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The resource implications of extending the routine invitation to breast screening to women aged 65-69 years

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Abstract

UK breast screening policy currently restricts routine three-yearly invitation to screening to 50-64 year olds. This paper first predicts the additional demand for breast screening if a routine three yearly invitation were to be extended to the 65-69 years age group and then indicates how the resource implications of such a policy might be determined. A stratified random sample of 1015 women aged 65-69 living in the Glasgow area was invited for breast screening. The binary choice did or did not attend is modelled using probit regression. The independent variables include (i) the woman's characteristics: her age; the deprivation score of the area she lives in; her screening history and (ii) the characteristics of the screening: whether the screening took place in a mobile van or at a static site; time of the year; and whether the invitation was accompanied by a letter of encouragement of the GP. The likely increase in the demand for screening facing each provider can then be calculated and re-expressed as a required increase in screening capacity (and funding). The issues raised concerning the incentive effects of the resource allocation mechanism are also discussed.

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1. INTRODUCTION

UK breast screening policy currently restricts routine three-yearly invitation to screening to 50-64 year olds. Older women can self refer but are not routinely invited. When the breast screening progamme was introduced in the UK it was restricted to women aged 50 to 64 years, in part, because of a belief that uptake from this group would be low. Since then a number of studies have compared the attendance rate of women aged 65-69 years with that of women aged 50-64 years.[1-5] Although the uptake by the older age group varies in these studies between 37% and 76%, attendance in the older group is roughly 90 per cent of that in the younger group.

Recognising that the uptake is likely to be higher than originally thought and that age is the most important risk factor for breast cancer, the UK Breast Screening Programmes are currently considering an extension of the age range for routine invitation to include 65-69 years old women. Demonstration projects have been set up in East Sussex, Leeds and Wakefield, and Nottingham in order to establish the effectiveness and cost-effectiveness of screening older women. This paper reports on the economic aspects of a related project which has been set up in Glasgow. The aims of this project are:

- to predict demand for breast screening if routine invitation in Scotland is extended to include the 65-69 years age group;
- to determine the factors most likely to influence attendance;
- to relate the increase in overall demand for breast screening to the current capacity of the Scottish Breast Screening Programme;
- to establish the resource implications resulting from any changes to current screening policy.

It should be noted that the aim of this study is <u>not</u> to assess whether or not extending the age range is cost-effective. There have been several studies examining the factors associated with women's participation in breast screening programmes. These

studies have investigated why some women do not attend initially (primary acceptance) and why those who do attend, do not attend for repeat screening (secondary acceptance). An extensive literature review by the Scottish Health Purchasing Information Centre showed that the main factors which influence the uptake of breast screening include age, socio-economic status, housing and educational level.[6] The failure of women to avail themselves of mammography screening is not necessarily related to lack of knowledge of breast cancer or their perceived risk of getting breast cancer. Many emotional and psychological factors play an important part in inhibiting women from participating in the screening programme and especially the fear and anxiety associated with coming to terms with potential ill-health.

None of these studies have attempted to model attendance by women aged 65-69 years with the aim of predicting attendance levels and the subsequent resource implications for breast screening services. This paper reports the ongoing economic analysis, specifically the methods employed are detailed, preliminary results from modelling of attendance are reported, and some of the broader economic issues raised are discussed.

2. ESTIMATING FUTURE DEMAND

A demonstration project was run where a sample of 1015 women aged 65-69 was invited for breast screening. Breast screening attendance is modelled using the data from this project. The developed model is used to predict future demand. However, the robustness of this model needs to be examined before any confidence can be placed on these predictions. First, the durability of the predictive model needs to be tested. Over time those women entering the 65 to 69 age group will increasingly have different screening histories from those whose behaviour has been modelled above. The most recent attendance of women aged 60-64 in the same area as the demonstration project is therefore modelled. Not only could more confidence be placed on the predictions for 65-69 year old women if the model showed similar results but also such a model could possibly detect trends in

attendance by the younger age group that might assist prediction of future attendance.

Second, the sample in the demonstration project is not representative of Scotland as a whole. The use of deprivation category of area of usual residence will to some extent mitigate any problems. The most recent attendance of women aged 60-64 in two other regions in Scotland is therefore also modelled. This establishes the extent of any systematic differences between those living in Glasgow and those living elsewhere in Scotland. The general model used to explain breast screening attendance of the different samples of women is discussed first.

