered adoption of LifeSpan and multiple LHNs to be assessed individually, with our estimator circumventing potential bias associated with using TWFE with multiple leads and lags, which is common in the literature. Prior studies on the impact of suicide prevention programs have focused on the overall effects after the trial has finished and therefore have not captured the temporal change in effects. Our event study approach estimated effects for each quarter LifeSpan was implemented, revealing that suicide prevention strategies take time to impact healthcare seeking behaviours, and their effects potentially dissipate if investment is removed.

Another limitation revolves around unpacking impacts of each component of LifeSpan strategies on healthcare resource use and costs. We could not achieve this as the strategies were implemented simultaneously within LHNs. Our results could reflect the impact of only one successful strategy, all nine successful strategies working independently, all nine successful strategies working in synergy, or any combination of strategies being successful.

7. Conclusion

Our study analysed the causal impact of LifeSpan, a multisector multilevel suicide prevention strategy, on healthcare use and costs. Our results highlighted variations in effects across different LHNs, but an overall decrease in healthcare use and costs, with deepened effects as the implementation matured. The reduction in costs was most associated with a reduction in healthcare use as unit costs were relatively stable. Effects started to dissipate as the trials finished within each LHN, suggesting that changed behaviours within the community and healthcare system are unlikely to persist without continued effort. We were unable to draw conclusions on the contributing effects of each LifeSpan strategy, however our study found effects differed across individual characteristics, who varied in their exposure to each strategy, suggesting some strategies may have contributed more to the effects than others.

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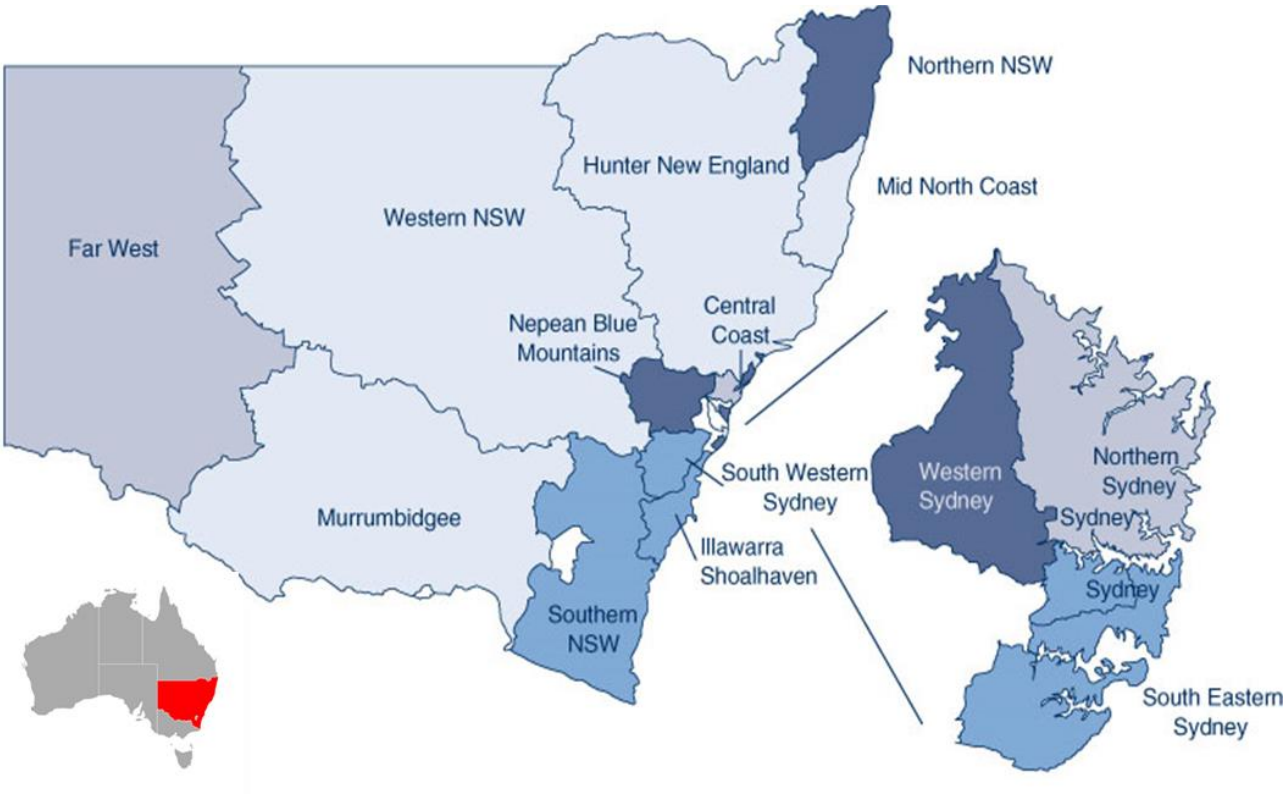
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Appendix A

