The Breast Cancer Epidemic:
Modeling and Forecasts Based on Abortion and Other Risk Factors

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ABSTRACT

Using national cancer registration data for female breast cancer incidence in eight European countries—England & Wales, Scotland, Northern Ireland, the Irish Republic, Sweden, the Czech Republic, Finland, and Denmark—for which there is also comprehensive data on abortion incidence, trends are examined and future trends predicted. Seven reproductive risk factors are considered as possible explanatory variables. Induced abortion is found to be the best predictor, and fertility is also a useful predictor. Forecasts are made using a linear regression model with these explanatory variables. Previous forecasts using the same model and incidence data for years through 1997 for England & Wales are compared with numbers of cancers observed in years from 1998–2004 in an Appendix. The forecast predicted 100.5% of the cancers observed in 2003, and 97.5% of those observed in 2004.

The Challenge of Abortion for Epidemiologists in Female Breast Cancer Research

It is difficult for epidemiologists to discover women’s abortion history. In any study the numbers of women who have had abortions may be underreported.1

National data on abortions in most countries tends to be deficient, with abortions underreported. Official abortion statistics in the United States2 and France3 are known to underestimate the numbers of legal induced abortions. The countries considered in this study are believed to have nearly complete official abortion counts.

The long lag time for the development of breast cancer magnifies the problem. The average age of diagnosis is over 60, while most abortions and live births occur at ages under 30. The modern increase in breast cancer incidence is obvious at ages over 45,4 and Figure 1 for England & Wales shows the increase is small below age 45.

Abortion did not become legal in most Western countries until the 1970s, and earlier abortions among older women are not recorded. Consequently, the older women, whose breast cancer incidence is known, have abortions not detectable by a longitudinal study,5,6 while the younger women, whose abortion history is known, tend to be too young to have experienced most of the modern increase in breast cancer.5,7,8 Where the increased risk is apparent, even under age 40 in a study free of recall bias,9 there is an acknowledged need to extend the study to women older than 40.

The long time lags, however, can be used to make long-term forecasts of cancer trends.

Trends

Since 1971 the overall increase has been 80%,4 as shown for England & Wales in Figure 1.

In contrast to other cancers, breast cancer is more common in upper-class women. This reverse gradient13 is becoming steeper: see Figure 2. The reported standardized mortality ratio (SMR) in England for the highest social class I increased to 174 for the years 1997–2000, compared to an SMR of 169 for the years 1993–1996. As upper-class women have higher survival rates, the incidence gradient is steeper than the mortality gradient. Fertility differences do little to explain this gradient. However, the age at first birth among women who have children does provide a two-fold partial explanation. The least deprived women studied in a British survey14 were found to have a greater preference for abortion when pregnant. Higher-class women have a later age at first birth15 and consequently higher-class women have nulliparous abortions, which are more carcinogenic.

Local variation within countries can be examined in addition to international comparisons. The South East of England has more breast cancer than other parts of the British Isles.16 It also has the highest abortion rate.17 Ireland has the lowest rate of breast cancer.
and the lowest abortion rate. Fertility, higher in Ireland than in England, is also a factor. But in the South East of England fertility is not lower than the English average and does not explain the above-average breast cancer rate.

**Risk Factors**

Seven known risk factors were examined as an explanation for these trends:

- When a woman is nulliparous, an induced abortion has a greater carcinogenic effect because it leaves breast cells in a state of interrupted hormonal development in which they are more susceptible.
- A low age at first birth is protective. A larger number of children (higher fertility) increases protection.
- Breastfeeding gives additional protection.
- Hormonal contraceptives are conducive to breast cancer.
- Hormone replacement therapy (HRT) is also conducive to breast cancer.

**Modeling for England & Wales**

For four of these risk factors we are fortunate to have useful English national data. The total fertility rates (TFRs) and completed cohort fertility rates are as published by the Office for National Statistics (ONS), and the total abortion rates (TARs) and cohort abortion rates are derived by the author from official data. Modeling for England & Wales is based on cumulated cohort incidence of breast cancer within ages 50–54. The correlation coefficient is high (>0.9), and it is useful to include this variable as an explanatory variable in modeling.

Figure 4 shows the rates decomposed into parous and nulliparous cohort rates. The increasing proportion of nulliparous abortions affecting the women now entering age groups where they are likely to have breast cancer is apparent. This trend is a driver of the further increases in breast cancer incidence now observed.

