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What affects the public healthcare costs of breast cancer in New Zealand?

Chunhuan Lao[1] | Mohana Mondal[1] | Marion Kuper-Hommel[2] | Ian Campbell[3,4] | Ross Lawrenson[1,5]

[1]Medical Research Centre, The University of Waikato, Hamilton, New Zealand

[2]Medical Oncology, Waikato District Health Board, Hamilton, New Zealand

[3]School of Medicine, The University of Auckland, Auckland, New Zealand

[4]General Surgery, Waikato District Health Board, Hamilton, New Zealand

[5]Strategy and Funding, Waikato District Health Board, Hamilton, New Zealand

Correspondence
Chunhuan Lao, Medical Research Centre, University of Waikato, Private Bag 3105, Hamilton 3240, New Zealand.
Email: chunhuan.lao@waikato.ac.nz

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Abstract

Backgrounds: The pressure to the healthcare system for providing ongoing monitoring and treatment for breast cancer survivors is increasing. This study aims to identify the factors that affect the public healthcare costs of stage I–III breast cancer and stage IV cancer in New Zealand.

Methods: We identified women diagnosed with invasive breast cancer between July 1, 2010 and June 30, 2018 and who received services in a public hospital. Patients were identified from the National Breast Cancer Register and/or New Zealand Cancer Registry and were linked to the national administrative datasets. A two-part model was used to identify the factors that affect the public healthcare costs of stage I–III breast cancer and stage IV cancer.

Results: We identified 16,977 stage I–III and 1,093 stage IV breast cancer patients eligible for this study. The costs of stage I–III cancer in the second to fifth year post diagnosis decreased over time, and the costs of stage IV cancer in the first year post diagnosis increased over time. After adjustment for other factors, the costs of stage I–IV cancer decreased with age but increased with cancer stage. HER2+ cancers had the highest costs, followed by triple negative cancers. After adjustment for other factors, Pacific and Asian women had lower costs, and Māori had similar costs compared to others. For stage I–III cancers, women living in nonmajor urban areas had a higher chance of incurring costs in follow-up years, and screen detected patients and patients having any services in a private hospital had a decreased probability of receiving any public healthcare services.

Conclusions: Pacific women had higher costs than others, but after adjustment for cancer stage, subtype, and other factors, they had lower costs than others. The early detection and better management of stage I–III breast cancer can lead to better outcome and lower costs in follow-up years.

KEYWORDS
age, breast cancer, ethnicity, healthcare costs, stage, subtype

1 | INTRODUCTION

Breast cancer is the most common cancer among New Zealand women, affecting one in nine women over their lifetime.[1] Due to the growing and aging population and increasing screening coverage, breast cancer incidence has been rising steadily, from 2799 cases in 2009 to 3572 in 2018 (28% increase).[2] Mortality from breast cancer (both in terms of number of deaths and mortality rates) is declining,[1,3] with 80% of breast cancer patients surviving more than 10 years. The pressure to the healthcare system for providing ongoing monitoring and treatment for breast cancer survivors is also increasing.

Breast cancer was the most expensive cancer to treat in New Zealand, with breast cancer diagnosis and treatments accounting for 15% of the total costs of cancer in New Zealand.[4] The economic burden of breast cancer keeps rising in New Zealand.[4] Overseas studies have shown that breast cancer diagnosis and treatment costs vary by ethnicity, age, cancer stage and biomarker status (estrogen receptor [ER], progesterone receptor, and human epidermal growth factor receptor 2 [HER2]).[5,6] No studies in New Zealand have been conducted to examine how patient demographics and tumor characteristics affect the costs of breast cancer.

The treatment pattern and prognosis of stage I–III breast cancer are very different from stage IV breast cancer. Therefore the costs are expected to be different between these two groups. This study aims to identify the factors that affect the public healthcare costs of stage I–III breast cancer and stage IV cancer in New Zealand.

2 | MATERIALS AND METHODS

2.1 | Data sources

All women diagnosed with invasive (stage I-IV) breast cancer between July 1, 2010 and June 30, 2018 were identified from the National Breast Cancer Register (NBCR) and/or from the New Zealand Cancer Registry. The identified breast cancer patients, who received healthcare services in a public hospital, were included in this study. The eligible breast cancer patients were linked with the Pharmaceutical Collection (PHARMS, including all publicly funded pharmaceuticals prescribed in both public and private hospitals), National Minimum Dataset (NMDS, including all publicly funded inpatient records), National Non-Admitted Patients Collection (NNAPC, including all publicly funded outpatient records), the Mortality Collection (MORT, coded mortality information), and death certificates (uncoded mortality information). The data linkage was through the National Health Index (NHI) number. NHI number is a unique identifier for people using publicly funded health and disability services in New Zealand.

2.2 | Cancer care pathway

We divided the cancer care pathway into two phases: (1) the initial treatment phase (TP, 3 months preceding and 12 months following diagnosis of breast cancer) and (2) the follow-up phase (second to fifth year following diagnosis) for stage I–III cancers and on-going treatment phase (second to fifth year following diagnosis) for stage IV cancers. We further broke down the follow-up phase/on-going treatment phase into the year 2(Y2), year 3(Y3), year 4(Y4), and year 5(Y5). We considered the date of death or the latest date of service (31/12/2019) available in the NNAPC, NMDS, and PHARMS as the censor date whichever was earlier. The estimation of costs for each phase only included patients who had follow-up time for that phase.