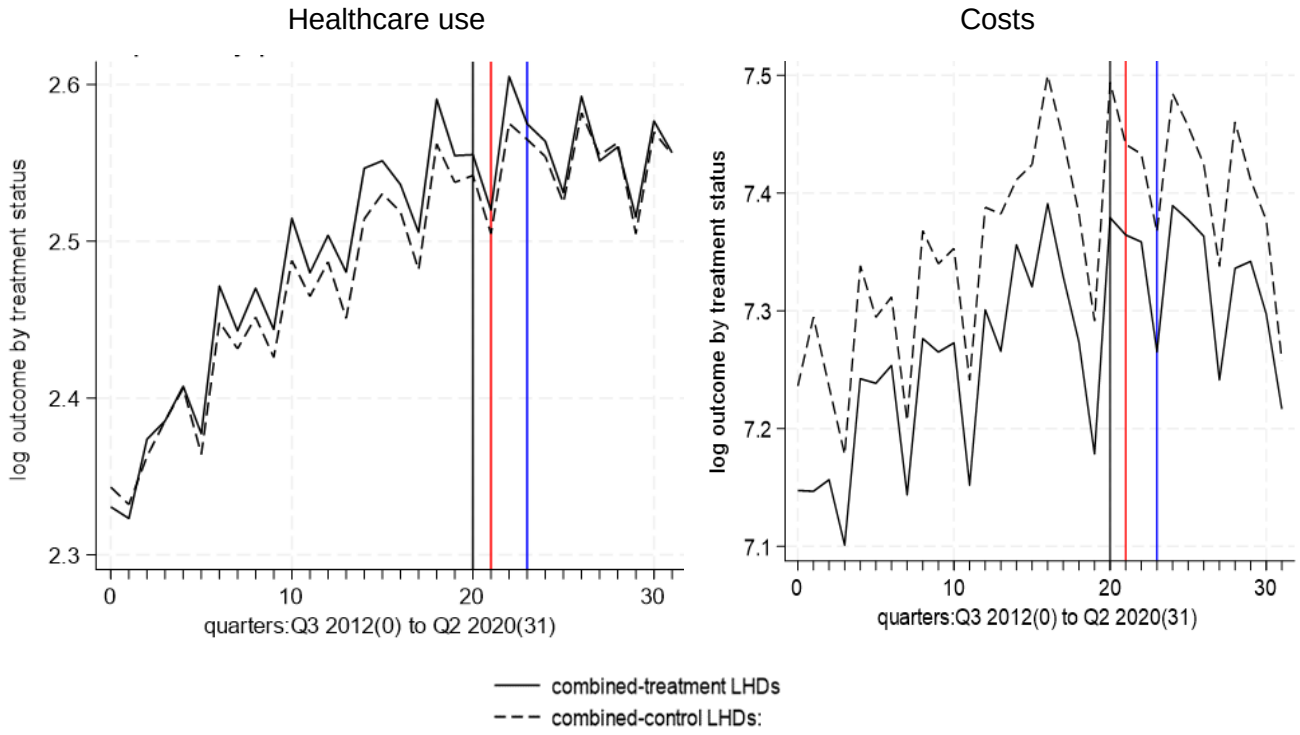
Figure A.1: Map of geographically based LHNs in NSW



Note: Four LHNs implemented LifeSpan, including Site 1= Hunter New England (Newcastle); Site 2 = Illawarra Shoalhaven; Site 3 = Central Coast; Site 4 = Murrumbidgee