Figure 5 shows average number of children, representing the cumulated cohort fertility rate for successive birth cohorts of English women compared with their breast cancer rate for cancer in women aged 50–54. The correlation coefficient is -0.57, so this variable is also useful to include in modeling.

Figure 6 shows mean age at first birth in England & Wales for successive birth cohorts. If the correlation were positive it could help to explain the trend, but it is negative.

Figure 7 shows cohort childlessness. The correlation in the graph is negative, and this variable is not used in the model to explain the British trend.

Two explanatory variables are selected for modeling: \( x_1 \) (abortion) and \( x_2 \) (fertility). The trends for abortion and fertility are shown in Figures 8 and 9 for countries considered.

The Mathematical Model is then:

\[
Y_i = a + b_1x_{1i} + b_2x_{2i} + e_i
\]

where \( Y \) represents cumulated cohort incidence of breast cancer within a particular age group; \( a \) is intercept, \( b_1 \) and \( b_2 \) are coefficients, and \( e \) is random error.
This model has desirable mathematical properties such as dimensional homogeneity, linearity, additivity, and parsimonious parameterization.

The model makes sense in terms of the factors not explicitly included. Higher fertility is associated with a lower age at first birth and less childlessness. Breastfeeding is strongly linked to fertility. Likewise lower fertility is associated with more use of hormonal contraceptives. Abortion can lead to prescription of hormonal contraceptives, and the mental health sequelae of abortion may lead to use of hormone replacement therapy.

The model was fitted to English female cohorts born in the years up to 1950 for cancer in women aged 50–54. The multiple R was 0.951. The estimated coefficient of abortion (b₁) is 0.0166 (95% CI, 0.0065–0.0396), and the coefficient of fertility (b₂) is −0.0047 (95% CI, −0.0135–0.0041). The coefficient of fertility is rather small, with the 95% confidence interval straddling zero. Some improvement in breastfeeding may be offsetting fertility decline. These results are summarized in Table 1.

### Forecasting for England & Wales

Forecasts are made using the model with the latest TFRs and TARs to estimate cumulated cohort rates of fertility and abortion for 25 years in the future. Here the recent rates for England & Wales in 2006 of TFR 1.86 and TAR 0.55 are used. Fitting this model gives an overall increase in the rate of cancer of 50.9%, which corresponds to a yearly compound increase of 1.7%. Assuming the breast cancer incidence rates for ages below 45 are constant, for ages 45–49 follow the trend as modeled for this age group, and for ages over 50 follow the trend as modeled for ages 50–54, we can estimate future breast cancer incidence rates for 25 future years with 2004 as base year for prediction. The numbers of new cancers to be expected in these years is then estimated using the Government Actuary’s population projections by applying the forecast incidence rates to the expected numbers of women in the relevant age groups in each year.

The numbers of newly diagnosed cancers forecast by this model are expected to increase to 65,252 in 2025, compared to the reported number 39,229 in 2004 (a 66.3% increase). These are shown with forecasts for intermediate years in Table 2.

The 1997-based forecasts using this model published in 2002 have anticipated quite well the reported increases in female breast cancer in England & Wales in 1998 to 2004 [Appendix A].

Cases of ductal carcinoma in situ (DCIS), which also requires treatment, are registered separately and are also forecast. DCIS is shown on mammography, and the number of cases has increased in the age groups targeted by screening. In 2004 there were 39,229 breast cancers and 3,827 cases of DCIS registered in England & Wales. The number of future cases is forecast by assuming that the ratio of cancers to DCIS stays constant in the main age groups affected. The increased numbers forecast are shown in Table 2.

These forecast numbers can be used to plan treatment facilities for women diagnosed with cancer.

### Modeling Applied to the Social Gradient

In Scotland the incidence gradient (Figure 10) is less than the gradient in England (Figure 2), and the mortality gradient is almost
Figure 9. Total Fertility Rates: TFR in England & Wales, Scotland, Northern Ireland, Republic of Ireland, Sweden, Czech Republic, Finland, and Denmark; 1968-2006

Figure 10. Cancer of the Female Breast, Scotland: Incidence, mortality and cause-specific survival at 5 years by deprivation quintile, for patients diagnosed 1991-95. Source: ISD publication Trends in Cancer Survival in Scotland 1971-1995

Figure 11. Breast Cancer in Women within Ages 45-49 in England & Wales, Scotland, Northern Ireland, Republic of Ireland, Sweden, Czech Republic, Finland, and Denmark; 1943-2005