2.3 | Cost estimation

The cost estimation was from the Ministry of Health perspective. We only included public medical costs, that is, costs for public outpatient services, public inpatient services, and funded pharmaceuticals (public or private hospital prescribed). Our clinical advisors checked the purchase unit codes definitions for outpatient services (in NNAPC), surgery codes for inpatient services (in NMDS), and pharmaceuticals. This study only included the inpatient, outpatient, and pharmaceutical records relevant to breast cancer. Diagnostic service costs (e.g., radiology and pathology) were included in the inpatient and outpatient costs. For pharmaceuticals, relevant endocrine therapy, chemotherapy, and HER2 targeted therapies were included. To avoid overestimation of costs, we did not include other medications such as those for pain relief as we could not identify whether they were related to breast cancer. All cost estimations were based on 2019/2020 New Zealand Dollars (NZ$, 1 NZ$ = .645 US$, 1NZ$ = .568€).[7]

Inpatient costs were estimated by multiplying the accumulated cost weights for all relevant events with the purchase unit price set by the National Pricing Programme. The cost weights provide resource utilization information and are calculated by the Ministry of Health for each diagnosis-related group code using the Weighted Inlier Equivalent Separation method. The Ministry of Health sets a purchase unit price for each year. The 2019/2020 cost-weight unit price was NZ$5,216.21.[8] Outpatient costs were estimated by multiplying the number of relevant outpatient visits recorded in the NNAPC with the outpatient visit unit cost (based on District Health Board contracted purchase unit prices). The publicly funded pharmaceutical costs were estimated by multiplying the quantity of pharmaceuticals dispensed by the unit prices for each pharmaceutical that appears in the Pharmaceutical Schedule.[9]

2.4 | Econometric model

Healthcare expenditure data have mixed distributions, characterized by a disproportionate proportion of zero-cost observations (nonusers) and a right-skewed distribution.[10] Therefore, we introduced a two-part model to identify what factors affect costs and to predict breast cancer costs with known patient factors.[11–13] All data analysis was conducted separately for stage I–III and stage IV cancers. In the first part of the model, we used a logit model to predict the probability of incurring a

cost in a given time period. In the second part of the model, we used a generalized linear model (GLM) model to estimate the costs conditional on the first part of model predicting positive probability. The GLM model used a gamma distribution and log link function.[17] An odds ratio (OR) higher than one in the logit model implies a higher probability of incurring a cost, and a positive coefficient in the GLM model means higher cost. Because this study only included patients who received healthcare services in a public hospital, all eligible patients incurred costs during in TP. Therefore, the first part of the model was not deemed necessary for TP, and only the GLM model was used.

For the two-part model, we included year of diagnosis, age group (<45, 45–59, 60–69, 70–79, and 80+ years), ethnicity (Māori, Pacific, Asian, and others), cancer stage (only for stage I–III cancers), subtype, socio-economic status (deprivation quintile estimated based on the NZDep2013 groups deprivation scores),[14] rurality (major urban versus other locality),[15] mode of detection (screen detected and symptomatic), and whether they had received any treatments in private hospitals as the predictor variables. Based on their prognosis and treatment pattern, breast cancer subtypes were categorized into three groups according to biomarker status: ER+/HER2-, HER2+, and triple negative.

All data analyses were performed in R Studio (Massachusetts, United States). Ethics approval for the study was granted through the Northern B Health and Disability Ethics Committee (reference: 19/NTB/188).

3 | RESULTS

During the study period, 16,977 stage I–III and 1,093 stage IV breast cancer patients received treatments in a public hospital (Appendix Table 1). The majority of these patients were aged 45–69 years, and 11.7% were Māori, 5.4% Pacific and 6.4% Asian. Most of them had stage I–II cancer, and majority had ER+/HER2- disease. Fifty-three percent of patients lived in major urban area, and 41.9% of the patients were screen detected. For stage I–III cancers, most (66.5%) of the healthcare costs were incurred in the TP (NZ$32,159), and the costs declined across the following years from NZ$6,788 in Y2 to NZ$2,915 in Y5(Table 1). For stage IV cancer, the costs were high across the whole follow-up period with $33,298 in TP, $22,010 in Y2, $20,632 in Y3, $19,008 in Y4 and $16,334 in Y5. The costs differed by subgroup.

For stage I–III cancer, the two-part model showed that the likelihood of receiving treatment in a public hospital in Y3–Y5 decreased overtime (Table 2, adjusted OR < 1 Appendix Table 2), and the associated costs also decreased overtime in Y2-Y5(Table 3, coefficient < 0) after adjustment for other factors. The costs of stage I-III cancer in TP did not change with time. For women aged 80 years or older, they were less likely to receive treatment in Y3–Y5 (OR < 1). Compared to women aged 45–59 years, the OR of having treatments in Y2 was 1.57 (95% confidence interval: 1.32–1.89) for women aged less than 45 years, and .89, .71, and .53 for those aged 60–69, 70–79, and 80+ years. This association was consistent when estimating the costs using the GLM model (Table 3), with negative correlation (negative coefficients) between age and costs from TP to Y5. Compared to others, Pacific and Asian women were less likely to incur costs in public hospitals in Y2 and Y3 (adjusted OR < 1 in Table 2). When estimating the costs (Table 3), there was a negative correlation between costs for Pacific and Asian women compared to costs for others (coefficient < 0).

For stage I–III cancer, both the probability of incurring any cost and the amount of costs increased with cancer stage for all follow-up years (Tables 2 and 3, adjusted OR > 1 and coefficient > 0). Compared to patients with ER+/HER2- cancer, patients with HER2+ cancer were significantly more likely to incur costs in Y2 (adjusted OR > 1) but were less likely to incur costs in Y3-Y5(adjusted OR < 1). Patients with triple negative cancers were less likely to incur costs in Y2–Y5 (adjusted OR < 1). When estimating the costs (Table 3), HER2+ cancers and triple negative cancers had higher costs during the TP-Y5 than ER+/HER2- cancers (coefficient > 0). Women living in nonmajor urban areas had a higher probability of incurring costs in Y2-Y5 (adjusted OR > 1), but their incurring costs were similar to the costs for women living in major urban areas. Being screen detected and having any services in a private hospital were associated with a decreased probability of receiving any public healthcare services (Table 2).

