RESEARCH ARTICLE

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Exploring Disparities in Breast Cancer Screening: An Ecological Analysis of Australian Data

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Abstract

The Australian National bowel Cancer Screening program provides an important tool for early diagnosis. Despite this, there are significant disparities in the uptake of the program and therefore understanding the factors that may impact participation has become an important issue. The objective of this paper was to analyse the socio-economic and demographic factors associated with screening participation. Using aggregate-level data on the bowel cancer screening program and Population Census data, the paper uses Geographically Weighted Regression to consider the significant factors impacting participation rates and the way that these factors vary spatially. Globally, screening participation varied according to income, English ability, education level, Indigenous background, and transport availability and each of these variables, in turn, exhibited significant spatial variability. The identification of significant spatial variability in the data provides important input into the design of programs aimed at increasing participation in screening regimes. In particular, the findings suggest that it would be prudent to consider approaches that both improved access to screening services, especially in regions with low participation but also targeted education or information campaigns focusing on target demographic groups.

Keywords: Breast cancer screening- early detection of cancer- spatial regression- Australia

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Introduction

In Australia, breast carcinoma continues to have a significant impact on women's lives. It is the second most diagnosed form of cancer (behind prostate cancer) and is the most commonly diagnosed cancer in women. In 2022, it was estimated that 20,640 new cases would be diagnosed, accounting for 13 per cent of all new cancer cases (Australian Government, 2023). As breast cancer is a progressive rather than a systemic disease (Tabar and Dean, 2010) the long-term prognosis of the disease can be improved through the implementation of a mammography screening regime (Czwikla et al., 2019). For several decades, countries around the world, including Australia, have implemented breast cancer screening programs with the aim of providing early detection of the disease. Although there are differing opinions (Tabar and Dean, 2010; Burton et al., 2012), the prevailing view is that early detection allows for more timely intervention and hence better survival. While estimates vary, it is suggested that mortality reduction attributed to screening is estimated to be up to 22 per cent (Dibden et al., 2020).

The Australian National Breast Screening Program (NBSP) also known as BreastScreen Australia, provides free biennial mammography screening for women aged 50-74 and encourages women aged 40-49 and 75 and over to also have regular mammography screening (Olver and Roder, 2017). The program which was introduced in 1991 operates across Australia and is available to women in both urban and rural areas. There are over 600 screening locations, including fixed clinics and mobile screening units that visit rural and remote areas (Department of Health and Aged Care, 2023). Although the BreastScreen Australia program has been praised for its effectiveness and comprehensive approach, it is also noted that significant disparities exist in the utilisation of breast cancer screening services among different populations (age, language and ethnic background) and locations (Department of Health and Aged Care, 2022). Moreover, the current screening rate of 50 % is well below the BreastScreen Australia target rate of 70%, pointing to the need to improve the uptake of screening services (Nickson et al., 2019; Khan, 2022).

In this context, it is important to develop a clear understanding of the factors associated with uneven screening rates. Within the literature, research has focused on understanding the impact of individual factors such as socio-economic, psychosocial, behavioural or health status on the level of breast screening participation. Factors including age (Maxwell et al., 2001; Jensen et al., 2012), the presence of children (Lagerlund et al., 2002), language ability or ethnicity (Lam et al., 2018; Miller et

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al., 2019; Paranjpe et al., 2022), educational (Jensen et al., 2012)or income level (Henry et al., 2014) or level of health-seeking behaviour or health literacy (Oldach and Katz, 2014; Rakhshkhorshid et al., 2018) have all been shown to impact screening participation.

Besides individual-level studies, there has been a growing use of ecological-based studies looking at the impacts of area composition on screening participation (Vogt et al., 2014; Lemke et al., 2015; Padilla et al., 2019). The use of ecological-based studies considers the aggregated features of people according to a spatial boundary (i.e., aggregate educational level, income, ethnic background) and is considered as an important addition to understanding the factors driving screening participation (Khan, 2022). Studies have revealed significant socioeconomic inequalities in breast cancer screening with women from disadvantaged communities less likely to receive regular breast cancer screening than women from more advantaged communities or backgrounds (Wang, 2016; Khan et al., 2021a; Khan et al., 2021b; Ouanhnon et al., 2022). Higher levels of aggregate education appear to the associated with higher rates of screening (Coughlin et al., 2008; Czwikla et al., 2019), while disengagement from the labour market is associated with lower rates of screening (Czwikla et al., 2019). Moreover, cultural factors may also play a part, with women from particular ethnic backgrounds or those from indigenous backgrounds having lower participation rates (Glazier et al., 2004), while the existence of strong social networks or community cohesion may result in higher participation (Leader and Michael, 2013; Shelton et al., 2016). Confounding these patterns, geographic location and access to screening services/ access to transport are also identified as key drivers of screening participation rates (Wang, 2016; Makurumidze et al., 2022; Wiese et al., 2023).

