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Health-Economic Evaluation of Extended Age Ranges and Increased Participation in Breast Cancer Screening in Four Major European Countries

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Please cite this report as:

Carlsson H, Fridhammar A, Košir U, Hofmarcher T. Health-economic evaluation of extended age ranges and increased participation in breast cancer screening in four major European countries. IHE REPORT 2026:8, IHE: Lund, Sweden.

Disclosure:

This report was funded by Novartis, which was given the opportunity to comment on initial drafts and review the material for factual accuracy and compliance. The views and opinions expressed in the report do not necessarily reflect those of Novartis. The authors retain sole responsibility for the analysis, interpretation, and conclusions presented.

IHE REPORT 2026:8
e-ISSN:1651-8187
ISSN:1651-7628

The report can be downloaded from IHE's website (www.ihe.se)

Foreword

Breast cancer screening is essential for detecting cancer earlier and reducing mortality. In 2022, the Council of the European Union recommended extending the target age range from 50–69 years to 45–74 years, while European quality guidelines call for participation rates of at least 75%. However, many countries have not yet reached these targets.

This report examines the health-economic implications of extending screening age limits and increasing participation in France, Germany, Italy, and Spain. Implementing the extended age range together with achieving 75% participation could save more than 3,200 lives annually across the four countries. Although expenditure on screening services and other healthcare services would increase, some costs would be offset by lower productivity losses. Increasing participation among women already eligible for screening was generally the most cost-effective strategy, while extending screening to younger and older women was cost-effective in nearly all scenarios.

These findings highlight the importance of improving access, health literacy, participation, and equity. We hope the report supports efforts to strengthen breast cancer screening across Europe.

The responsibility for the analysis and conclusions lies solely with the authors.

Lund, August 2026

Peter Lindgren
Managing Director, IHE

Table of Contents

Summary

Background

In 2022, the Council of the European Union recommended extending the target age group for breast cancer screening from 50-69 years to 45-74 years. European quality guidelines aim for a 75% participation rate in screening programs. Many European countries do not yet reach these targets.

Methods

The study used a prevalence-based societal perspective to analyze costs and health effects of breast cancer screening over one year among women aged 45 to 74 in France, Germany, Italy, and Spain. Five scenarios, 1) lowering the lower age limit, 2) raising the upper age limit, 3) adjusting both age limits, 4) increasing the participation rate, and 5) all changes together were compared with current practices using a decision-analytic model.

Results

Extending the age ranges and improving screening participation rates would save over 3,200 lives per year (9.3% reduction in breast cancer deaths) across the four countries. The annual gains in health outcomes come at an additional societal cost of EUR 519 million, corresponding to 3.8% of the current societal costs. All scenarios were below estimated country-specific willingness-to-pay thresholds from both the payer and societal perspective, except for lowering the screening age limit in Spain. Generally, raising participation was the most cost-effective intervention.

Conclusions

Expanding the age range led to additional lives saved, but increasing participation among women already eligible for screening produced the greatest reductions in breast cancer mortality and was the most cost-effective option. Policymakers should therefore prioritize improving access, equity, and engagement within existing breast cancer screening programs.

List of abbreviations

AI - Artificial intelligence

DBT - Digital breast tomosynthesis

EU - European Union

EUR - Euro (€)

G-BA - Federal Joint Committee in Germany

ICER - Incremental cost-effectiveness ratio

NHS - National Health Service

QALYs - Quality-adjusted life years

UK - United Kingdom

1. Introduction

Breast cancer is the most commonly diagnosed cancer among women in Europe and represents one of the leading causes of cancer mortality (1). The economic burden is substantial, and breast cancer represented approximately EUR 15 billion of the total EUR 126 billion in cancer-related costs in the European Union (EU) in 2009, ranking it the second most expensive cancer after lung cancer (2). Early detection is crucial, and mammography screening has been shown to substantially reduce breast cancer mortality (3) and has been widely adopted across European countries (4). Despite this widespread adoption, substantial disparities remain between countries and regions in screening implementation, coverage and the role of opportunistic screening.

In 2003, the Council of the European Union recommended biennial, organized population-based mammography screening for women aged 50–69 years (5). This recommendation was updated in 2022 to extend the target age range to 45–74 years (3). In France, the national screening program includes women aged 50–74 (6), and the government has requested a review of whether the minimum screening age should be lowered (7). The German national screening program included women aged 50–69 until 2024 when the upper limit was increased to 75 years (8). Lowering the starting age from 50 to 45 has also been approved by the Federal Joint Committee (G-BA), but reimbursement and implementation are pending (9). In Italy, several regions already offer screening to women aged 45–49 and 70–74, and the 2026 budget law provides funding to extend screening nationally to these age groups (10). While the national screening program in Spain only includes women aged 50–69 (11), several regions have extended the age limits to include younger or older women (12).

One key determinant of the effectiveness and cost effectiveness of the screening programs is the participation rate among eligible women. Participation rates are influenced by multiple factors, including socioeconomic inequalities, organizational and structural differences in screening programs, whether women are invited to book an appointment or are given a pre-scheduled one, and the possibility to take time off from work for the appointment. The participation rates in France (47%), Germany (52%), Italy (55%), and Spain (69%) (13) all fall below the desired threshold of 75% in the European Quality Assurance Guidelines (14). In addition, the rates of opportunistic screening, outside of the national screening programs, were 14% in France, 5% in Germany, 19% in Italy, and 20% in Spain in 2015 (15). National screening programs operate under strict quality assurance protocols, which can help limit unnecessary interventions compared to opportunistic screening. Shifting screening activities and resources from opportunistic screening to organized screening programs is therefore important.

The four countries in the analysis represent diverse organizational models of breast cancer screening. Germany and France operate nationally organized screening programs, while Spain and Italy have decentralized, regionally based screening programs with differences in screening implementation and participation rates (4, 12, 16).

Although the European guidelines are based on substantial evidence (3), implementation decisions rely on the local authorities and require careful consideration of benefits, harms, epidemiological patterns, budget impact, cost-effectiveness, and available human resources. The process of extending screening age ranges must thus be evaluated within context-specific healthcare data.

The aim of this study is to evaluate the health effects, costs, productivity losses and cost-effectiveness of extending the age range to 45–74 years and increasing participation in national screening programs in France, Germany, Italy, and Spain.

2. Methods

Study design

The study used a prevalence-based approach, analyzing costs and health effects over a one-year period. The analysis was performed from a societal perspective, including both healthcare costs and productivity losses. The study included all women aged 45–74 years in France, Germany, Italy, and Spain. The five scenarios assessed are described in Table 1.

Table 1: Modelled breast cancer screening scenarios

Scenario	Description
1. Lower age limit of 45 years	The lower age limit for breast cancer screening is reduced to 45 years, while the existing upper age limit and participation rate remain unchanged.
2. Upper age limit of 74 years	The upper age limit for breast cancer screening is increased to 74 years, while the existing lower age limit and participation rate remain unchanged.
3. Extended age range of 45 to 74 years	Both age limits are adjusted, extending breast cancer screening to women aged 45 to 74 years. The participation rate remains unchanged.
4. Participation rate of 75%	The participation rate is increased to 75% within the existing screening age range.
5. Combined changes	The screening age range is extended to 45 to 74 years and the participation rate is increased to 75%. The higher participation rate also applies to women in the newly included age groups.