For stage IV cancer, the differences in probabilities of incurring costs by subgroup were not significant after adjustment for other factors, except for Pacific women who had a lower chance of incurring costs in Y3 and Y5 compared to others (adjusted OR < 1 in Table 4). When estimating the costs for stage IV cancers with the GLM model (Table 5), there was a negative correlation between age and costs (coefficient < 0). Asian and Pacific women had lower costs than costs than others in Y2 (coefficient < 0). HER2+ cancers had higher costs than ER+/HER2- cancers throughout the whole study period (coefficient > 0), and triple negative cancers had higher costs than ER+/HER2- cancers but only in TP (coefficient > 0). Other factors were not significant in the two-part model for stage IV cancers.

4 | DISCUSSION

This study found that the costs of stage I-III breast cancer were associated with year of diagnosis, patient age, ethnicity, cancer stage, cancer subtype, socioeconomic status, mode of detection, and rurality. The costs of stage I–III breast cancer in TP did not change in 2010–2018, but the costs in FU2-FU5 decreased over time. This can be attributed to the reduced risk of metastatic relapse over time.[16] This result is encouraging. Better management for stage I–III cancers in the first year post diagnosis can improve prognosis and reduce follow-up costs. The costs of stage IV breast cancer were associated with year of diagnosis, patient age, ethnicity, and subtype. The costs of stage IV cancer in TP increased over time. This is probably related to Pharmac funding pertuzumab for HER2+ advanced breast cancer in January 2017.[17]

Both the costs of stage I–III breast cancer and the costs of stage IV cancer decreased with age before and after adjustment for other factors including stage and subtype. Our previous papers showed that

TABLE 1 Estimated mean costs for breast cancer patients from two-part model

	Stage I-III					Stage IV				
Subgroup	**TP**	**Y2**	**Y3**	**Y4**	**Y5**	**TP**	**Y2**	**Y3**	**Y4**	**Y5**
Year of diagnosis										
2010–2012	$31,918	$7,780	$3779	$3687	$3272	$29,556	$20,960	$20,883	$17,370	$17,443
2013–2015	$32,236	$6,792	$3193	$3259	$2641	$32,409	$20,736	$18,483	$20,745	$15,331
2016–2018	$32,263	$6,000	$2857	$1839	NA	$39,372	$25,250	$24,387	$17,937	NA
Ethnicity										
Māori	$37,282	$7643	$3479	$3058	$3089	$41,501	$25,103	$21,954	$25,254	$21,496
Pacific	$38,364	$11,053	$3366	$3981	$3607	$36,446	$20,852	$23,738	$18,887	$17,185
Asian	$32,713	$6690	$2707	$2514	$2754	$37,721	$21,315	$21,089	$25,710	$18,682
Others	$30,926	$6385	$3287	$3246	$2859	$31,111	$21,682	$19,996	$17,562	$15,345
Age (years)										
<45	$43,350	$12,832	$5689	$6163	$4678	$54,656	$32,618	$33,942	$35,166	$25,821
45–59	$34,874	$7891	$3651	$3370	$3175	$42,003	$27,950	$21,787	$18,875	$15,262
60–69	$29,866	$4799	$2143	$2077	$2141	$29,758	$18,635	$20,837	$22,571	$19,425
70–79	$26,242	$4216	$2822	$3136	$2378	$24,764	$15,611	$14,079	$7,431	$10,129
80+	$20,738	$2319	$2270	$1781	$2286	$13,911	$4,954	$4,099	$2,548	$3,985
Cancer stage										
Stage I	$27,255	$4549	$2215	$2151	$2538					
Stage II	$32,431	$6524	$3027	$2808	$2421					
Stage III	$39,814	$10,518	$5191	$5294	$4204					
Stage IV						$33,298	$22,010	$20,632	$19,008	$16,334
Subtype										
ER+/HER2-	$26,056	$3035	$2594	$2337	$2199	$21,331	$11,217	$10,723	$9,092	$8,321
HER2+	$63,575	$23,864	$6068	$6581	$5786	$75,596	$56,115	$55,299	$51,527	$43,549
Triple negative	$28,383	$4977	$5131	$5863	$4753	$33,397	$17,417	$8,069	$4,630	$14,218
Deprivation quintile										
1 (least deprived)	$28,674	$6290	$3310	$3005	$2632	$33,005	$19,609	$18,295	$15,179	$10,410
2	$30,445	$6693	$2969	$3025	$2779	$34,296	$23,653	$24,033	$24,042	$22,468
3	$31,881	$6543	$3122	$3078	$3260	$31,711	$22,410	$24,505	$18,191	$14,576
4	$34,151	$6583	$3427	$3580	$2898	$31,878	$20,907	$16,603	$18,948	$20,014
5 (most deprived)	$35,639	$7828	$3574	$3368	$2990	$35,055	$23,327	$20,612	$18,821	$13,842
Rurality										
Major urban	$32,036	$7277	$3759	$3601	$3111	$34,722	$24,466	$21,623	$21,177	$20,241
Others	$32,329	$6242	$2773	$2785	$2695	$31,661	$19,086	$19,266	$16,052	$11,234
Mode of detection										
Symptomatic	$33,422	$8106	$4214	$4276	$3668	$36,802	$22,849	$20,762	$19,239	$18,415
Screen-detected	$29,599	$5920	$2951	$2873	$2468	$34,401	$27,875	$25,624	$26,745	$21,457
Received any treatment in private hospitals										
No	$35,554	$6994	$3582	$3401	$3073	$33,247	$20,927	$18,798	$17,206	$15,476
Yes	$16,532	$5822	$1970	$2427	$2278	$34,224	$35,982	$38,878	$35,637	$24,427
Total	$32,159	$6788	$3279	$3215	$2915	$33,298	$22,010	$20,632	$19,008	$16,334