Figure 12. Breast Cancer in Women within Ages 50-54 in England & Wales, Scotland, Northern Ireland, Republic of Ireland, Sweden, Czech Republic, Finland, and Denmark; 1943-2005

Figure 11. Breast Cancer in Women within Ages 45-49 in England & Wales, Scotland, Northern Ireland, Republic of Ireland, Sweden, Czech Republic, Finland, and Denmark; 1943-2005

Cancer registrations in Scotland started in 1960. Rates have been higher than in England, but recently the increase over all ages in Scottish breast cancer rates has been less than in England (Figures 11 and 12). Figure 8 shows the lower Scottish abortion rates. Figure 9 shows the greater decline in Scottish birth rates. The trend in cohort breast cancer in ages 50–54 up to 2004 proved non-linear and difficult to fit the model. The model was fitted for Scotland for ages 45–49 with results shown in Table 1.

Forecasts were made using the latest 2006 TAR for Scotland, 0.376, and the latest TFR, 1.67, giving an overall increase in the rate of cancer of 17.2%, or a yearly increase of 0.64%. Numbers of new cancers expected in Scotland are 6,177 in 2025 compared to the 3,917 reported for 2004, which is a 57.7% increase, in line with the aging of the population.

The lower abortion rates in Scotland lead to a forecast of a lesser further increase in incidence of breast cancer in Scotland compared to England, partly offset by lower fertility now in Scotland. Breastfeeding rates have been very low in Scotland, and this has reduced the protective effects of higher Scottish fertility in the past. With encouragement in recent years, the increase in breastfeeding has apparently offset the effects of the decline in the Scottish birth rate.

Northern Ireland

Data is limited, as cancer registration started in 1993. The incidence trends for the age groups 45–49 and 50–54 are shown in Figures 11 and 12. Abortions in England on women resident in Northern Ireland as reported in English abortion statistics are used to derive abortion rates for Northern Ireland. The trends in abortion and fertility in Northern Ireland are shown in Figures 8 and 9. Abortion rates in Ireland, where abortion is illegal, are much lower than in Great Britain. By smoothing the graph of cohort cancer incidence for Northern Ireland it was possible to fit the model and make estimates.

With this model fitted on the available years of data to 2004 for the age range 45–49, and the latest abortion and fertility rates...
entered, the 2006 TAR for Northern Ireland is 0.16, the latest TFR is 1.87, and the forecast increase in the rate of cancer is 9.3% (yearly increase 0.36%).

This forecasts an increase in new cancers in Northern Ireland to 1,626 in 2025 compared to the 1,117 reported for 2004, which is a 46% increase, largely due to aging of the population. This small increase follows from the very low abortion rate and comparatively high fertility in Northern Ireland.

Republic of Ireland

Data is limited, as cancer registration started in 1994. The incidence trends for the age groups 45–49 and 50–54 are shown in Figures 11 and 12. Data on women resident in the Republic in English abortion statistics are used to derive Irish abortion rates. The trends in abortion and fertility in the Republic of Ireland are shown in Figures 8 and 9. Abortion rates in the Republic are low, and Irish fertility rates are high compared with England.

Modeling used the latest available cancer data up to 2005 fitted for cohort incidence within ages 45–49. Forecasting used the TAR of 0.18 for 2006 and TFR of 1.86, giving a forecast increase in the rate of cancer of 8.3%, which corresponds to a yearly compound increase of 0.32%. This predicts an increase in numbers of new cancers in the Republic of Ireland to around 3,601 in 2025, compared to the 2,336 reported for 2005. The 54% increase is largely a consequence of the expected growth and aging of the Irish population.

Sweden

In Sweden cancer registration started in 1958. The incidence trends for the age groups 45–49 and 50–54 are shown in Figures 11 and 12. The trends in abortion and fertility in Sweden are shown in Figures 8 and 9. The nonlinear trend in fertility makes modeling difficult. The abortion rates in Sweden are higher than in England at the adult ages, but in Sweden most abortions are parous. Breastfeeding is also successfully promoted in Sweden, offsetting the carcinogenic effect of a high abortion rate.

Modeling is possible using recent data. Forecasting with the latest TAR for Sweden of 0.65 and the latest TFR of 1.75 produces an overall increase in the rate of cancer of 31.3%, which corresponds to a yearly compound increase of 1.12%. This predicts an increase in numbers of new cancers in Sweden to around 10,895 in 2025, compared to the 2,793 reported for 2005, a 49% increase.