The comparator in all scenarios was the current age ranges and participation rates in the respective countries. The participation rates in the analysis included screenings conducted within the national program but excluded opportunistic screening. As Germany and Italy only recently extended the age limits of the screening programs, the former age group 50-69 was used as the comparator in the analysis.

A decision analytic model constructed in Microsoft Excel was used. The model was originally developed to evaluate the cost-effectiveness of adjusting the lower and upper age limits for the Swedish national breast cancer screening guidelines (17), and it was recently used to evaluate the cost-effectiveness of screening with digital breast tomosynthesis (DBT) (18). For this study, the model was updated to include stage-specific incidence and costs for breast cancer in situ and stages I–IV, as well as productivity losses for all stages.

The model employed methods described in a meta-analysis evaluating the benefits and harms of breast cancer screening by the Independent UK Panel on Breast Cancer Screening (19). Absolute reductions in breast cancer mortality due to screening were estimated by applying published relative reductions in breast cancer-specific mortality to the breast cancer mortality in each country. It was assumed that screening had no effect on mortality during the first five years of screening, and that the relative mortality reduction persisted for ten years after the final screening.

Stage shift due to screening was included in the model to account for earlier detection. Women who did not participate in screening were assumed to have the same stage distribution as women not invited to screening. Stage distributions for women participating in screening were estimated from the difference between invited and not invited women, adjusted for participation rate.

A potential harm of mammography screening is overdiagnosis, defined as the detection of breast cancers through screening that would not have become clinically apparent during a woman's lifetime in the absence of screening, leading to unnecessary treatment (19). The absolute increase in breast cancer incidence was estimated by applying published frequencies of overdiagnosis due to screening to the breast cancer incidence in each country. Outcome measures included lives saved, life years gained, quality-adjusted life years (QALYs) gained, healthcare costs, productivity losses, and incremental cost-effectiveness ratios. The human capital approach was used to value lost productivity, measuring losses by the market value of wages and employer social contributions. QALYs and productivity losses associated with breast cancer mortality were discounted at 3% annually. Incremental cost-effectiveness ratios were compared to estimated country-specific willingness-to-pay thresholds (20), standardized to 2024 price levels.

Input data

Population size and screening participation rates were obtained from Eurostat for all countries (13, 21). Recall rates were sourced from country-specific studies; see Appendix Table 3 to Table 6. Breast cancer incidence data were obtained from the Global Cancer Observatory (2022) for France, Italy, and Spain (52), and from the national cancer registry (2023) for Germany (22). The stage distribution of invasive breast cancer at diagnosis was obtained from country-specific studies; see Appendix Table 3 to Table 6. In the absence of stage-specific French data for women aged 45–49 years, the average stage distribution from Germany and Spain was used, as they had similar stage distributions in women age 50-69. The proportion of cancer in situ relative to invasive cancer was available only for Germany and was used for the other countries (Appendix Table 4).

Relative breast cancer incidence for women invited to screening, used to estimate overdiagnosis, was sourced from the European Guidelines on Breast Cancer Screening and Diagnosis (3); see Appendix Table 7. No estimate was available for women aged 45–49, so data from ages 50–74 were used instead. Relative breast cancer incidence for screened women was estimated from invited women, assuming a participation rate of 75% in the underlying randomized clinical trials.

Breast cancer mortality and life tables were sourced from Eurostat for all four countries, available by country in Appendix Table 3 to Table 6. Relative breast cancer mortality reduction for women invited to screening was obtained from the European Guidelines on Breast Cancer Screening and Diagnosis, separately for women aged 45-49 and 70-74 years (3). Relative breast cancer mortality for screened women was estimated from invited women, assuming a participation rate of 70% in the underlying randomized clinical trials (Appendix Table 7).

Stage distributions under the current screening programs for invited and not invited were collected from country-specific studies; see Appendix Table 3 to Table 6. In the model, women aged 45–49 and 70–74 who were invited to screening were assigned the same stage distribution as women aged 50-69 (50–74 in France) invited to screening. To estimate the effect of increased participation in breast cancer screening on women currently invited, a hypothetical group of women aged 50-69 (50–74 in France) not invited to screening was constructed. This group was assigned the average stage distribution of women aged 45–49 and 70–74 not invited to screening.

Quality of life data by stage of breast cancer were retrieved from the NHS England Cancer Quality of Life Survey, combined with the population norm from England (Appendix Table 7). The baseline general population quality of life by country is available in Appendix Table 3 to Table 6.

Healthcare costs, including invitation to screening, screening examination, recall, and stage-specific treatment costs were based on country-specific studies; see Appendix Table 3 to Table 6. Where cost data were missing, values were imputed based on information from other countries. All costs were standardized to 2024 price levels.

The average number of days absent from work due to breast cancer was obtained from country-specific studies; see Appendix Table 3 to Table 6. Stage-specific days absent from work were estimated based on stage-specific data reported in a Swedish study (23). Daily production was estimated using employment rates, working hours, and labor costs including employers' social contributions sourced from Eurostat; see Appendix Table 3 to Table 6.

3. Results

The expected outcomes of extending the age ranges and improving participation rates in screening in line with European recommendations and guidelines are profound. The number of lives saved, life years, and discounted QALYs for the individual scenarios are shown in Figures 1-3. When all changes are implemented simultaneously, participation increases in extended age groups, resulting in total changes that are larger than in the individual scenarios. Implementing all changes in the four countries was estimated to save more than 3,200 lives per year (9.3% reduction in total breast cancer deaths), resulting in nearly 53,000 life years and more than 35,000 discounted QALYs gained.

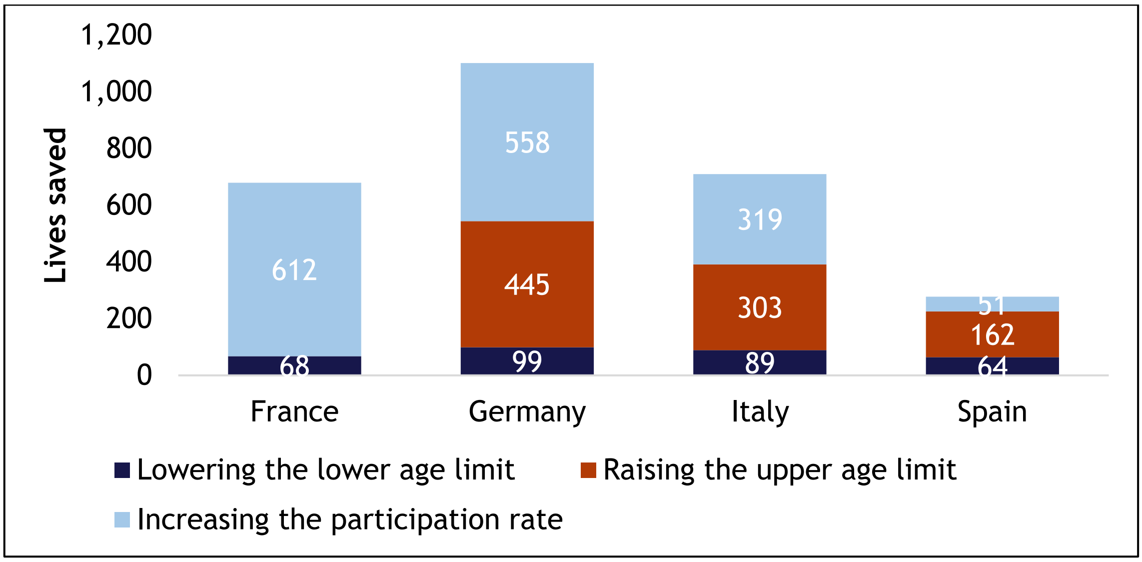

Figure 1: Number of lives saved by country and scenario.