TABLE 2 Adjusted odds ratio of incurring costs from the logit regression model for stage I-III breast cancers

Subgroup	Y2 OR (95% CI)	Y3 OR (95% CI)	Y4 OR (95% CI)	Y5 OR (95% CI)
Year (continuous)	1.01 (.99–1.03)	.93 (.91–.94)***	.90 (.88–.92)***	.87 (.84–.89)***
Age group				
<45	1.57 (1.32–1.89)***	1.13 (.98–1.31)	.98 (.85–1.14)	1.03 (.88–1.21)
45-59	Reference			
60-69	.89 (.80–.98)*	1.00 (.90–1.10)	1.03 (.93–1.14)	1.16 (1.03–1.29)*
70-79	.71 (.62–.81)***	.91 (.80–1.03)	1.02 (.89–1.18)	1.08 (.93–1.27)
80+	.53 (.45–.62)***	.63 (.53–.74)***	.65 (.55–.78)***	.71 (.58–.86)***
Ethnicity				
Māori	1.14 (.98–1.33)	1.10 (.96–1.26)	1.01 (.87–1.17)	1.06 (.90–1.24)
Pacific	.65 (.54–.80)***	.77 (.64–.93)**	.82 (.67–1.01)	.93 (.74–1.18)
Asian	.78 (.66–.92)**	.80 (.68–.94)**	.98 (.82–1.17)	1.10 (.91–1.35)
Others	Reference			
Cancer stage				
Stage I	Reference			
Stage II	1.55 (1.41–1.70)***	1.46 (1.34–1.60)***	1.55 (1.41–1.70)***	1.52 (1.37–1.69)***
Stage III	3.01 (2.62–3.46)***	2.71 (2.39–3.07)***	2.48 (2.18–2.83)***	2.26 (1.97–2.59)***
Subtype				
ER+/HER2-				
HER2+	1.90 (1.64–2.22)***	.88 (.79–.99)*	.86 (.76–.97)*	.80 (.70–.91)***
Triple negative	.28 (.25–.32)***	.25 (.22–.28)***	.26 (.22–.30)***	.27 (.23–.31)***
Deprivation (quintile)				
1 (Most deprived)	Reference			
2	1.10 (.96–1.25)	1.22 (1.09–1.38)***	1.21 (1.07–1.38)**	1.14 (.99–1.31)
3	1.03 (.91–1.17)	1.05 (.93–1.18)	1.09 (.96–1.24)	1.07 (.93–1.23)
4	1.31 (1.14–1.50)***	1.38 (1.21–1.56)***	1.24 (1.08–1.41)**	1.13 (.98–1.31)
5 (Least deprived)	1.01 (.88–1.17)	1.05 (.92–1.19)	1.29 (1.11–1.49)***	1.22 (1.04–1.43)*
Rural/Urban				
Major urban	Reference			
Others	1.22 (1.11–1.34)***	1.27 (1.16–1.38)***	1.21 (1.10–1.32)***	1.15 (1.04–1.27)**
Mode of detection				
Symptomatic	Reference			
Screen detected	.62 (.56–.70)***	.70 (.63–.77)***	.80 (.72–.90)***	.87 (.77-.98)*
Received any treatment in private hospitals				
No	Reference			
Yes	.74 (.66–.82)***	.77 (.70–.85)***	.79 (.71–.87)***	.83 (.74-.93)**

*** < .001, ** < .01, * < .05.

younger women were more likely to be diagnosed with advanced cancer and more aggressive subtype, and they receive more treatment than older women.[18,19] Increasing age was associated with decreasing use of surgery, adjuvant radiotherapy, endocrine therapy, and chemotherapy, even after adjustment for stage and level of comorbidity.[18,19] Before adjustment for other factors, Māori and Pacific patients seemed to incur higher public healthcare costs. However, after adjustment, Māori patients had equivalent costs, and Pacific patients had lower costs than others for both stage I–III cancer and stage IV cancer. This can be partly explained by that Māori and Pacific women were younger, had more advanced cancer at diagnosis and more aggressive subtypes.[20–22] Māori and Pacific women were less likely to receive trastuzumab when diagnosed with HER2+ breast cancer.[22,23] Māori and Pacific women were less likely to receive treatment in private hospital than New Zealand European women, and this study only included public healthcare costs but excluded the private

TABLE 3 Coefficients for predicting costs from the generalized linear model (GLM) model for stage I-III breast cancers