The aim of this study is to assess the scale and nature of the socio-spatial patterns of participation in the Australian national breast cancer screening program using aggregate screening data and associated social-demographic information. The social and spatial patterns identified can be used to highlight the uneven uptake of screening practices and provide focal areas for public policy intervention.

Materials and Methods

Unit of analysis

To undertake the socio-spatial analysis outlined for this study Statistical Area 3 regions are the unit of analysis. Statistical Area 3 (SA3) regions are aggregate geographic regions developed by the Australian Bureau of Statistics (ABS) intended for the output of regional information and are often the functional zones of regional towns and cities or groups of interconnected suburbs around commercial or transport hubs within large urban areas (ABS, 2016).

Data

The geographically linked dataset used in this paper was derived using the QGIS software (https://www.qgis.org/en/site/). The dependent variable used in the study relates to participation in the Australian national breast cancer screening program. The data is obtained from the Australian Institute of Health and Welfare and measures the participation rate of all women aged between 50 and 75 who were invited to take part in the screening program. As invitations to participate are sent out every two years, the screening rate data for 2018 and 2020 were averaged to provide the dependent variable.

The independent variables used in the study are from the Australian Bureau of Statistics 2021 Census of Population and Housing. All variables are measured at the Statistical Area 3 level. The potential impact of socioeconomic status is accounted for by two variables:

• The income variable is the number of low-income women aged 50 to 75 as a percentage of all women aged 50 to 75.

• The education variable is the number of women aged 50 to 75 who have a minimum university degree as a percentage of all women aged 50 to 75.

The impact of ethnic background is accounted for by the number of women aged 50 to 75 with poor self-reported English skills as a percentage of all women aged 50 to 75. Indigenous status is measured by the number of women aged 50 to 75 who are Aboriginal or Torres Strait Islander as a percentage of all women aged 50 to 75. The potential impact of car ownership on screening participation rates is accounted for by the number of households with no registered vehicle as a percentage of all households. Finally, to account for the possible impact of social capital on screening rates a proxy measure (volunteer) is included. This measure is the number of people (regardless of age) who say that they volunteer on a regular basis as a percentage of the population.

Statistical analysis

The main analysis was performed using the Multi-Scale Geographically Weighted Regression software downloaded from the School of Geographical Sciences and Urban Planning at Arizona State University (https://sgsup.asu.edu/sparc/multiscale-gwr). In particular, the analysis uses the geographically weighted regression (GWR) functionality within the software to construct Gaussian regression equations using the dependent and independent variables listed above.

In traditional regression models, the relationship between the independent and dependent variables is assumed to be constant across all observations. However, in many cases, there may be a spatial relationship between the observations, such that the strength and direction of the relationship between the predictors and the dependent variable vary based on the location of the observations. In these cases, geographically weighted regression is used to analyse the relationship between a dependent variable and one or more independent variables while taking into account the spatial or geographic relationships among the data points. The GWR software estimates and evaluates local models by fitting a regression equation to every feature (in this case each SA3) in the dataset. It constructs these separate equations by incorporating the dependent and independent variables of the features falling within the neighbourhood of each target feature. The output from

GWR includes estimates and fit statistics for a global model, together with local estimates and fit statistics for each separate feature.

Results

The average screening rate across Australia was 52.3 per cent. Regarding the spatial variation in screening rates, the analysis of the data shows significant spatial clustering, identifying groups of regions with high rates (high-high) or regions with low rates (low-low) (figure 1). Significant areas of high-high spatial association (hotspots) are in regions within the eastern states, especially in New South Wales and Queensland. Areas of low-low are in the northwest in the Northern Territory and Western Australia.