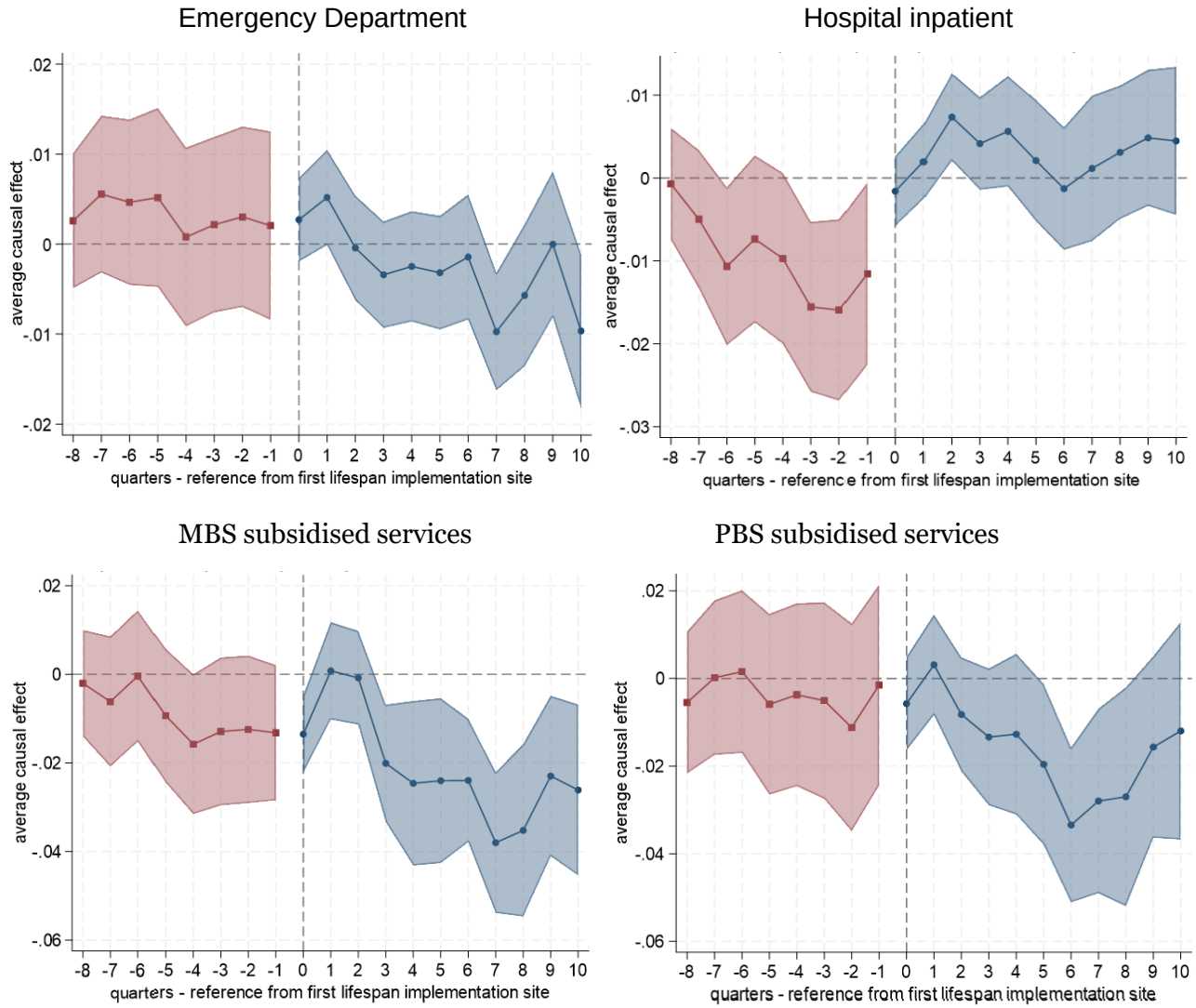
Appendix B

Chart B.1: Trends in healthcare use and cost over time by treatment



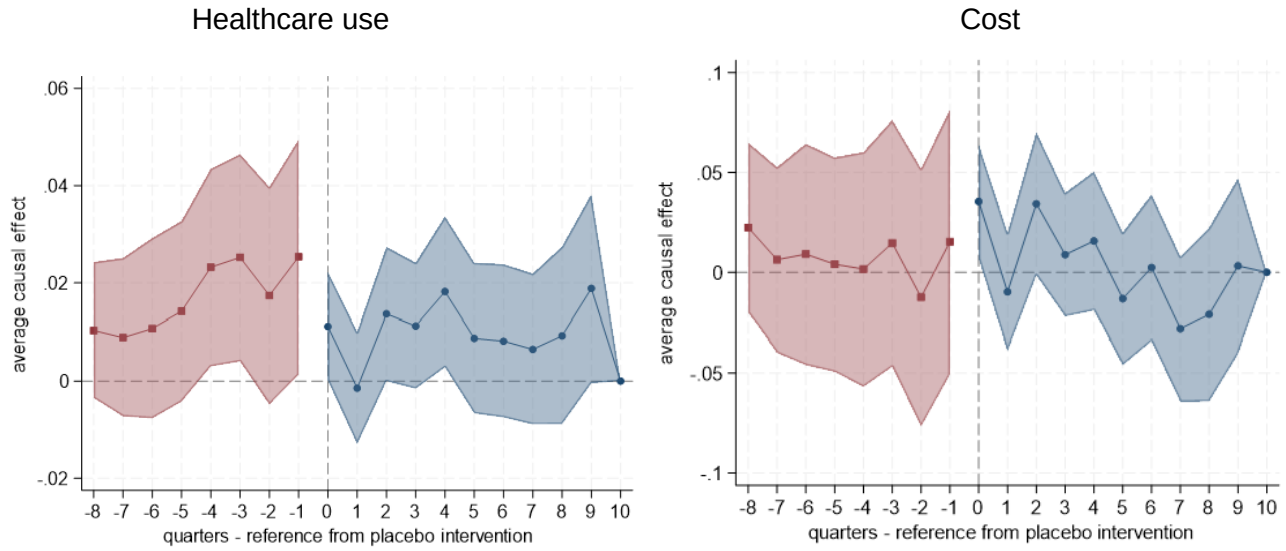
Note: Outcomes represent average quarterly utilisation and costs per-patient across combined treatment and control LHNs. The black line represents the start of LifeSpan implementation in sites 1 and 2, the red line represents the start of LifeSpan implementation in site 3, while the blue line represents the start of LifeSpan implementation in site 4.