Subgroup	TP coefficient (95% CI)	Y2 coefficient (95% CI)	Y3 coefficient (95% CI)	Y4 coefficient (95% CI)	Y5 coefficient (95% CI)
Year of diagnosis (continuous)	.00 (.00–.01)	−.03 (−.05–(−.01))*	−.06 (−.09–(−.02))***	−.07 (−.11–(−.03))***	−.08 (−.14–(−.01)*
Age group					
<45	.10 (.05–.14)***	.35 (.19–.52)***	.28 (.06–.50)*	.39 (.14–.64)**	.14 (−.18–.46)
45–59	Reference				
60–69	−.14 (−.16–(−.11))***	-.39 (-.52–(-.27))***	−.48 (−.65–(−.32))***	−.43 (−.61–(−.24))***	−.36 (−.59–(−.13))**
70–79	−.34(−.38–(−.31))***	−.50 (−.65–(−.33))***	−.33 (−.54–(−.11))**	−.16 (−.40–.08)	−.42 (−.73–(−.09))**
80+	−.61(−.66–(−.56))***	−.96 (−1.16–(−.75))***	−.67 (−.94–(−.38)***	−.64 (−.96–(−.30))***	−.46 (−.88–.00)*
Ethnicity					
Māori	−.02 (−.06–.02)	−.13 (−.29–.03)	−.13 (−.33–.09)	−.05 (−.29–.19)	−.09 (−.39–.23)
Pacific	−.14 (−.20–(−.08))***	−.13 (−.36–.12)	−.59 (−.90–(−.25))***	−.24 (−.58–.13)	−.18 (−.62–.30)
Asian	−.11 (−.16–(−.06))***	−.43 (−.63–(−.21))***	−.65 (−.93–(−.36)***	−.58 (−.88–(−.25))***	−.40 (−.77–.01)
Others	Reference				
Cancer stage					
Stage I	Reference				
Stage II	.16 (.14–.19)***	.17 (.06–.29)**	.13 (−.03–.28)	.12 (−.06–.29)	-.08 (-.30–.15)
Stage III	.32 (.28–.35)***	.51 (.38–.65)***	.55 (.36–.73)***	.51 (.29–.72)***	.21 (−.06–.49)
Subtype					
ER+/HER2-	Reference				
HER2+	.98 (.94–1.01)***	2.03 (1.90–2.17)***	.78 (.59–.96)***	.98 (.78–1.20)***	1.00 (.74–1.28)***
Triple negative	.11 (.07–.15)***	.49 (.29–.69)***	.57 (.29–.87)***	.80 (.48–1.14)***	.75 (.35–1.20)***
Deprivation (quintile)					
1 (Most deprived)	Reference				
2	.05 (.01–.08)*	.16 (.00–.32)*	−.05 (−.26–.16)	.01 (−.23–.24)	.03 (−.27–.33)
3	.04 (.00–.08)*	.01 (−.15–.17)	−.11 (−.32–.10)	−.02 (−.26–.22)	.14 (−.16–.44)
4	.08 (.04–.12)***	.06 (−.10–.21)	.00 (−.21–.21)	.17 (−.07–.40)	.04 (−.26–.35)
5 (Least deprived)	.06 (.02–.10)**	.14 (−.03–.31)	.04 (−.18–.26)	.04 (−.21–.29)	.02 (−.31–.34)
Rural/Urban					
Major urban	Reference				
Others	.02 (−.01–.05)	−.05 (−.16–.05)	−.23 (−.37–(−.08))**	−.15 (−.31–.02)	−.10 (−.30–.10)
Mode of detection					
Symptomatic	Reference				
Screen detected	−.04 (−.07–(−.01))*	−.04 (−.17–.09)	−.03 (−.21–.16)	−.03 (−.23–.17)	−.11 (−.37–.15)
Received any treatment in private hospitals					
No	Reference				
Yes	−1.05 (−1.08–(−1.01))***	−.54 (−.67–(−.40))***	−.67 (−.84–(−.49))***	−.45 (−.64–(−.26))***	−.55 (−.79–(−.30))**

*** <.001, ** <.01, * <.05.

costs. Asian women had lower costs than others, which is probably associated with the lower probability of metastatic relapse for Asian women.[24]

Consistent with overseas findings, this study also found that breast cancer costs are higher for patients whose breast cancer is more advanced at diagnosis.[25–27] Patients with stage I disease had the lowest costs across all phases. This is because they were less likely to receive adjuvant therapy and were less likely to have cancer recurrence or metastatic relapse in following years. For patients with metastatic breast cancer, the costs during the Y2–Y5 were substantially higher than other cancer stages. It was because more endocrine therapies, chemotherapy, HER2 targeted therapies and bisphosphonates and radiation therapy were used for metastatic breast cancer in the following years. The higher costs for HER2+ cancers were due to the

TABLE 4 Adjusted odds ratio of incurring costs from the logit regression model for stage IV breast cancers

Subgroup	Y2 OR (95% CI)	Y3 OR (95% CI)	Y4 OR (95% CI)	Y5 OR (95% CI)
Year (continuous)	1.07 (.95–1.22)	.95 (.83–1.10)	.94 (.78–1.14)	1.07 (.83–1.39)
Age group				
<45	1.39 (.61–3.41)	1.52 (.63–3.92)	1.03 (.40–2.83)	.77 (.25–2.40)
45–59	Reference			
60–69	2.15 (.88–6.08)	2.20 (.87–6.36)	3.64 (.97–13.67)	2.41 (.73–9.62)
70–79	.81 (.38–1.79)	.89 (.40–2.01)	1.78 (.68–5.07)	1.93 (.60–7.03)
80+	.93 (.38–2.47)	1.84 (.55–8.46)	.75 (.23–2.68)	3.16 (.48–64.15)
Ethnicity				
Māori	.95 (.40–2.53)	1.02 (.38–3.24)	6.59 (.82–52.70)	1.39 (.35–7.20)
Pacific	.42 (.18–1.04)	.32 (.13–.82)*	.41 (.14–1.21)	.29 (.09–.91)*
Asian	.72 (.22–3.28)	.32 (.10–1.12)	1.12 (.24–8.31)	1.09 (.22–8.27)
Others	Reference			
Subtype				
ER+/HER2-	Reference			
HER2+	.52 (.25–1.11)	.57 (.27–1.28)	1.04 (.40–3.00)	1.27 (.44–4.11)
Triple negative	.44 (.15–1.61)	NA	.64 (.16–3.27)	NA
Deprivation (quintile)				
1 (Most deprived)	Reference			
2	.80 (.28–2.19)	.69 (.25–1.82)	.49 (.15–1.49)	.49 (.09–2.13)
3	.72 (.25–1.94)	1.24 (.40–4.10)	1.05 (.29–3.75)	.52 (.10–2.28)
4	.93 (.32–2.49)	1.51 (.50–4.63)	1.42 (.40–5.03)	.72 (.13–3.36)
5 (least deprived)	.60 (.22–1.52)	.62 (.23–1.59)	.52 (.15–1.66)	.34 (.06–1.45)
Rural/Urban				
Major urban	Reference			
Others	.64 (.33–1.25)	1.20 (.57–2.56)	.79 (.35–1.79)	1.07 (.42–2.82)
Mode of detection				
Symptomatic	Reference			
Screen detected	1.05 (.33–4.69)	1.49 (.46–6.73)	NA	.73 (.22–2.68)
Received any treatment in private hospitals				
No	Reference			
Yes	1.35 (.44–5.96)	1.42 (.44–6.44)	1.27 (.41–4.89)	.81 (.21–3.55)