2.1 Modelling breast screening attendance

There is potentially a wide range of factors involved in the decision whether or not to attend for breast screening. However, because the primary motivation behind this research is to identify the resource implications of an extension of routine three yearly invitations to breast screening, the range of factors which is considered is necessarily very limited. The model developed can only include variables for which there are data available for all eligible women throughout the country. Such data are quite limited but they are potentially important enough to provide robust predictions at a group level if not at an individual level. The included factors are: (i) the woman's characteristics: her age; the deprivation score of the area she lives in; and her screening history; and (ii) the characteristics of the screening session: whether the screening took place in a mobile van or at a static site.

Woman's characteristics

The woman's characteristics included are: her age; the deprivation score of the area she lives in; and her screening history. Age is included as a continuous variable. It is hypothesised that older women are less likely to attend the breast screening session. The impact of the socio-economic characteristics of the area in which the woman resides on attendance is estimated by using the Carstairs deprivation index[7] which is derived from data collected in the 1991 Census. The Carstairs index is a composite

score based on four variables: (i) unemployment; (ii) overcrowding; (iii) non car ownership; and (iv) low social class. All four variables are standardised using Z scores and the overall score for each postcode sector is simply the unweighted combination of the scores. There are seven different categories ranging from 1 (least deprived) to 7 (most deprived). The following dummy variables are created: Deprivation 1-3; Deprivation 4-5; Deprivation 6; and Deprivation 7. Deprivation 1-3 is used as the base case.

The previous screening record can vary substantially across women. The total number of attendances per woman can in principle not exceed three because the Scottish Breast Screening Programme started in 1991 and a woman is invited only every three years after she attended. However, the number of invitations can be more than three because if a woman does not take up the invitation she may be invited again the year after. This results in many potentially different screening histories. Seven distinct screening histories are distinguished:

1. Those women invited more than once previously and who attended each time.
2. Those women invited once previously and who attended the session.
3. Those women invited more than once previously and who attended the most recent but not all of the sessions.
4. Those women invited more than once previously and who attended at least one session but not the most recent one.
5. Those women never previously invited.
6. Those women invited once previously and who did not attend.
7. Those women invited more than once and who never attended any of the sessions.

Group 1 is used as the base case. It is hypothesised that the women in this group are most likely to attend. Therefore, all the signs of the coefficients on the six dummy variables for previous screening history are expected to be negative. It is hypothesised that women who were invited more than once but did not attend any of the sessions are least likely to attend followed by women who were invited once

but did not attend. Women who were never invited previously are more likely to attend than the two previous groups of women but less likely than those who were invited more than once and attended some of the sessions (groups 3 and 4). Groups 3 and 4 are modelled separately because it can be hypothesised that women who attended the session after the first invitation but not after the second invitation are less likely to attend than women who attended after the second invitation but not after the first invitation.

Women who were invited once and did attend are most likely to attend with respect to the other included dummy variables but less likely than the base case. This is because a 100% uptake has a different meaning depending on the number of invitations the woman received. A woman is clearly committed to breast screening if she is invited three times and she attended all three times while the level of commitment cannot so clearly be observed if she has only been invited once. The same applies to a 0% uptake. If a woman is invited three times but she never attends it is likely that she is not committed to breast screening while there may be other reasons why she did not attend when the woman is invited once only.

In some cases women are invited in subsequent years because the mammogram indicated that something might be wrong (early recalls). A dummy variable is included in the model which indicates whether women have been recalled early in the past. Competing hypotheses can be generated for this variable. Because women might think they are more likely to have breast cancer detected they are more likely to attend. On the other hand, they have attended more sessions in the past than average and may therefore perceive the marginal benefit of the current session to be lower.

Some women refer themselves to breast screening. A dummy variable is included which indicates whether women have referred themselves to breast screening in the past. It could be hypothesised that they are less likely to attend because they have been screened more recently than women who have not self referred themselves.