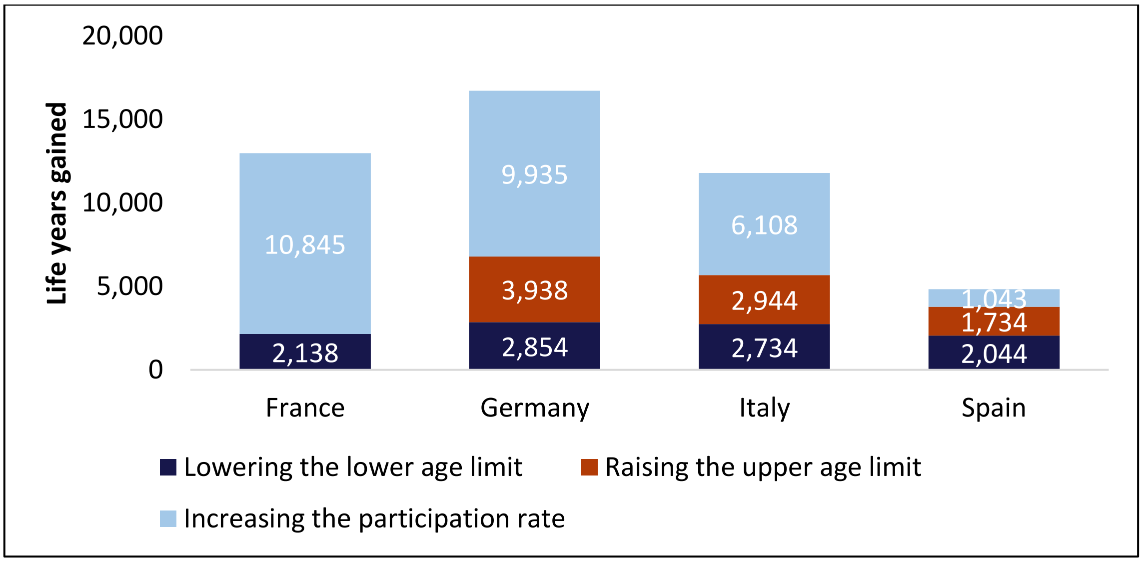

Figure 2: Number of life years gained by country and scenario.

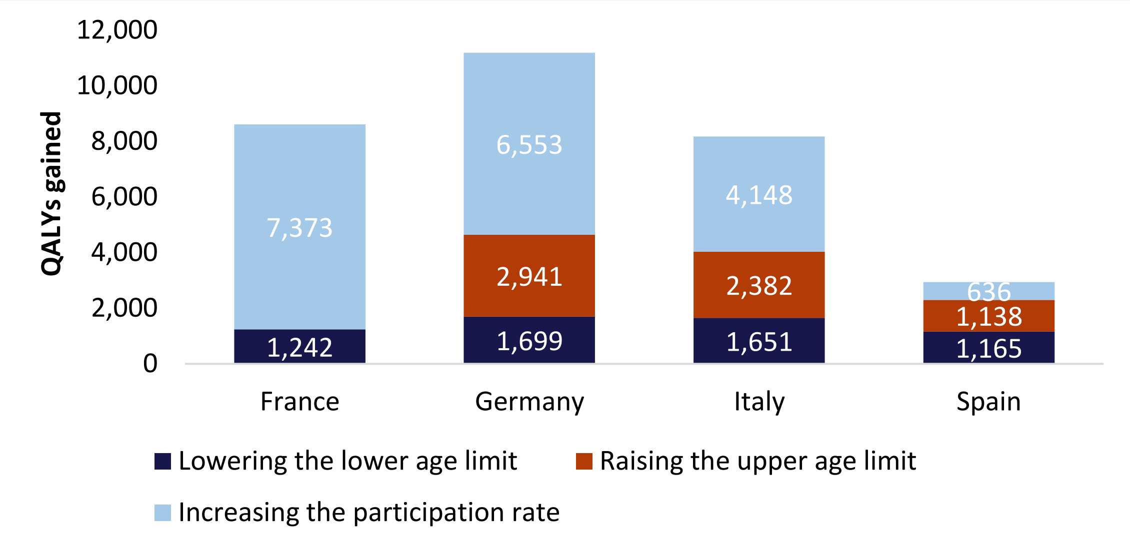

Figure 3: Number of discounted QALYs gained by country and scenario.

These annual gains in health outcomes come at an additional cost of EUR 662 million in healthcare expenditure, corresponding to a 10.8% increase of current healthcare spendings, as screening costs increase by EUR 749 million but treatment costs decrease by EUR 87 million. In addition, productivity losses decrease by EUR 142 million (1.9% reduction of current productivity losses). This results in a EUR 519 million increase in societal costs, corresponding to 3.8% of the current societal costs.

Across all scenarios, the diagnosis of breast cancer in situ and at stage I increases, partly due to stage shift and partly due to overdiagnosis, see detailed results in Appendix Table 8 to Table 11. At the same time, the number of cancers detected at stages II-IV decreases. Screening costs (including the cost of invitation, mammography, and recall), treatment costs, and productivity losses for each intervention compared to the current situation are presented in Table 1. Cost-effectiveness results are presented by country in Figure 4, Figure 5, Figure 6 and Figure 7.

Table 2: Costs in EUR million by country and scenario.

Costs in EUR million	Current program	Differences				
		Lower	Upper	Lower & upper	Participation rate	All changes*
			France			
Screening	252	50	N/A	N/A	148	228
Treatment	1 519	1	N/A	N/A	-11	-11
Productivity losses	2 234	-15	N/A	N/A	-4	-28
Total, Healthcare perspective	1 772	50	N/A	N/A	137	217
Total, Societal perspective	4 006	36	N/A	N/A	133	189
			Germany			
Screening	308	61	58	120	134	306
Treatment	1 874	-3	-14	-17	-18	-42
Production losses	2 906	-39	0	-39	-22	-78
Total, Healthcare perspective	2 183	59	45	103	116	263
Total, Societal perspective	5 092	21	45	65	95	187

Italy						
Screening	149	38	30	68	43	130
Treatment	941	-1	-7	-8	-8	-18
Production losses	1 265	-14	0	-14	-5	-25
Total, Healthcare perspective	1 091	37	23	60	36	112
Total, Societal perspective	2 355	23	23	46	30	87
Spain						
Screening	140	42	25	67	12	85
Treatment	920	-3	-9	-12	-3	-16
Production losses	1 140	-10	0	-10	-2	-13
Total, Healthcare perspective	1 061	39	16	56	9	69
Total, Societal perspective	2 201	29	16	45	7	56

*Notes: * When all changes are implemented simultaneously, participation increases in extended age groups, resulting in total changes that are larger than in the individual scenarios.*

France

In France, women aged 70-74 years are already included in the screening program and increasing the participation rate to 75% was estimated to save 612 lives annually, compared with 68 lives saved by lowering the lower age limit. When implementing both changes simultaneously, breast cancer deaths were reduced by 721 (8.6%). Increasing the participation rate resulted in most life years and QALYs gained. Increasing the participation rate also induced the largest savings in cancer treatment costs (EUR 11 million), whereas lowering the age limit led to the largest productivity gains (EUR 15 million). Lowering the lower age limit had the lowest estimated additional healthcare and societal cost at EUR 50 and EUR 36 million, respectively. Implementing both changes simultaneously increased total societal costs of breast cancer by EUR 189 million (4.7%). Lastly, increasing the participation rate was the most cost-effective scenario from both the healthcare and the societal perspective.