Chart B.2: Event study plot of cumulative ITT effects on individual healthcare use



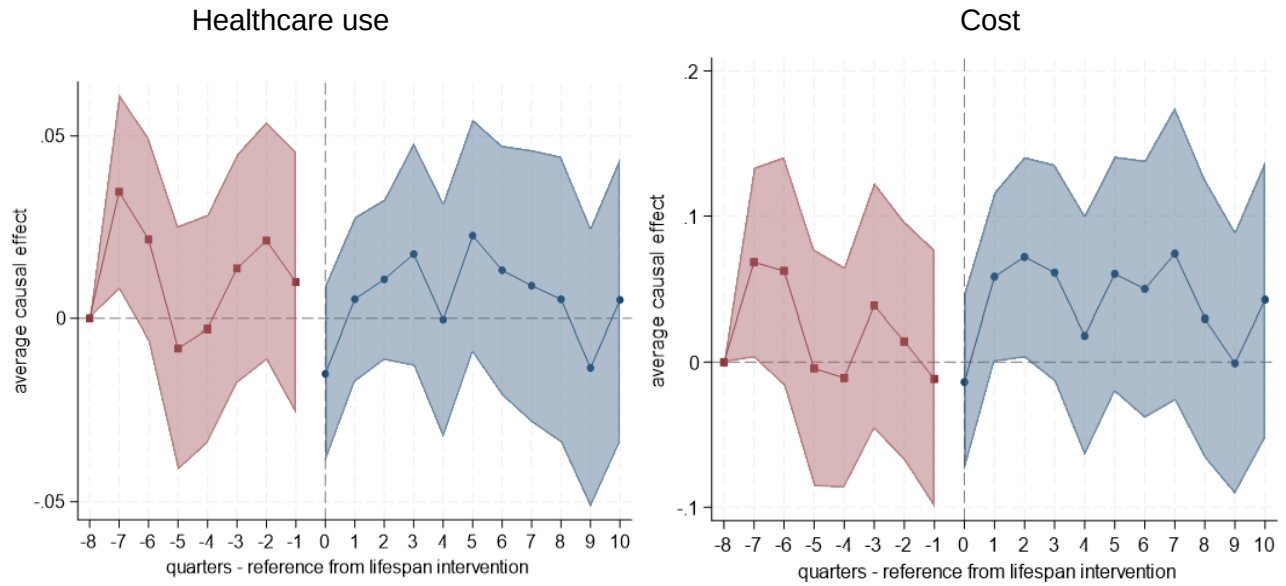
Note: MBS = Medicare Benefits Schedule; PBS = Pharmaceutical Benefits Schedule

Chart B.3: Event study plot of placebo test



Note: A placebo test was undertaken by moving the LifeSpan start dates back two years, using data that only represents the pre-treatment period (Q2 2013 to Q2 2017). LifeSpan was assumed to start in Q1 2015 for sites 1 and 2, Q2 2015 for site 3 and Q3 2015 for Site 4. These were compared to the same two control LHNs.

Chart B.4: Event study plot of negative control test



Note: A negative control test was undertaken by randomly selecting one control LHN and labelling it as treated, while retaining the other control LHN. All four treated LHNs were removed from the analysis. The proxy treated LHN was assumed to start LifeSpan in the same quarter as the first two sites, using the same pre-treatment and post treatment periods.