Note: NA: not available because the number in this subgroup is too small.
***<.001, **<.01, *<.05.

expensive HER2 targeted therapies. Trastuzumab has been funded for HER2+ metastatic breast cancer since 2002, and for HER2+ stage I–III breast cancer since 2007.[28] However, ER+/HER2- cancers had a higher chance of incurring costs in Y3–Y5 than HER2+ and triple negative cancers. This is probably because of the endocrine therapy, which is often recommended for 5–10 years for ER+ cancers.

Screen detected stage I–III breast cancers had lower costs than non-screen detected cancers. Most of screen detected cancers were stage I, ER+/HER2- cancers, and had a lower risk of disease recurrence. They were more likely to have lower costs, which would suggest that there is an economic benefit for breast cancer screening.[29] The two-part model showed that even after adjustment for cancer stage, subtype, and other patient factors, screening was still associated with lower breast cancer costs. There might be other economic benefits of breast screening other than identifying early stage and less aggressive cancers. However, screening can cause overdiagnosis and overtreatment and may lead to some unnecessary costs. Women with stage I–III cancers living in nonmajor urban areas had a higher chance of having costs in Y2–Y5 than women living in major urban areas. This may be associated with their worse prognosis than women living in urban areas.[30] Our study also showed that less deprived women incurred similar or higher costs compared with more deprived patients after adjustment for other factors, which suggest that there was no disadvantage in access to breast cancer treatments for those living in more deprived area.

One of the strengths of this study is that we had comprehensive data on all breast cancer patients by combining the NBCR data with

TABLE 5 Coefficients for predicting costs from the generalized linear model (GLM) model for stage IV breast cancers

Subgroup	TP coefficient (95% CI)	Y2 coefficient (95% CI)	Y3 coefficient (95% CI)	Y4 coefficient (95% CI)	Y5 coefficient (95% CI)
Year of diagnosis (continuous)	.06 (.03–.09)***	−.01 (−.08–.05)	−.04 (−.11–.03)	.05 (−.04–.13)	−.10 (−.23–.04)
Age group					
<45	.10 (−.12–.32)	−.25 (−.68–.19)	.19 (−.25–.64)	.36 (−.11–.84)	.03 (−.54–.62)
45–59	Reference				
60–69	−.33 (−.53–(−.12))**	−.65 (−1.04–(−.25))**	−.35 (−.77–.09)	−.14 (−.58–.30)	−.01 (−.52–.51)
70–79	−.47 (−.66–(−.27))***	−.54 (−.94–(−.12))**	−.23 (−.66–.22)	−.81 (−1.25–(−.36))***	−.64 (−1.18–(−.10))*
80+	−.89 (−1.11–(−.67))***	−1.39 (−1.88–(−.87))***	−1.18 (−1.73–(−.58))***	−1.52 (−2.10–(−.89)***	−.93 (−1.67–(−.11))*
Ethnicity					
Asian	−.07(−.38–.27)	−.71 (−1.30–(−.01))*	−.56 (−1.20–.20)	.39 (−.29–1.19)	.19 (−.55–1.04)
Māori	−.09 (−.31–.13)	−.18 (−.61–.28)	.01 (−.47–.52)	.12 (−.35–.64)	−.11 (−.75–.60)
Pacific	−.16 (−.39–.09)	−.52 (−.99–.00)*	−.08 (-.61–.49)	−.29 (−.85–.34)	−.40 (−1.21–.50)
Others					
Subtype					
ER+/HER2-	Reference				
HER2+	1.13 (.94–1.31)***	1.64 (1.27–2.01)***	1.62 (1.23–2.03)***	1.68 (1.25–2.12)***	1.70 (1.19–2.24)***
Triple negative	.37 (.12–.64)**	.34 (−.23–1.00)	−.49 (−1.17–.30)	−1.07 (−1.78–.23)**	.67 (−.08–1.55)
Deprivation (quintile)					
1 (Most deprived)	Reference				
2	−.10(−.33–.13)	−.06 (−.52–.40)	−.11 (−.59–.37)	−.43 (−.95–.08)	.06 (−.57–.70)
3	−.05 (−.29–.18)	.04 (−.43–.50)	−.02 (−.51–.47)	−.27 (−.77–.23)	−.15 (−.75–.45)
4	−.06 (−.28–.17)	.01 (−.43–.45)	−.42 (−.88–.03)	−.12 (−.61–.36)	.54 (-.07–1.13)
5 (least deprived)	−.04 (−.27–.19)	.27 (−.19–.71)	.09 (−.42–.60)	−.06 (−.59–.46)	.08 (−.62–.79)
Rural/Urban					
Major urban	Reference				
Others	.04 (−.12–.19)	−.09 (−.42–.23)	−.08 (−.42–.26)	−.06 (−.41–.29)	−.23 (−.63–.17)
Mode of detection					
Symptomatic	Reference				
Screen detected	−.29 (−.60–.04)	−.10 (−.62–.47)	−.20 (−.72–.36)	−.19 (−.69–.35)	−.42 (−1.04–.24)
Received any treatment in private hospitals					
No	Reference				
Yes	−.11 (−.40–.21)	.26 (−.25–.84)	.43 (−.08–1.00)	.65 (.13–1.21)*	.46 (−.21–1.19)

***<.001, **<.01, *<.05.

the national administrative datasets. Therefore, the detailed data on patient demographics and tumor characteristics enabled us to examine the factors that affect the costs of breast cancer. One of the limitations of this study is that we have only included endocrine therapy, chemotherapy, and HER2 targeted therapy but no other drugs that might have been used for breast cancer, for example, antiemetic drugs, grow factors, pain killers, and bisphosphonates because we could not identify whether these drugs were used for breast cancer or other diseases, for example, arthritis and osteoporosis. This study only estimated public healthcare costs. More research is needed on the private costs as well as patient costs.