Characteristics of the screening session

The characteristics of the screening session include when the screening took place, whether the screening took place in a mobile van or at a static site, and whether the invitation is accompanied by a letter from the GP. In this sample about 75% of the breast screening sessions take place at a static site. To examine whether the location (static site or mobile van) to which the women are invited influences attendance a dummy variable for mobile van is included. No prior hypothesis is generated.

Another screening characteristic that might have an impact on attendance is the date of the session. It can be hypothesised that a relatively low proportion of the women invited in December and January attend the session. Dummy variables for the different seasons are therefore included. It is anticipated that whether or not the invitation was accompanied by a letter of encouragement from the woman's GP might have an impact on attendance.

Econometric issues

Given a binary dependent variable (did or did not attend) either logit or probit estimation are potentially applicable. Probit regression is asymptotically unbiased, efficient and normal. For the asymptotic properties the rule of thumb is that there should be 50 cases per parameter.

The probit model can be expressed as follows:[8]

$$y_i^* = a + bx_i + e_i,\ e \sim N[0,1]$$

$$y_i = 1 \text{ if } y_i^* > 0$$

$$0 \text{ otherwise}$$

where y_i is a binary variable indicating whether or not the woman attended for breast screening, x_i is a vector of independent variables, and e_i is a random error term.

The interpretation of coefficients in probit models is less straightforward than in OLS because of the nonlinearity of the relationship between the probability that $y=1$ and each of the independent variables. The most common method used to interpret

the coefficients of dummy variables is to estimate the change in probability when the dummy variable changes from 0 to 1.[9] This is estimated whilst holding all other independent variables at their mean values.

There is no standard measure of goodness of fit for qualitative dependent models. There have been several attempts to construct goodness of fit measures and these can be divided into two broad categories: those measuring explained variation and those measuring the ability to predict the observed outcome. The purpose of the model developed in this study is to predict the uptake of screening rather than testing hypotheses about the determinants of screening behaviour. Since the focus is on the predictive ability of the model a goodness of fit measure concerned with the ability to predict is more appropriate. One measure often used is the count R^2 based on the proportion of correct predictions.[10] The count R^2 can be misleading because by choosing the outcome with the largest percentage of observed cases it is possible to correctly predict at least 50% of the cases.[9] For example, if 60% of the sample did attend and if the prediction was that all women would attend, the prediction would be correct 60% of the time. The count R^2 therefore needs to be adjusted to account for the largest row marginal (i.e. the number of cases in the outcome with the most observations).

It is important to test for heteroscedasticity in qualitative dependent variable models because this misspecification leads to inconsistent estimators.[11] Therefore a multiplicative heteroscedastic model is also estimated. In the multiplicative heteroscedastic model the variance term is defined as follows: $\mathrm{Var}[e_i] = [\exp(g' w_i)]^2$. Since the main concern in this paper is the model's predictive ability it is tested whether a multiplicative heteroscedastic model predicts better than a homoscedastic model. In addition the likelihood ratio statistic is used to test the homoscedasticity assumption of the model.[8]

In probit analysis (unlike OLS) omitted variables can lead to bias even if they are not correlated with any of the included variables. In order to test for omitted variable bias it is necessary to have data on variables whose omission might be regarded as a source of bias. However, the data available is very limited and is unlikely to contain any strong candidates.

2.2. Demonstration project

A demonstration project was run in the Glasgow area where a stratified random sample of 1015 women aged 65-69 was invited for breast screening. Sixty-four invitations were returned by the Post Office. The sample is therefore reduced to 951 women.

The age of the woman at the time of the appointment was either 64, 65, 66, 67, 68, 69 or 70 years old. As can be seen from Appendix 1 three women were invited before their sixty-fifth birthday and eight women were invited after their seventieth birthday. It should be noted that the age range of women included in the demonstration project is relatively small and as a result the impact of age is less likely to show up in the regression results.

The number of times women were invited previously to breast screening ranges from zero to four (30 women were never invited, 270 were invited once, 629 twice, 19 three times and 3 were invited four times). The previous screening record of the women are reported in Table 1.