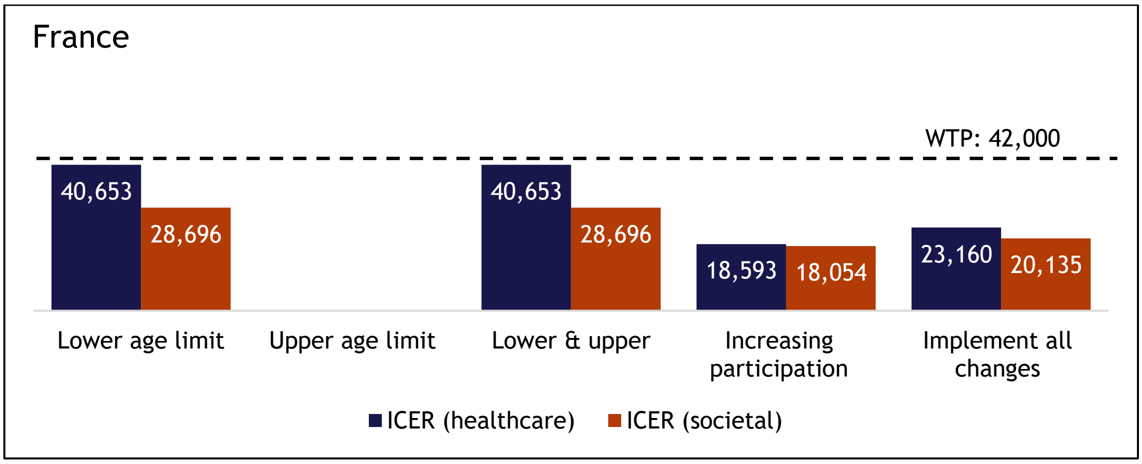

Figure 4: ICERs for the scenarios in France (bars) and willingness-to-pay thresholds (dotted lines).

Notes: ICER = Incremental cost-effectiveness ratio. Country-specific willingness-to-pay thresholds are estimated and standardized to 2024 price levels (EUR per QALY).

Germany

It was estimated that increasing the participation rate to 75% in Germany could save 558 lives annually, compared with 445 lives saved by raising the upper age limit and 99 lives saved by lowering the lower age limit. Implementing all changes simultaneously resulted in a reduction in breast cancer deaths by 1,342 (10.4%). Increasing the participation rate also resulted in most life years and QALYs gained, as well as the largest savings in cancer treatment costs at EUR 18 million. Raising the upper age limit had the lowest estimated additional healthcare cost at EUR 45 million, whereas lowering the lower age limit had the lowest estimated additional societal cost (EUR 21 million) and led to the largest productivity gains at (EUR 39 million). Implementing all changes simultaneously increased the total societal costs of breast cancer by EUR 187 million (3.7%). Raising the upper age limit was the most cost-effective scenario from the healthcare perspective, whereas lowering the lower age limit was the most cost-effective from the societal perspective.

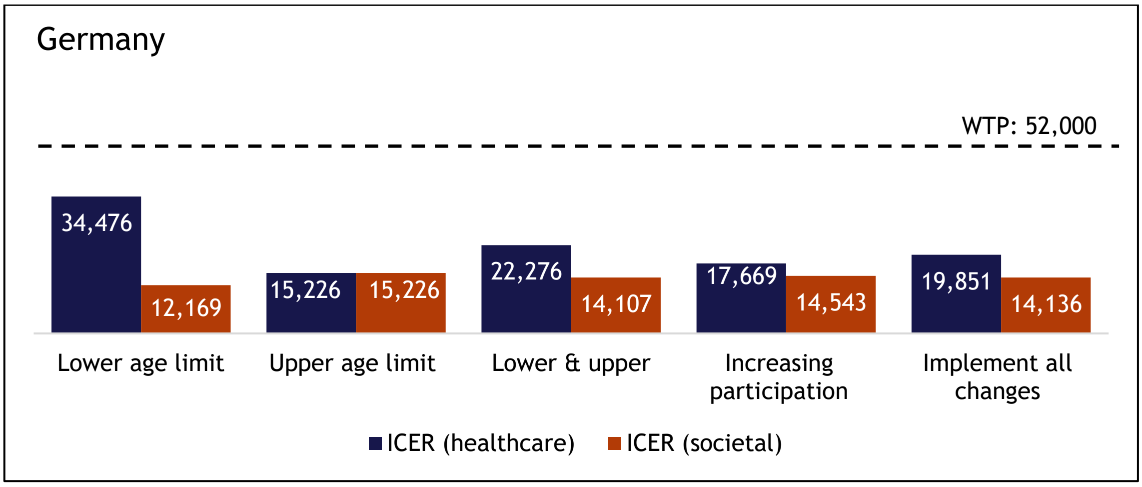

Figure 5: ICERs for the scenarios in Germany (bars) and willingness-to-pay thresholds (dotted lines).

Notes: ICER = Incremental cost-effectiveness ratio. Country-specific willingness-to-pay thresholds are estimated and standardized to 2024 price levels (EUR per QALY).

Italy

In Italy, increasing the participation rate to 75% was estimated to save 319 lives annually, compared with 303 lives saved by raising the upper age limit and 89 lives saved by lowering the lower age limit. Implementing all changes at once reduced breast cancer deaths by 849 (9.7%). Increasing the participation rate resulted in most life years and QALYs gained, as well as the largest savings in cancer treatment costs at EUR 8 million. Raising the upper age limit had the lowest estimated additional healthcare and societal cost, both at EUR 22.7 million. Lowering the lower age limit on the other hand induced the largest productivity gains at EUR 14 million. Implementing all changes simultaneously increased the total societal costs of breast cancer by EUR 87 million (3.7%). Increasing the participation rate was the most cost-effective scenario from both the healthcare and the societal perspective, closely followed by raising the upper age limit.