Czech Republic

In the Czech Republic cancer registration started in 1977. The incidence trends are shown in Figures 11 and 12. Czech rates of breast cancer are low by comparison with other countries considered. Perhaps there is less genetic susceptibility. The trends in abortion and fertility in the Czech Republic are shown in Figures 8 and 9. Abortion rates in the Czech Republic were high, and most abortions are parous. Data for recent years was used to fit the model.

Forecasts using the latest TAR for the Czech Republic of 0.35 and the latest TFR of 1.23 gave an overall increase in the rate of cancer of 39.2%, or a yearly increase of 1.33%. The Czech abortion rate has declined markedly, but the Czech birth rate has declined even more remarkably in recent years. These are offsetting factors for breast cancer. The model predicts 8,412 new malignancies in the Czech Republic in 2025 compared to the 5,449 reported for 2003, a 54% increase.

Finland

In Finland cancer registration started in 1953 and data is available for years since 1977. The incidence trends are shown in Figures 11 and 12. The trends in abortion and fertility in Finland are shown in Figures 8 and 9. By using data for recent years it was possible to fit the model.

The latest available TAR for Finland is 0.34 and the latest TFR is 1.7. In the modeling these gave an expected decrease in the rate of cancer of 6.8%, i.e. a yearly compound decrease of 0.28%, reflecting the decline in the Finnish abortion rate and some recovery in the birth rate in Finland. The forecast increase to 4,045 breast cancers in 2025, compared to the 3,794 reported for 2003, results from the aging of the population.

A negative social gradient in Finland is reported in a large study. “Cancers of the breast were most common in high social classes throughout the whole observation period 1971–1995. The relative difference between the SIRs (Standardised Incidence Ratios) of social classes I and IV diminished from 2-fold in the period 1971–1975 to 1.5-fold in 1991–1995. SIRs were 1.67 in social class I and 0.81 in social class IV in 1971–1975 and 1.4 and 0.81 respectively in 1991–1995.”

The social gradient was not explicable in terms of fertility. “In Finland there is relatively little difference between social classes in the age at first birth and average number of children.” Abortion was not considered as an explanatory variable in this study. If it had been considered, the gradient might have been better understood. The lessening of the social gradient may be linked to a decline in the Finnish abortion rate.

Denmark

In Denmark cancer registration goes back to the 1940s but data after 2001 is not available. The trend is similar to other countries discussed above (Figures 11 and 12). Abortion rates declined after 1989 (Figure 8) and are less than in Sweden and England. Fertility shows a decline similar to that in Sweden (Figure 9).

Cohort fertility for years of birth before 1945 and abortion rates before 1973 were estimated. Age-specific fertility rates were not available for earlier years, and approximate estimates were made. Trend lines proved nonlinear, and model fitting was difficult. Modeling used a fixed intercept and recent data with results summarized in Table 1. The latest TAR (0.45) and TFR (1.8) gave an expected decrease in the rate of cancer of 4.1%, i.e. a yearly compound decrease of 0.16%. This decline reflects the decline in the Danish abortion rate.

A social gradient has also been found in Denmark. A large Danish national study found a higher incidence of breast cancer in the higher social classes. Academics (persons with higher education) had the highest risk of breast cancer, which was 74% above that of women in agriculture, who had the lowest risk. The records were adequate to control for various risk factors, and the study concluded that “the large social differences in fertility history among Danish women could not explain the social differences in breast cancer risk.” In particular, “[a]ge at first birth and parity
could not explain the effect of socioeconomic group on breast cancer incidence and mortality. Abortion was not considered as a relevant factor. If it had been considered the gradient might have been explained.

Summary

In most countries considered, women now over age 45 have had more abortions and fewer children than previous generations of women, and a further increase in breast cancer incidence is to be expected. Variations in breast cancer incidence across social class and across geographic regions can also be expected to increase.

In England, a high rate of abortion leads to the large forecast increase. In Scotland, the lower abortion rate, offset by lower fertility than in England, leads to a slightly lower rate of increase expected. In both Irish jurisdictions, a continuation of low abortion rates and comparatively high fertility rates lead to low forecast increases in incidence of breast cancer. In Sweden a high abortion rate is offset partly by fewer nulliparous abortions and a high level of fertility and breastfeeding.

In the Czech Republic, the forecast of an increase in breast cancer incidence is largely the result of the fallen birth rate. In Finland and Denmark, lower abortion rates imply less breast cancer in the future.