Table 1. Previous screening record

	Number of times previously attended					
	0	1	2	3	4	TOTAL
Never invited	30	*NA*	*NA*	*NA*	*NA*	*30*
Invited once	96	174	*NA*	*NA*	*NA*	*270*
Invited twice	140	99	390	*NA*	*NA*	*629*
Invited three times	0	3	6	10	*NA*	19
Invited four times	0	0	0	1	2	3

Table 2 shows the percentage attending by deprivation category and by previous screening history (Table A1 in the Appendix shows the number of women by deprivation category by screening history). The table shows that the percentage attending tends to be lower for women who live in more deprived areas. The relative percentages for the screening histories are as expected.

Table 2. Percentage attending by deprivation category and by screening history

	Deprivation category				Total
Screening history	1+2+3	4+5	6	7	
Invited > 1 – attended all	84.5	80.6	76.4	71.6	78.9
Invited once – did attend	82.6	72.3	61.5	64.3	70.7
Invited > 1 – attended last but not all	46.7	43.8	20.0	45.0	39.4
Invited > 1 – attended some but not last	40.0	57.1	12.5	22.2	30.2
Never invited	33.3	40.0	10.0	0.0	20.0
Invited once – did not attend	12.5	14.8	16.7	3.4	11.5
Invited > 1 – did not attend any	0.0	7.1	2.9	7.4	5.0
Total	63.2	60.6	46.6	41.2	52.9

There were a number of constraints with respect to the organisation of invitations for older women, specifically a need to minimise any impact of the study on the ongoing screening of 50 to 64 year olds and to stratify invitations by deprivation category. As a result, there is a closer relationship between the timing of the invitation and whether it was to a static or mobile site than is ideal. Since, in addition, invitations were issued over the period July to April rather than a full year the timing of the invitation is not considered.

Results

Half the sample did attend the screening session (503 women – 49.6% of those invited or 52.9 of those assumed to have received an invitation). Table 3 shows the probit regression results. Only two of the hypothesised variables are not statistically

significant. These are the age of the woman and the dummy variable for the deprivation category 4+5.

The dummy variables for deprivation categories 6 and 7 show that women who live in relatively deprived areas are less likely to attend the session. Previous screening history has an influence on attendance. Women who were invited more than once and attended all sessions are most likely to attend. Women who were invited more than once and never attended followed by women who were invited once and did not attend are least likely to attend. As hypothesised, in the case of women who were invited more than once but did not attend every time, those who attended the last session were more likely to attend than those who did not attend the last session. In summary all coefficients with respect to screening history have the expected sign and relative size. Women who self referred themselves to breast screening or had an early recall in the past are less likely to attend. Women invited to a mobile site are also less likely to attend.

Two multiplicative heteroscedastic models were then estimated. Both the dummy variables for deprivation category and for previous screening history were tested for heteroscedasticity. The count R^2's indicated that the multiplicative heteroscedastic model did not predict any better than the homoscedastic models. The likelihood ratio test also showed that the homoscedasticity assumption could not be rejected for the deprivation dummies (likelihood ratio 5.61 (3 degrees of freedom)) nor for the previous screening history dummies (likelihood ratio 7.82 (6 degrees of freedom)).

Table 3. Regression results

	b	p-value*	dF / dx**
Intercept	1.365	0.000	
Deprivation category 4+5	-0.151	0.268	-0.060
Deprivation category 6	-0.430	0.002	-0.169
Deprivation category 7	-0.519	0.000	-0.204
Never invited	-0.358	0.007	-0.141

Invited once – did not attend	-1.194	0.000	-0.404
Invited once – did attend	-1.474	0.000	-0.452
Invited > 1 – did not attend any	-1.894	0.000	-0.497
Invited > 1 – attended last but not all	-2.188	0.000	-0.570
Invited > 1 – attended at least 1 but not last	-2.616	0.000	-0.644
Self referral	-2.239	0.000	-0.523
Early recall	-1.018	0.003	-0.352
Mobile unit	-0.334	0.003	-0.132
Cases	951		
Pseudo R^2	0.3792		
Count R^2	81.9		
Adjusted count R^2	61.6		

* standard errors are estimated using the Huber/White/sandwich estimator; ** change in probability for an infinitesimal change in each independent continuous variable and discrete change in the probability for dummy variables.

The count R^2 of the probit model in Table 3 indicates that attendance/non-attendance was correctly predicted for 82% of the women. The adjusted count R^2 indicates that knowledge of the independent variables compared to basing the prediction only on the marginal distributions reduces the error in prediction by 62%.