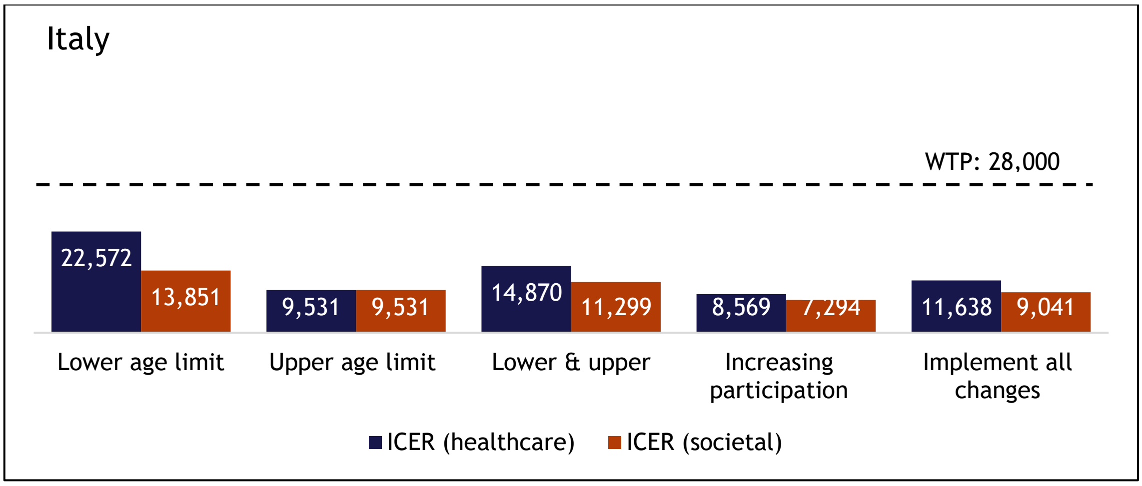

Figure 6: ICERs for the scenarios in Italy (bars) and willingness-to-pay thresholds (dotted lines).

Notes: ICER = Incremental cost-effectiveness ratio. Country-specific willingness-to-pay thresholds are estimated and standardized to 2024 price levels (EUR per QALY).

Spain

Raising the upper age limit in Spain was estimated to save 162 lives annually, compared with 64 lives saved by lowering the lower age limit and 51 lives saved by increasing the participation rate to 75%. In contrast, lowering the lower age limit resulted in most life years and QALYs gained. Implementing all changes simultaneously resulted in a decrease in breast cancer deaths of 297 (6.9%). Increasing the participation rate had the lowest estimated additional healthcare cost and societal cost at EUR 9 and EUR 7 million respectively. Raising the upper age limit induced the largest savings in cancer treatment costs EUR 9 million, and lowering the age limit led to the largest productivity gains at EUR 10 million. When implementing all changes simultaneously, the total societal costs of breast cancer increased by EUR 56 million (2.5%). Increasing the participation rate was the most cost-effective scenario from both the healthcare and the societal perspective, closely followed by raising the upper age limit.

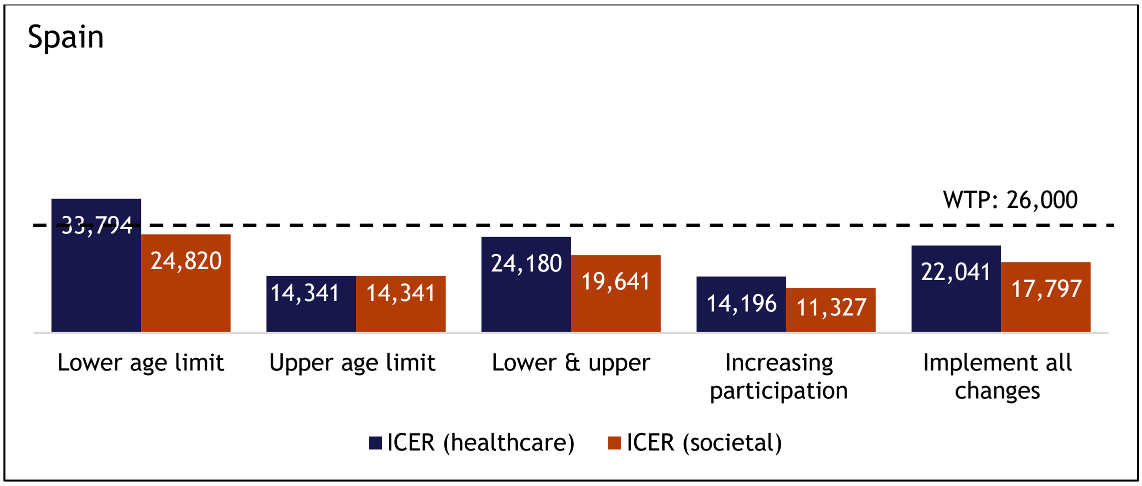

Figure 7: ICERs for the scenarios in Spain (bars) and willingness-to-pay thresholds (dotted lines).

Notes: ICER = Incremental cost-effectiveness ratio. Country-specific willingness-to-pay thresholds are estimated and standardized to 2024 price levels (EUR per QALY).

4. Discussion

This study evaluated the health outcomes, screening and healthcare costs, productivity losses, budget impact, and cost-effectiveness of extending the age range to 45–74 years and increasing the participation rate to 75% in national breast cancer screening programs in France, Germany, Italy, and Spain. Across all four countries, the modeled changes resulted in substantial reductions in breast cancer mortality and gains in life years and QALYs. When both the extended age ranges and increased participation were implemented simultaneously, the number of lives saved annually were estimated to be 721 in France, 1,342 in Germany, 849 in Italy, and 297 in Spain. Increasing the participation rate to 75% had the largest effects in France, Germany, and Italy, while raising the upper age limit to 74 years had the largest effects in Spain, where the current participation rate is already at 69%. All scenarios were below estimated country-specific willingness-to-pay thresholds from both the payer and societal perspective, except for lowering the lower age limit in Spain.

These findings are broadly consistent with previous European modelling evidence. A systematic review of 32 economic evaluations found that breast cancer screening models generally projected gains in life expectancy or QALYs at costs considered acceptable, despite substantial methodological variation across studies (24). The present study adds to this literature by applying a consistent modelling framework across four European countries and by comparing changes in screening age limits, participation rates, and their combined implementation.

Across the four countries, extensions of breast cancer screening age limits are either under consideration, in the process of implementation, or already in place on regional or national level. Germany currently screen women aged 70-75 (8), whereas France screen those aged 70-74 (6), and both countries are evaluating lowering the age limit to include women aged 45-49 (7, 9). Several regions in Italy and Spain have expanded both the lower and upper age limits, and Italy is also in the process of extending the lower and upper age limits at the national level (10). Overall, these developments suggest a gradual convergence toward the Council of the European Union's recommendations, despite remaining gaps in implementation.

Increasing participation rates in breast cancer screening presents a more complex policy challenge. Low participation can be explained by system-level factors such as program organization. Prebooked appointments, sending reminders of appointments and navigation services have been shown to increase participation (25, 26). Digital invitations and reminders may also increase participation rates (27, 28). The use of multiple communication channels rather than just one has also been shown to increase participation (29). Another important factor is the screening cost paid by the woman. However, as breast cancer screening within the organized program is free of charge in all four countries (30), this does not seem to be a barrier to participation.

Low participation in breast cancer screening can also be explained by individual-level determinants, such as socio-demographic characteristics and health literacy (31, 32). Approximately half of the European population is estimated to have limited health literacy (33), which is associated with lower awareness of screening programs, poorer understanding of benefits and risks, and lower participation in mammography screening (34). Health literacy is strongly associated with socioeconomic status and education, which are also directly associated with disparities in breast cancer outcomes (35). Increasing participation may therefore require targeted strategies that address these underlying inequities. Studies show that reminders, education and navigation services are especially effective in increasing participation in underserved groups (25).

Denmark, Finland, Norway, Sweden, and Slovenia have the highest participation rates in Europe ranging from 77% to 83% (13). The high participation rates in these countries can be explained by several factors. Common for all these countries is that the appointments are prebooked in the invitation to screening (36-38) Denmark, Finland, Norway, and Slovenia send reminders to non-participants, while in Sweden it varies by region. In Slovenia the reminder includes a new prebooked appointment. The screening appointment is free in all countries, except for Norway. Interestingly, the rate of opportunistic screening is below 5% in the four Nordic countries, while it is at 13% in Slovenia (15).