5 | CONCLUSION

The costs of stage I–III breast cancer were associated with year of diagnosis, patient age, ethnicity, cancer stage, cancer subtype, socioeconomic status, mode of detection, and rurality. The costs of stage IV breast cancer were associated with year of diagnosis, patient age, ethnicity, and subtype. Pacific women had higher costs than others, but after adjustment for cancer stage, subtype and other factors, they had lower costs than others. The early detection and better management of stage I–III breast cancer can lead to better outcome and lower costs in follow-up years.

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CONFLICT OF INTEREST

The authors declare that they have no conflict of interest to declare.

DATA AVAILABILITY STATEMENT

The data used for this study are not publically available because of the ethics for patient information. They can be accessed through the National Breast Cancer Register and the Ministry of Health with appropriate ethics approval.

ETHICS STATEMENT

Ethics approval for the study was granted through the Northern B Health and Disability Ethics Committee, reference: 19/NTB/188.

ORCID

Chunhuan Lao https://orcid.org/0000-0002-2319-8916
Ross Lawrenson https://orcid.org/0000-0003-0437-8839

REFERENCES

1. Breast Cancer Foundation New Zealand. *Breast Cancer in New Zealand*. Breast Cancer Foundation New Zealand; 2021.
2. Ministry of Health. *New Cancer Registrations 2018*. Ministry of Health;2020.
3. Ministry of Health. *BSA New Zealand District Health Board Coverage Report: period ending 30 September 2018*. Ministry of Health; 2018.
4. Ministry of Health. *The Price of Cancer: The Public Price of Registered Cancer in New Zealand*. Ministry of Health;2011.
5. Yabroff KR, Lund J, Kepka D, Mariotto A. Economic burden of cancer in the United States: estimates, projections, and future research. *Cancer Epidemiol Biomarkers Prev*. 2011;20(10):2006-2014.
6. National Cancer Institute. *Financial Burden of Cancer Care*. National Cancer Institute; 2018. https://progressreport.cancer.gov/after/economic_burden
7. Organisation for Economic Co-operation and Development (OECD). *Exchange Rates*. OECD; 2022. https://data.oecd.org/conversion/exchange-rates.htm
8. *WIESNZ19 cost weights*. Ministry of Health. 2020. Accessed November 23, 2020. https://www.health.govt.nz/nz-health-statistics/data-references/weighted-inlier-equivalent-separations/wiesnz19-cost-weights
9. *Pharmaceutical Schedule*. PHARMAC. 2020 Accessed November 23, 2020. https://pharmac.govt.nz/pharmaceutical-schedule/
10. Powers CA, Meyer CM, Roebuck MC, Vaziri B. Predictive modeling of total healthcare costs using pharmacy claims data: a comparison of alternative econometric cost modeling techniques. *Med Care*. 2005;43(11):1065–1072.
11. Barnet SB, Nurmagambetov TA. Costs of asthma in the United States: 2002–2007. *J Allergy Clin Immunol*. 2011;127(1):145–152.
12. Vyas A, Madhavan SS, Sambamoorthi U, et al. Healthcare utilization and costs during the initial phase of care among elderly women with breast cancer. *J Natl Compr Canc Netw*. 2017. 15(11):1401–1409.
13. Ciminata G, Geue C, Langhorne P, Wu O. A two-part model to estimate inpatient, outpatient, prescribing and care home costs associated with atrial fibrillation in Scotland. *BMJ Open*. 2020;10(3):e028575.
14. Atkinson J, Salmond C, Crampton P. *NZDep2013 index of deprivation*. Dunedin: University of Otago; 2014.
15. Statistics New Zealand. *Urbal Rural 2018 (Generalised)*. Statistics New Zealand; 2021.
16. Lao C, Kuper-Hommel M., Elwood M, Campbell I, Lawrenson R. Metastatic relapse of stage I-III breast cancer in New Zealand. *Cancer Causes Control*, 2021;32(7):753–761.
17. *Breast cancer targeted therapy*. Breast Cancer Foundation New Zealand. 2021. Accessed May 25, 2021. https://www.breastcancerfoundation.org.nz/breast-cancer/treatment-options/targeted-therapy
18. Blackmore T, Lawrenson R, Lao C, et al. The characteristics, management and outcomes of older women with breast cancer in New Zealand. *Maturitas*, 2018;112:64–70.
19. Lawrenson R, Lao C, Campbell I, et al. The use of trastuzumab in New Zealand women with breast cancer. *Asia Pac J Clin Oncol*, 2018;14(2):e152-e160.
20. Seneviratne S, Lawrenson R, Harvey V, et al. Stage of breast cancer at diagnosis in New Zealand: impacts of socio-demographic factors, breast cancer screening and biology. *BMC Cancer*, 2016;16:129.
21. Brown C, Lao C, Lawrenson R, Tin Tin S, Schaaf M, Kidd J, et al. Characteristics of and differences between Pasifika women and New Zealand European women diagnosed with breast cancer in New Zealand. *N Z Med J*. 2017;130(1467):50–61.
22. Lawrenson R, Lao C, Campbell I, et al. Treatment and survival disparities by ethnicity in New Zealand women with stage I-III breast cancer tumour subtypes. *Cancer Causes Control*. 2017;28(12):1417–1427.
23. Lao C, Kuper-Hommel M, Campbell I, Elwood M, Lawrenson R. Use and results of systemic treatments for de novo and recurrent metastatic breast cancer: a population-based cohort study. *N Z Med J*. 2021;134(1545):47–59.
24. Lao C, Lawrenson R, Edwards M, Campbell I. Treatment and survival of Asian women diagnosed with breast cancer in New Zealand. *Breast Cancer Res Treat*. 2019;177(2):497–505.
25. Blumen H, K. Fitch, and V. Polkus, Comparison of treatment costs for breast cancer, by tumor stage and type of service. *Am Health Drug Benefits*. 2016;9(1):23–32.
26. Sun L, Legood R, Dos-Santos-Silva I, Gaiha SM, Sadique Z Global treatment costs of breast cancer by stage: a systematic review. *PLoS One*, 2018;13(11):e0207993.
27. Ansaripour A, Zendehdel K, Tadayon N, Sadeghi F, Uyl-de Groot CA, Redekop WK Use of data-mining to support real-world cost analyses: an example using HER2-positive breast cancer in Iran. *PLoS One*. 2018;13(10):e0205079.
28. Lawrenson R, Lao C, Campbell I, et al. The use of trastuzumab in New Zealand women with breast cancer. *Asia-Pacific J Clin Oncol*. 2017;14(2):e152-e160.
29. Lawrenson R, Lao C, Jacobson G, et al. Outcomes in different ethnic groups of New Zealand patients with screen-detected vs. non-screen-detected breast cancer. *J Med Screen*. 2019;26(4):197–203.
30. Lawrenson R, Lao C, Elwood M, Brown C, Sarfati D, Campbell I Urban rural differences in breast cancer in New Zealand. *Int J Environ Res Public Health*. 2016;13(10):1000.