As can be seen from Table 4 the model is better at predicting attendance than at predicting non-attendance. The model predicted attendance correctly for 88% of the women and it predicted non-attendance correctly for 75% of the women.

Table 4. Overall predictions

Observed	*Predicted outcome*		
Outcome	Attended	Did not attend	Total
Attended	444	59	503
Did not attend	113	335	448
Total	557	394	951

2.3. Attendance of women aged 60-64 in the Glasgow area

Data on age, deprivation score of the area the woman lives, and previous screening record are extracted from the SBSP database for each woman born between 1935 and 1939 for the same general practices in Glasgow. The most recent attendance is

modelled and this model is compared with the model estimated from the demonstration project. The models are compared in terms of goodness of fit and a Chow-type Likelihood Ratio test is used to test the hypothesis that the coefficient vectors are the same for the two models. Unfortunately, the data are not yet available.

2.4. Attendance of women aged 60-64 in two other regions of Scotland

Data on age, deprivation score of the area the woman lives, and previous screening record are extracted from the SBSP database for each woman born between 1935 and 1939 living in two other regions of Scotland. The most recent attendance of these women is modelled. This model is compared with the model estimated from the demonstration project. The models are again compared in terms of goodness of fit and a Chow-type Likelihood Ratio test is used to test the hypothesis that the coefficient vectors are the same for the two models. Unfortunately, the data are not yet available.

2.4. Predicting future demand

Providing that the model estimated from the demonstration project is robust, this model is used to make predictions of uptake by post-code sector for the whole of Scotland should the routine invitation to screening be extended. The prediction of additional demand for screening involves using those variables which are significant predictors of attendance to define different sub-groups of women. For each sub-group a probability of attendance following invitation is estimated from the model. The number of women in each sub-group is then multiplied by the relevant probability and the products summed in order to provide an estimate of the number of women in any post-code sector who will attend following invitation.

As noted above women whose invitations were returned by the post office were excluded from the analysis (n=64). When making predictions for the whole of Scotland a certain percentage of returned invitations will need to be assumed in order to make accurate predictions. Finally, in order to estimate the increase in

demand the predicted attendance must be adjusted to allow for the women who would have self-referred had no invitation been made.

3. ESTIMATING SCREENING CAPACITIY

The primary motivation behind modelling participation in the screening programme by older women is to assist NHS decision making with respect resource allocation should the decision be taken to extend routine invitation to screening to 65 to 69 year olds. While a more complete picture might be obtained by modelling not only future attendance in the 65 to 69 age group but also future attendance in the 50 to 64 age group, the latter approach is outwith the scope of the present study. In effect it will be assumed that attendance in the 50 to 64 age group is stable or at any rate readily predictable. Analytic effort is thus concentrated initially on the older age group about whom less is known.

Identification of the resources required by the six providers who make up the Scottish Breast Screening Programme if they are to screen women aged 65 to 69 years is not straightforward, even given accurate estimates of future demand. It must take account of several factors including the capacity constraints faced by each provider, how the cost of screening older women differs from screening younger women, and the efficiency of the different providers.

Indivisibilities with respect to capital equipment and some labour inputs will influence the allocation of costs into fixed and variable costs. So it is not adequate simply to estimate the variable cost of screening and use this as a basis for predicting the cost of screening older women but it is necessary to consider how fixed costs vary with the scale of activity and this will vary across providers. Moreover, the available cost data on breast screening are with respect to the 50 to 64 year age group. In order to predict the resource implications of screening a woman aged 65 to 69 from data for women aged 50 to 64 allowance must be made for differences in the recall rates and the additional time it takes to screen older women.

Different methods of allocating resources to meet the increased demand are likely to have different incentive effects. The allocation of resources to the breast screening programme is currently based on assumptions about uptake rates. If the programme is extended to include women aged 65 to 69 a decision will have to be made concerning what additional resources to make available to each provider. The incentive effects will depend on whether providers are equally efficient or differ in terms of their efficiency, and on how the additional payment per woman screened is determined. Some of the possible reimbursement options are:

1. Payment equal to the Scottish unit cost
2. Payment equal to the unit cost of the lowest cost provider
3. Payment equal to the unit cost of the highest cost provider
4. Payment equal to the unit cost of the specific provider.