To consider the socio-spatial associations with screening rates a Geographically Weighted Regression (GWR) was applied to the dependent and independent variables described above. The analysis provides a global model without accounting for spatial variations and a geographically weighted model. The global model has a low R^2 (0.327) and an Akaike information criterion (AIC) of 848.58 (Table 1). As the variables are standardised, the coefficients are interpreted as the relative strength of association between screening rates and each independent variable. There is a positive global association between the percentage of women aged 50 to 75 who have a minimum university degree and breast cancer screening rates. A higher proportion of indigenous women aged 50 to 75 years is associated with lower breast screening rates as is a higher proportion of women with self-assessed poor English skills. Lower socio-economic status, measured by the percentage of low-income women aged 50 to 75, is associated with lower screening rates. Finally, as the percentage of households with one or fewer registered motor vehicles increases, the level of breast cancer screening decreases (Table 1).

The geographically weighted regression (GWR) explains substantially more variance in breast cancer screening rates compared to the global model. The R^2 value has risen to 0.89 and the Akaike information criterion (AIC) has improved, falling to 391.92. The local parameter estimates display significant spatial variability as illustrated by the results from the Monte Carlo test for spatial variability (Table 2). In contrast to the global results, the summary statistics for the regression model accounting for spatial variation show that the local association between a given indicator and the rate of breast cancer screening varies significantly with both positive and negative local parameter estimates (Table 3).

Visually, the local parameter estimates for the presence of indigenous women aged 50 to 75 (Figure 2a) vary from negative in large areas of regional and remote

Table 1. Global Regression Results, Breast Cancer Screening Rates and Selected Socio-Economic Variables

Variable	Parameter estimates	Standard error
Intercept	0	0.042
Per cent of women aged 50 to 75 who are Aboriginal or Torres Strait Islander	-0.339**	0.05
Per cent of women aged 50 to 75 with poor self-reported English skills	-0.218**	0.072
Per cent of women aged 50 to 75 who have a minimum university degree	0.268**	0.059
Per cent of low-income women aged 50 to 75	-0.166**	0.057
Per cent of people (regardless of age) who say that they volunteer on a regular basis (social capital proxy)	-0.022	0.076
Per cent of households with no registered vehicle	-0.204**	0.054

R^2, 0.37; Akaike information criterion (AIC) =845.58; **, significant at 0.05

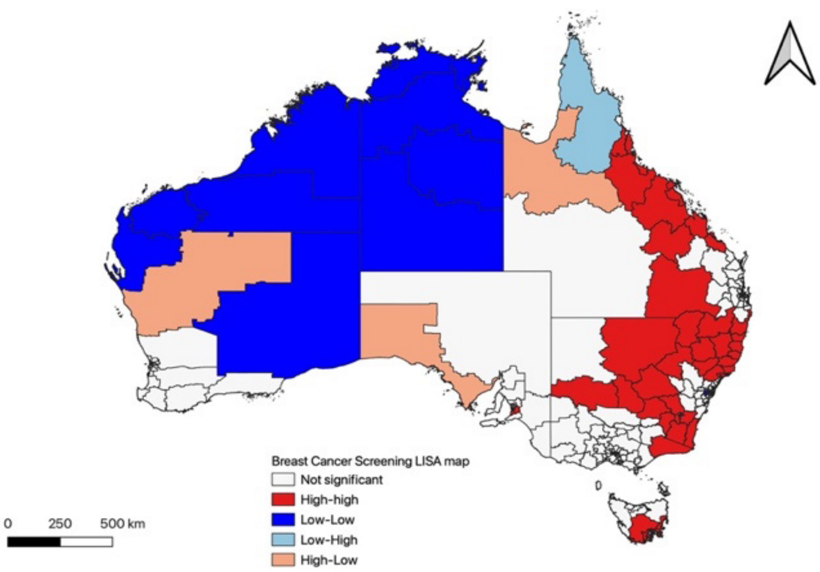
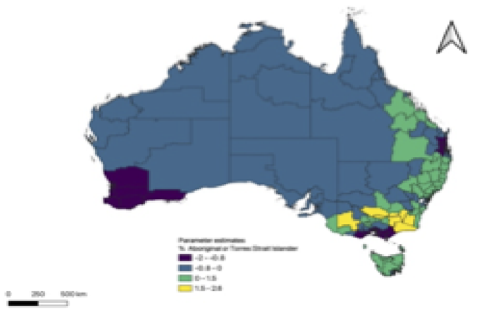
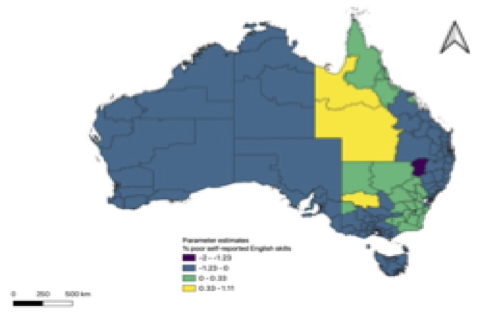