Extending the age limits and increasing participation in breast cancer screening, though cost-effective, is estimated to increase screening and healthcare costs. However, the analysis does not consider potential shifts from opportunistic screening to organized screening programs, although interventions that increase participation in organized screening may at the same time decrease engagement in opportunistic screening. Organized screening programs operate under strict quality assurance protocols with standardized reading procedures and follow-up, which may limit unnecessary interventions, while opportunistic screening may involve more frequent examinations, less adherence to evidence-based intervals, and limited oversight, potentially increasing costs. In France, Italy, and Spain, where opportunistic screening rates range from 14% to 20%, policies aimed at shifting participation from opportunistic screening to organized programs may partially offset the increased costs of extending organized screening.

Increasing the number of women participating in organized screening would further increase the pressure on practicing radiologists and increase the demand of new ones, partially offset by reduced opportunistic screening, making considerations of capacity important in accommodating such changes in a sustainable way. Advances in imaging technologies, including digital breast tomosynthesis (3D mammography), and the integration of artificial intelligence (AI) for image reading have the potential to reduce radiologist workload. Evidence from the Swedish MASAI trial suggests that AI-supported screening may achieve comparable or improved diagnostic performance with fewer recalls, while reducing radiologist workload by around 44% (in a setting with double reading) (39). Moreover, advances such as the use of AI for automatic speech recognition in record keeping could potentially increase efficiency and free up resources for clinicians (40). Increasing the use of AI in radiology may therefore result in lower costs associated with breast cancer screening and healthcare.

This study has several strengths. It presents a comparative cost-effectiveness analysis of breast cancer screening strategies across four major European countries using a consistent modelling framework. By assessing five policy-relevant scenarios, the analysis enables direct comparison of alternative screening strategies and supports prioritization of interventions based on value for money. The stratification of breast cancer by stage enables analysis of how stage distribution and associated costs are affected by screening. The presentation of screening costs, healthcare costs, and productivity losses separately enables budget impact analysis and enhances the policy relevance of the findings.

Nonetheless, several limitations should be acknowledged. Data availability varied across countries, leading to partial gaps in input parameters including stage distribution, screening and treatment costs, and productivity losses. Consequently, assumptions and extrapolations were required. Moreover, the analysis did not fully capture age-specific variation in the benefits and harms of screening, which may affect the estimated outcomes of extending screening to women aged 45–49 and 70–74 years. Evidence indicates that benefit-to-harm trade-offs differ according to the ages at which screening begins and ends (41). In addition, the analysis did not account for opportunistic screening. Finally, the analysis does not explicitly incorporate the costs of policies or interventions designed to increase participation in organized screening programs, such as public awareness campaigns, organizational changes, or facilitated appointment booking. Although some of these measures may involve relatively modest additional costs, their inclusion could influence cost-effectiveness estimates and should be addressed in future research.

5. Conclusion

This analysis evaluated potential strategies to improve the impact of breast cancer screening by extending the age ranges and increasing participation. While expanding the age range led to additional lives saved, increasing participation among women already eligible for screening resulted in the greatest reduction in breast cancer mortality and was the most cost-effective option. Policymakers should prioritize measures that enhance access, equity, and engagement within breast cancer screening programs and ensure that concerned healthcare facilities are allocated sufficient resources to accommodate screening program expansions.

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Appendix

Table 3: Input data for France

	Value	Reference
Screening program		
Starting age	50	Santé publique France (6)
Ending age	74	
Screening interval, years	2	
Participation rate	46.7%	Eurostat (13)
Recall rate	6.1%	Santé publique France (42)
Healthcare costs, EUR 2024		
Invitation to screening	1.3	(43)
Screening	85	
Recall	187	Estimated from (44) and (42)
Breast cancer in situ	11,776	Cost for cancer in situ and stage I-III were estimated as 1.02 times the corresponding costs in Germany (45), using the difference in cost of stage IV breast cancer (€50,378 in France and €49,228 in Germany).
Stage I breast cancer	25,764	
Stage II breast cancer	30,739	
Stage III breast cancer	36,098	
Stage IV breast cancer	50,378	(46)
Production loss, days		
Screening	0.2	Assumption
Recall	0.5	Assumption
Breast cancer in situ	38	Stage-specific production losses were estimated from the average production loss due to breast cancer in France (47), weighted by the difference in production loss between breast cancer stages in Sweden (23)
Stage I breast cancer	84	
Stage II breast cancer	163	
Stage III breast cancer	226	
Stage IV breast cancer	323	
Daily production, EUR 2024		
45-54 years	237	Age-specific daily production for women was estimated from Eurostat (48-50)
55-64 years	166	
Quality of life		
45-54 years	0.898	(51)
55-64 years	0.887	
65-74 years	0.889	
75+	0.830	
Breast cancer incidence, 2022		
45-49 years	4,530	Global Cancer Observatory (52)
50-54 years	5,606	
55-59 years	6,519	
60-64 years	7,233	
65-69 years	7,960	
70-74 years	8,490	
Breast cancer mortality, 2023		
45-49 years	416	Eurostat (53)
50-54 years	640	
55-59 years	852	
60-64 years	948	
65-69 years	1,122	
70-74 years	1,351	
75-79 years	1,525	
80-84 years	1,513	
Population size, 2023		
45-49 years	2,142,636	Eurostat (21)
50-54 years	2,292,849	
55-59 years	2,279,651	
60-64 years	2,182,389	
65-69 years	2,075,075	
70-74 years	2,008,716	
Stage at diagnosis		
Not invited, 45-49		
In situ	7%	Assumed same as in Germany (45)
Stage I	41%	Assumed to be average of Germany (45) and Italy (54)

Stage II	36%	
Stage III	10%	
Stage IV	5%	
Not invited, 50-69		
In situ	6%	Assumed to be average of 45-49 and 70-74
Stage I	39%	
Stage II	36%	
Stage III	11%	
Stage IV	7%	
Not invited, 70-74		
In situ	5%	Assumed same as in Germany (45)
Stage I	37%	Assumed to be average of Germany (45) and Italy (54)
Stage II	37%	
Stage III	13%	
Stage IV	8%	
Invited, 45-49		
In situ	12%	Assumed to be same as 50-69
Stage I	47%	
Stage II	28%	
Stage III	8%	
Stage IV	4%	
Invited, 50-69		
In situ	12%	Assumed same as in Germany (45)
Stage I	47%	(55)
Stage II	28%	
Stage III	8%	
Stage IV	4%	
Invited, 70-74		
In situ	12%	Assumed to be same as 50-69
Stage I	47%	
Stage II	28%	
Stage III	8%	
Stage IV	4%	