If all providers are equally efficient option 4 might avoid disincentive effects, whereas option 1 would appear to be the worst in that it would give low cost providers more resources than they require and high cost providers too few resources. If providers differ in terms of efficiency and the higher the unit cost the less efficient the provider, option 2 would appear to be the best and option 3 the worst. Since option 2 might encourage the inefficient providers to become more efficient by giving them inadequate resources to meet the increased demand without achieving reductions in cost. Whereas option 3 would not provide any incentive to the high cost provider and might weaken the incentive of the low cost provider to be efficient. However, the impact of any incentives may be limited in that each provider is a local monopolist.

4. DISCUSSION

The response of 951 women aged between 64 and 70 living in Glasgow to an invitation for breast screening was modelled in this paper. It was then indicated how the resulting model can be used to predict the additional demand for the whole of Scotland for breast screening if a routine three yearly invitation were to be extended to the 65-69 years age group. Finally, how the resource implications of such a policy might be identified was outlined and some potential incentive effects were noted.

The modelling of attendance was quite successful in that all variables had the expected sign. As hypothesised previous screening history, deprivation category of the area in which the woman lives, whether the woman had been recalled or had self-referred previously, and whether the session took place in a mobile van, all influenced attendance. Age was the only characteristic included which was not statistically significant. This is not completely surprising since the age range is relatively small and age is not completely independent of screening history. The attendance decision was correctly predicted for 82% of the women included in the study. Once data are available for the whole of Scotland on all the variables that were statistically significant the Scotland-wide additional demand can be predicted. However, the robustness of the model needs to be tested first by modelling the most recent attendance of women aged 60-64 in the same Glasgow area and in two other regions of Scotland.

There are a number of potential limitations to this study which should be considered. The women invited to attend for breast screening were necessarily informed that they were part of a study. The question arises whether their decision to attend or not attend might be influenced by this knowledge. It is not obvious why their response to a trial invitation should be any different from their response to a routine invitation. However, this invitation was issued a longer time after their previous invitation than would be the case if it were an established part of the breast screening programme. While it might be anticipated that the longer the time since their last invitation the lower the probability that they would attend, it might also be argued that the potential benefit to being screened will be higher the longer it is since they were previously screened.

The deprivation category of the postcode sector in which the woman resides is based on data collected at the 1991 Census. Depending on the rate of socio-economic change this classification may not be a particularly good measure of socio-economic differences between areas. However, it is probably the best available and

is still quite widely used. A more serious shortcoming might be with respect to the extent to which the deprivation category adequately reflects the character of an area. It might for example be satisfactory in densely populated urban areas but less satisfactory in more sparsely populated rural areas.

The purpose of the model developed in this study was to predict the uptake of screening rather than testing hypotheses about the determinants of screening behaviour. The issues raised are therefore more concerned with predictive ability of the model rather than biases in the estimation of the coefficients. The latter would be of interest if the aim of the study were to test hypotheses about the determinants of screening behaviour.

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Appendix 1. Descriptive statistics

Variable		N	%
Age	64	3	0.3
	65	153	16.1
	66	214	22.5
	67	199	20.9
	68	191	20.1
	69	183	19.2
	70	8	0.8
Deprivation	1	90	9.5
	2	70	7.4
	3	63	6.6
	4	168	17.7
	5	91	9.6
	6	219	23.0
	7	250	26.3
Screening	Static	702	73.8
	Mobile	249	26.2
Early recall	yes	20	2.1
	no	931	97.9
Self-referral	yes	33	3.5
	no	918	96.5

Table A2. Number of subjects by deprivation category by screening history

	Deprivation category				Total
Screening history	1+2+3	4+5	6	7	
Invited > 1 – attended all	103	129	89	81	403
Invited once – did attend	46	47	39	42	174
Invited > 1 – attended last but not all	15	16	15	20	66
Invited > 1 – attended some but not last	10	7	8	18	43
Never invited	9	5	10	6	30
Invited once – did not attend	16	27	24	29	99
Invited > 1 – did not attend any	24	28	34	54	140
Total	223	259	219	250	951