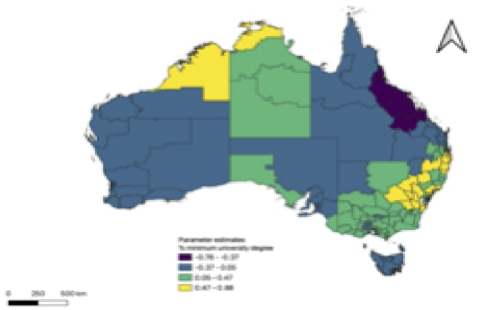
Figure 1. Local Indicators of Spatial Association (LISA) map, Breast Cancer Screening Rates



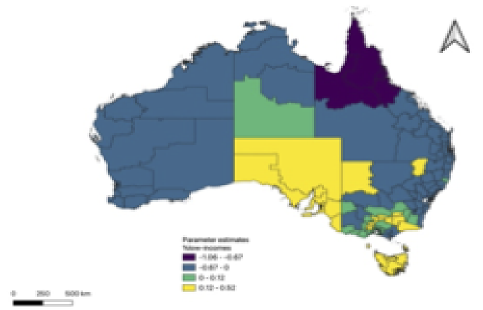
a) Parameter estimates for % women aged 50 to 75 who are Aboriginal or Torres Strait Islander



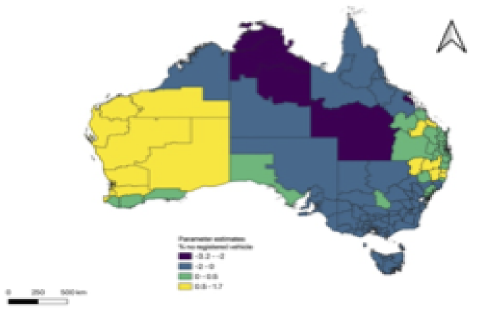
b) Parameter estimates for % women aged 50 to 75 with poor self-reported English skills



c) Parameter estimates for % women aged 50 to 75 who have a minimum university degree



d) Parameter estimates for % women aged 50 to 75 with low-incomes



e) Parameter estimates for % households with no registered vehicle

Figure 2. Spatial Distribution of the Local Parameter Estimates for the Independent Variables

Table 2. P-values, Monte-Carlo Test for Spatial Variability of the Local Estimates

Variable	p-value
Intercept	0.00
Per cent of women aged 50 to 75 who are Aboriginal or Torres Strait Islander	0.00
Per cent of women aged 50 to 75 with poor self-reported English skills	0.00
Per cent of women aged 50 to 75 who have a minimum university degree	0.00
Per cent of low-income women aged 50 to 75	0.00
Per cent of people (regardless of age) who say that they volunteer on a regular basis (social capital proxy)	0.00
Per cent of households with no registered vehicle	0.00

Table 3. Summary Statistics for Geographically Weighted Regression Local Parameter Estimates

Variable	Mean/ standard deviation	Minimum	Maximum
Intercept	-0.024+/- 0.472	-1.023	1.343
Per cent of women aged 50 to 75 who are Aboriginal or Torres Strait Islander	-0.38+/- 0.764	-2.015	2.648
Per cent of women aged 50 to 75 with poor self-reported English skills	-0.205+/- 0.3	-2.005	1.113
Per cent of women aged 50 to 75 who have a minimum university degree	0.175 +/- 0.286	-0.782	0.882
Per cent of low-income women aged 50 to 75	-0.14 +/- 0.297	-1.06	0.518
Per cent of people (regardless of age) who say that they volunteer on a regular basis (social capital proxy)	-0.007 +/- 0.545	-3.233	1.729
Per cent of households with no registered vehicle	-0.17 +/- 0.218	-0.417	1.41

Australia to positive in selected regions located in the east and southeast of Australia. The local parameter estimates for the percentage of women aged 50 to 75 with poor self-reported English skills (Figure 2b) are negatively associated with screening rates in regions of Western Australia, South Australia, Northern Territory and Tasmania, together with some regions in Queensland. In contrast, the indicator of English ability is positively associated with screening rates in regions within New South Wales and in some remote regions of Queensland.