Table 4: Input data for Germany

	Value	Reference
Screening program		
Starting age	50	Gemeinsamer Bundesausschuss (56)
Ending age	74	
Screening interval, years	2	
Participation rate	52.0%	Eurostat (13)
Recall rate	2.9%	Kooperationsgemeinschaft Mammographie (57)
Healthcare costs, EUR 2024		
Invitation to screening	1.3	Assumed same cost as in France
Screening	91	(58)
Recall	117	
Breast cancer in situ	11,507	(45)
Stage I breast cancer	25,175	
Stage II breast cancer	30,037	
Stage III breast cancer	35,273	
Stage IV breast cancer	49,228	
Production loss, days		
Screening	0.2	Assumption
Recall	0.5	Assumption
Breast cancer in situ	38	Assumed to be same as in France
Stage I breast cancer	84	
Stage II breast cancer	163	
Stage III breast cancer	226	
Stage IV breast cancer	323	
Daily production, EUR 2024		
45-54 years	216	Age-specific daily production for women was estimated from Eurostat (48-50)
55-64 years	179	
Quality of life		
45-54 years	0.860	(59)
55-64 years	0.860	
65-74 years	0.850	
75+	0.770	
Breast cancer incidence, 2023		
45-49 years	4,772	Zentrum für Krebsregisterdaten (22)
50-54 years	7,557	
55-59 years	8,116	
60-64 years	9,501	
65-69 years	9,437	
70-74 years	7,309	
Breast cancer mortality, 2023		
45-49 years	480	Eurostat (53)
50-54 years	763	
55-59 years	1,177	
60-64 years	1,495	
65-69 years	1,667	
70-74 years	1,978	
75-79 years	2,126	
80-84 years	3,267	
Population size, 2023		
45-49 years	2,414,497	Eurostat (21)
50-54 years	2,957,693	
55-59 years	3,392,030	
60-64 years	3,130,500	
65-69 years	2,637,527	
70-74 years	2,298,350	
Stage at diagnosis		
Not invited, 45-49		
In situ	7%	(45)
Stage I	36%	
Stage II	42%	
Stage III	10%	
Stage IV	5%	

Not invited, 50-69		
In situ	6%	Assumed to be average of 45-49 and 70-74
Stage I	35%	
Stage II	40%	
Stage III	11%	
Stage IV	7%	
Not invited, 70-74		
In situ	5%	(45)
Stage I	35%	
Stage II	38%	
Stage III	12%	
Stage IV	9%	
Invited, 45-49		
In situ	12%	Assumed to be same as 50-69
Stage I	44%	
Stage II	31%	
Stage III	8%	
Stage IV	5%	
Invited, 50-69		
In situ	12%	(45)
Stage I	44%	
Stage II	31%	
Stage III	8%	
Stage IV	5%	
Invited, 70-74		
In situ	12%	Assumed to be same as 50-69
Stage I	44%	
Stage II	31%	
Stage III	8%	
Stage IV	5%	

Table 5: Input data for Italy

	Value	Reference
Screening program		
Starting age	45/50	Ministero della Salute (60). National policy is 50-69 years every 2 years. Some regions start at 45 years and/or continue to 74 years. Some regions screen younger women every year.
Ending age	69/74	
Screening interval, years	2	
Participation rate	55.4%	Eurostat (13)
Recall rate	4.9%	(61)
Healthcare costs, EUR 2024		
Invitation to screening	6.2	(62)
Screening	44	
Recall	114	
Breast cancer in situ	8,075	(63)
Stage I breast cancer	18,747	
Stage II breast cancer	21,301	
Stage III breast cancer	24,401	
Stage IV breast cancer	34,460	Cost for stage IV was estimated as 70% of the corresponding costs in Germany (45), based on the differences between cost of stage I-III breast cancer in Italy and Germany
Production loss, days		
Screening	0.2	Assumption
Recall	0.5	Assumption
Breast cancer in situ	34	Stage-specific production losses were estimated from the average production loss due to breast cancer in Italy (64), weighted by the difference in production loss between breast cancer stages in Sweden (23)
Stage I breast cancer	77	
Stage II breast cancer	148	
Stage III breast cancer	206	
Stage IV breast cancer	294	
Daily production, EUR 2024		
45-54 years	131	Age-specific daily production for women was estimated from Eurostat (48-50)
55-64 years	97	
Quality of life		
45-54 years	0.941	(65)
55-64 years	0.929	
65-74 years	0.879	
75+	0.817	
Breast cancer incidence, 2022		
45-49 years	4,338	Global Cancer Observatory (52)
50-54 years	5,387	
55-59 years	5,836	
60-64 years	5,600	
65-69 years	5,935	
70-74 years	6,532	
Breast cancer mortality, 2023		
45-49 years	426	Eurostat (53)
50-54 years	704	
55-59 years	931	
60-64 years	965	
65-69 years	1,055	
70-74 years	1,280	
75-79 years	1,495	
80-84 years	1,929	
Population size, 2023		
45-49 years	2,265,326	Eurostat (21)
50-54 years	2,423,852	
55-59 years	2,449,604	
60-64 years	2,149,368	
65-69 years	1,883,761	
70-74 years	1,762,660	
Stage at diagnosis		
Not invited, 45-49		
In situ	7%	Assumed same as in Germany (45)
Stage I	47%	(54)
Stage II	31%	

Stage III	10%	
Stage IV	5%	
Not invited, 50-69		
In situ	6%	Assumed to be average of 45-49 and 70-74
Stage I	43%	
Stage II	33%	
Stage III	12%	
Stage IV	6%	
Not invited, 70-74		
In situ	5%	Assumed same as in Germany (45)
Stage I	39%	(54)
Stage II	35%	
Stage III	13%	
Stage IV	8%	
Invited, 45-49		
In situ	12%	Assumed to be same as 50-69
Stage I	50%	
Stage II	26%	
Stage III	8%	
Stage IV	5%	
Invited, 50-69		
In situ	12%	Assumed same as in Germany (45)
Stage I	50%	(54)
Stage II	26%	
Stage III	8%	
Stage IV	5%	
Invited, 70-74		
In situ	12%	Assumed to be same as 50-69
Stage I	50%	
Stage II	26%	
Stage III	8%	
Stage IV	5%	

Table 6: Input data for Spain

	Value	Reference
Screening program		
Starting age	50	Ministerio de sanidad (11). National screening policy is age 50-69 every 2 years. Some regions start at 45 years and/or continue to 74 years.
Ending age	69	
Screening interval, years	2	
Participation rate	68.9%	Eurostat (13)
Recall rate	3.2%	(66)
Healthcare costs, EUR 2024		
Invitation to screening	1.3	Assumed same as in France
Screening	55	(67)
Recall	105	(68)
Breast cancer in situ	12,965	(67)
Stage I breast cancer	22,764	
Stage II breast cancer	29,185	
Stage III breast cancer	37,924	
Stage IV breast cancer	65,975	
Production loss, days		
Screening	0.2	Assumption
Recall	0.5	Assumption
Breast cancer in situ	70	Stage-specific production losses were estimated from the average production loss due to breast cancer in Spain (69), weighted by the difference in production loss between breast cancer stages in Sweden (23)
Stage I breast cancer	158	
Stage II breast cancer	306	
Stage III breast cancer	424	
Stage IV breast cancer	605	
Daily production, EUR 2024		
45-54 years	130	Age-specific daily production for women was estimated from Eurostat (48-50)
55-64 years	94	
Quality of life		
45-54 years	0.919	(70)
55-64 years	0.878	
65-74 years	0.829	
75-84 years	0.747	
85+ years	0.576	
Breast cancer incidence, 2022		
45-49 years	3,773	Global Cancer Observatory (52)
50-54 years	4,388	
55-59 years	4,525	
60-64 years	4,175	
65-69 years	3,608	
70-74 years	3,179	
Breast cancer mortality, 2023		
45-49 years	301	Eurostat (53)
50-54 years	424	
55-59 years	516	
60-64 years	508	
65-69 years	509	
70-74 years	590	
75-79 years	731	
80-84 years	713	
Population size, 2023		
45-49 years	2,008,433	Eurostat (21)
50-54 years	1,898,816	
55-59 years	1,818,254	
60-64 years	1,627,006	
65-69 years	1,381,513	
70-74 years	1,219,802	
Stage at diagnosis		
Not invited, 45-49		
In situ	7%	Assumed same as in Germany (45)
Stage I	31%	(71)
Stage II	43%	
Stage III	16%	