The negative or reverse social gradient whereby upper class women have more breast cancer is apparent in four countries where it is measured: England & Wales, Scotland, Finland, and Denmark. In all of these countries the known reproductive factors other than abortion fail to explain the gradient. But the known likelihood for upper class and upwardly mobile women to prefer abortions when pregnant could provide some explanation of this gradient. If abortions had been examined in the studies of this social gradient, the role of this factor could have been made clear.

Conclusion

The increase in breast cancer incidence appears to be best explained by an increase in abortion rates, especially nulliparous abortions, and lower fertility. And the social gradient, which is not explained by fertility, seems also attributable circumstantially to abortion. A linear regression model of successive birth cohorts of women with abortion and fertility as explanatory variables fitted to the cancer incidence up to 1977 has produced forecasts that have performed well in the years 1998–2004 in Great Britain (Appendix A). The new forecasts for eight countries can be tested in the coming years.

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REFERENCES


Appendix A. Female Breast Cancers and Ductal Carcinoma in Situ (DCIS) in England & Wales: Comparison of Forecast Numbers Published in 2002\textsuperscript{st} with Reported Incidence in the Years 1998–2004

Modelling based on breast cancer incidence data up to 1997 was used to forecast incidence over future years through 2027. Forecast rates were applied to the projected female population in the 1997-based forecast made by the UK Government Actuary to calculate forecast numbers of cancers.

In these 1997-based forecasts, the same rate of increase in incidence was assumed to apply to all age groups.

Two forecasts were made: (1) Using model fitting without weighting to allow for additionally carcinogenic effect of nulliparous abortions gave a lower increase in rates of 44.4% over 30 years, or 1.25% per annum. (2) With weighting to allow for the additionally carcinogenic effects of nulliparous abortions, the model gave a higher increase of 2.2% per annum or 92% over 30 years.

### Table A1. Number of Female Breast Cancers in England & Wales, Observed v. Predicted from Unweighted Model

<table>
<thead>
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<th>Year</th>
<th>Age Groups</th>
<th>Expected</th>
<th>Observed</th>
<th>% Observed/Expected</th>
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<td>15-44</td>
<td>3842</td>
<td>3189</td>
<td>101.5</td>
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<tr>
<td></td>
<td>45-49</td>
<td>4678</td>
<td>3585</td>
<td></td>
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<tr>
<td></td>
<td>50-54</td>
<td>3880</td>
<td>2880</td>
<td></td>
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<tr>
<td></td>
<td>55-59</td>
<td>4351</td>
<td>3430</td>
<td></td>
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<td></td>
<td>60+</td>
<td>4153</td>
<td>3195</td>
<td></td>
</tr>
<tr>
<td></td>
<td>All ages</td>
<td>18856</td>
<td>15460</td>
<td></td>
</tr>
</tbody>
</table>

### Table A2. Number of Cases of Female DCIS in England & Wales, Observed v. Predicted from Unweighted Model

### Table A3A. Combined Cases of Female Breast Cancer and DCIS in England & Wales, Observed v. Predicted from Unweighted Model

### Table A4. Number of Female Breast Cancers in England & Wales, Observed v. Predicted from Model Weighted for Nulliparous Abortions

### Table A5A. Number of Cases of Female DCIS in England & Wales, Observed v. Predicted from Model Weighted for Nulliparous Abortions

### Table A6A. Combined Cases of Female Breast Cancer and DCIS in England & Wales, Observed v. Predicted from Model Weighted for Nulliparous Abortions

Tables 1A–3A show the observed cases from official counts of new cases and the expected numbers calculated with the unweighted model, for cancers, ductal carcinoma in situ (DCIS), and cancers combined with DCIS, respectively. The forecast tended to underestimate slightly the number of cancers; the ratio of observed to expected was 1.013 (101.3%) in 2004. For DCIS, the underestimate, O/E = 1.54 (154.3%) for 2004, was much more notable, probably owing to extension of screening programs. The combined rate of cancers and DCIS was somewhat underestimated, O/E = 1.04 (104.4%) in 2004.

Weighting for the increased carcinogenicity of nulliparous abortions gave the results shown in Tables 4A–6A for cancers, DCIS, and cancers combined with DCIS, respectively. Cancers were slightly overestimated, O/E = 0.946 (94.6%) for 2004. DCIS was underestimated, but so less than with the first model: O/E = 1.44 (144%) in 2004. The combined forecast proved quite good, with 100.5% of the total new malignancies anticipated in 2003, and 97.5% in 2004.