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APPENDIX

TABLE A1 Patient demographics and tumor characteristics

	Stage I–III		Stage IV		Total	
Subgroup	***n***	**(%)**	***n***	**(%)**	***N***	**(%)**
Year of diagnosis						
2010–2012	4643	(27.3%)	390	(35.7%)	5033	(27.9%)
2013–2015	6454	(38.0%)	406	(37.1%)	6860	(38.0%)
2016–2018	5880	(34.6%)	297	(27.2%)	6177	(34.2%)
Ethnicity						
Māori	1973	(11.6%)	137	(12.5%)	2110	(11.7%)
Pacific	854	(5.0%)	114	(10.4%)	968	(5.4%)
Asian	1096	(6.5%)	54	(4.9%)	1150	(6.4%)
Others	13,054	(76.9%)	788	(72.1%)	13,842	(76.6%)
Age (years)						
<45	1931	(11.4%)	163	(14.9%)	2094	(11.6%)
45–59	6711	(39.5%)	318	(29.1%)	7029	(38.9%)
60–69	4674	(27.5%)	200	(18.3%)	4874	(27.0%)
70–79	2316	(13.6%)	232	(21.2%)	2548	(14.1%)
80+	1345	(7.9%)	180	(16.5%)	1525	(8.4%)
Cancer stage						
Stage I	6405	(37.7%)			6405	(35.4%)
Stage II	6744	(39.7%)			6744	(37.3%)
Stage III	3828	(22.5%)			3828	(21.2%)
Stage IV			1093	(100.0%)	1093	(6.0%)
Subtype						
ER+/HER2-	12,055	(74.8%)	511	(62.3%)	12,566	(74.2%)
HER2+	2576	(16.0%)	218	(26.6%)	2794	(16.5%)
Triple negative	1482	(9.2%)	91	(11.1%)	1573	(9.3%)
Unknown	864		273		1137	
Deprivation quintile						
1 (least deprived)	3400	(20.0%)	175	(16.0%)	3575	(19.8%)
2	3374	(19.9%)	209	(19.1%)	3583	(19.8%)
3	3424	(20.2%)	208	(19.0%)	3632	(20.1%)
4	3540	(20.9%)	239	(21.9%)	3779	(20.9%)
5 (most deprived)	3231	(19.0%)	261	(23.9%)	3492	(19.3%)
Unknown	8		1		9	
Rurality						
Major Urban	8987	(53.1%)	566	(52.0%)	9553	(53.1%)
Others	7929	(46.9%)	523	(48.0%)	8452	(46.9%)
Unknown	61		4		65	
Mode of detection						
Symptomatic	6761	(56.3%)	600	(90.6%)	7361	(58.1%)

(Continues)

TABLE A1 (Continued)

	Stage I–III		Stage IV		Total	
Subgroup	***n***	**(%)**	***n***	**(%)**	***N***	**(%)**
Screen-detected	5248	(43.7%)	62	(9.4%)	5310	(41.9%)
Unknown	4968		431		5399	
Received any treatment in private hospitals						
No	13,851	(81.6%)	1034	(94.6%)	14,885	(82.4%)
Yes	3126	(18.4%)	59	(5.4%)	3185	(17.6%)
Total	16,977		1093		18,070	

TABLE A2 Proportion of patients receiving treatments in different years

	TP	Y2	Y3	Y4	Y5
Stage I–III					
Surgery	68.2%	11.9%	9.2%	8.1%	7.2%
Radiotherapy	62.3%	21.9%	15.2%	13.4%	12.5%
Chemotherapy	32.4%	3.0%	3.2%	3.4%	3.2%
Targeted therapy	11.8%	10.8%	1.1%	1.2%	1.1%
Endocrine therapy	65.6%	60.2%	55.7%	53.5%	51.5%
Stage IV					
Surgery	52.1%	22.6%	21.8%	22.3%	21.3%
Radiotherapy	53.5%	33.6%	31.9%	29.0%	26.0%
Chemotherapy	40.7%	25.5%	26.7%	28.1%	27.6%
Targeted therapy	18.8%	16.9%	13.0%	13.1%	12.6%
Endocrine therapy	68.3%	66.1%	62.6%	60.7%	54.7%