Holding all other variables constant, higher levels of education (Figure 2c) are associated with higher screening rates (positive parameter estimates) in a number of regions including in the far north of Australia and in regions in the southeast of the country. Negative associations were identified in regional and remote Queensland, through to parts of South Australia and Western Australia as well as Tasmania. The local parameter estimates for the low-income (Figure 2d) are positively associated with screening rates in regions located in the south and negatively associated with screening in regions located towards the north of Australia. Finally, not having access to a motor vehicle (Figure 2e) reduces the screening rate in a large number of regions, although is associated with increased screening rates in some northern New South Wales and southern Queensland regions and in southern and central Western Australia.

Discussion

This paper examines the socio-spatial characteristics of breast cancer screening participation in Australia. Using data from the Australian Institute of Health and Welfare and the Australian Bureau of Statistics the analysis has contributed to an understanding of the factors that may explain differences in participation in breast screening practices.

The results illustrate the complex spatial and contextual factors that may determine differences in screening participation. In the context of previous research, this paper provides support for existing assumptions regarding screening but expands on these by noting the global findings may not always translate into local patterns. At the global level, the regression results largely supported previously reported research. Lower screening rates were associated with higher proportions of indigenous women (Glazier et al., 2004), women with poor self-reported poor English(Wang et al., 2022), low-income women (Khan et al., 2021a; Khan, 2022) and women without access to a motor vehicle (Wang, 2016). Higher screening rates were associated with women with higher levels of formal education (Czwikla et al., 2019). In contrast to several existing studies (Leader and Michael, 2013; Dean et al., 2014; La Frinere-Sandoval et al., 2022) there was a non-significant association between the proxy measure of social capital (volunteering) and screening rates.

The global regression results hide the significant spatial variation evident in the data, with the results of the geographically weighted regression showing marked spatial variation in the association between breast cancer screening rates and the independent variables. While locally there was some concordance between the global results and the local results, there also existed significant regional clusters where the local results were in direct contrast to the global model. For example, while there were large clusters of regions where higher percentages of indigenous women were associated with lower screening rates, there also existed some regions where the opposite was true. Similarly, although a lack of access to transport in the form of a private vehicle was associated with lower screening rates in many regions, this did not hold for all regions considered.

From a policy viewpoint, the differentiation between the global and local results and the variation in local results across regions points to the need to consider local contexts when attempting to address shortfalls in screening rates. While it is essential to develop appropriate messaging regarding the importance of breast screening, taking a global approach may be less effective than developing more bespoke local programs and approaches.

The findings of the paper need to be considered in the context of certain limitations. Firstly, as the analysis present is an ecological study care must be taken not to equate aggregate outcomes to individual outcomes (ecological fallacy) (Sandoval et al., 2018). Secondly, the results and their interpretation are limited by the Modifiable Area Unit Problem (Buzzelli, 2020). The unit of measurement chosen for this analysis was the statistical Area 3, however, it is possible that a finer level of aggregation would have resulted in different statistical and spatial patterns. The screening data used is related to women accessing publicly funded and run screening centres and therefore may exclude women who choose to attend private clinics. A final limitation relates to the time period covered by the data. It should be noted that the later tranche of data relates to the early COVID-19 period. During this time many screening procedures including breast screening were either halted or significantly curtailed (Bu and Morgan, 2021).

In conclusion, From a public health perspective, addressing shortfalls in breast cancer screening participation is an important priority (Nickson et al., 2019). However, as the findings of this paper suggest, understanding uneven participation rates is dependent on uncovering both the socio-demographic drivers as well as the geographic or spatial factors. As such, it would be prudent to consider approaches that both improved access to screening services, especially in regions with low participation and also targeted education or information campaigns focusing on target demographic groups.

Author Contribution Statement

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