Stage IV	3%	
Not invited, 50-69		
In situ	6%	Assumed to be average of 45-49 and 70-74
Stage I	28%	
Stage II	42%	
Stage III	19%	
Stage IV	5%	
Not invited, 70-74		
In situ	5%	Assumed same as in Germany (45)
Stage I	25%	(71)
Stage II	41%	
Stage III	22%	
Stage IV	7%	
Invited, 45-49		
In situ	12%	Assumed to be same as 50-69
Stage I	40%	
Stage II	32%	
Stage III	13%	
Stage IV	4%	
Invited, 50-69		
In situ	12%	Assumed same as in Germany (45)
Stage I	40%	(71)
Stage II	32%	
Stage III	13%	
Stage IV	4%	
Invited, 70-74		
In situ	12%	Assumed to be same as 50-69
Stage I	40%	
Stage II	32%	
Stage III	13%	
Stage IV	4%	

Table 7: Common inputs used for all countries

	Value	Reference
Frequency of overdiagnosis		
45-74 years, invited	10%	European Commission Initiative on Breast Cancer (3)
45-74 years, participants	13%	Estimated assuming 75% participation rate in the RCTs
Relative mortality reduction		
45-49 years, invited	14%	European Commission Initiative on Breast Cancer (3)
50-74 years, invited	23%	
45-49 years, participants	19%	Estimated assuming 75% participation rate in the RCTs
50-74 years, participants	31%	
Breast cancer utility decrements		
In situ	-0.03	Assumed to be same as stage I
Stage I	-0.03	Estimated from NHS England Cancer quality of Life Survey (72) and UK quality of life population norms (73)
Stage II	-0.07	
Stage III	-0.09	
Stage IV	-0.13	
Duration of utility decrement		
In situ	6 months	Assumption
Stage I	5 years	Assumption based on Torres et al., 2024 (74)
Stage II	5 years	
Stage III	5 years	
Stage IV	4 years	Median survival for stage IV breast cancer

Table 8: Detailed results for France

	Current program	Differences				
		Lower	Upper	Lower & upper	Participation rate	All changes
Events						
Invitation	5 419 340	1 071 318	0	1 071 318	0	1 071 318
Screening	2 530 832	500 306	0	500 306	1 533 673	2 337 162
Recall	154 381	30 519	0	30 519	93 554	142 567
Breast cancer	42 955	306	0	306	1 365	1 858
In situ	4 194	196	0	196	1 128	1 453
Stage I	19 060	340	0	340	2 069	2 627
Stage II	13 506	-183	0	-183	-941	-1 251
Stage III	3 944	-39	0	-39	-506	-572
Stage IV	2 252	-9	0	-9	-384	-399
Breast cancer death	8 367	-68	0	-68	-612	-721
Life years, undiscounted	-166 085	2 138	0	2 138	10 845	14 278
Quality-adjusted life years						
Screening	0	0	0	0	0	0
Recall	0	0	0	0	0	0
In situ	-63	-3	0	-3	-17	-22
Stage I	-2 859	-51	0	-51	-310	-394
Stage II	-4 727	64	0	64	329	438
Stage III	-1 775	17	0	17	228	257
Stage IV	-4 351	35	0	35	318	375
Breast cancer death	-100 263	1 179	0	1 179	6 825	8 719
Total	-114 037	1 242	0	1 242	7 373	9 373
Direct costs, EUR million						
Invitation	7	1	0	1	0	1
Screening	216	43	0	43	131	200
Recall	29	6	0	6	18	27
In situ	49	2	0	2	13	17
Stage I	491	9	0	9	53	68
Stage II	415	-6	0	-6	-29	-38
Stage III	142	-1	0	-1	-18	-21
Stage IV	422	-3	0	-3	-31	-36
Total	1 772	50	0	50	137	217
Production losses, EUR million						
Screening	60	24	0	24	36	74
Recall	9	4	0	4	6	11
In situ	18	2	0	2	4	7
Stage I	186	7	0	7	17	28
Stage II	262	-7	0	-7	-16	-28
Stage III	104	-2	0	-2	-10	-14
Stage IV	177	-4	0	-4	-7	-14
Breast cancer death	1 418	-37	0	-37	-34	-94
Total	2 234	-15	0	-15	-4	-28

Table 9: Detailed results for Germany

	Current program	Differences				
		Lower	Upper	Lower & upper	Participation rate	All changes
Events						
Invitation	6 058 875	1 207 249	1 149 175	2 356 424	0	2 356 424
Screening	3 150 615	627 769	597 571	1 225 340	1 393 541	3 160 859
Recall	132 326	26 366	25 098	51 464	58 529	132 756
Breast cancer	49 742	360	540	900	1 068	2 366
In situ	5 127	287	566	853	1 071	2 334
Stage I	20 750	554	959	1 513	1 901	4 133
Stage II	16 509	-446	-418	-864	-1 218	-2 515
Stage III	4 519	-51	-281	-332	-398	-894
Stage IV	2 836	16	-286	-270	-290	-693
Breast cancer death	12 953	-99	-445	-544	-558	-1 342
Life years, undiscounted	-214 215	2 854	3 938	6 792	9 935	19 731
Quality-adjusted life years						
Screening	0	0	0	0	0	0
Recall	0	0	0	0	0	0
In situ	-77	-4	-8	-13	-16	-35
Stage I	-3 113	-83	-144	-227	-285	-620
Stage II	-5 778	156	146	302	426	880
Stage III	-2 034	23	126	149	179	402
Stage IV	-6 736	52	231	283	290	698
Breast cancer death	-126 680	1 556	2 589	4 145	5 959	11 938
Total	-144 417	1 699	2 941	4 640	6 553	13 263
Direct costs, EUR million						
Invitation	6	1	1	2	0	2
Screening	287	57	54	112	127	288
Recall	15	3	3	6	7	16
In situ	59	3	7	10	12	27
Stage I	522	14	24	38	48	104
Stage II	496	-13	-13	-26	-37	-76
Stage III	159	-2	-10	-12	-14	-32
Stage IV	638	-5	-22	-27	-27	-66
Total	2 183	59	45	103	116	263
Production losses, EUR million						
Screening	94	27	0	27	42	81
Recall	10	3	0	3	4	8
In situ	26	2	0	2	6	9
Stage I	223	10	0	10	22	37
Stage II	333	-16	0	-16	-27	-51
Stage III	120	-3	0	-3	-12	-16
Stage IV	241	-6	0	-6	-10	-19
Breast cancer death	1 863	-56	0	-56	-44	-125
Total	2 909	-38	0	-38	-20	-76

Table 10: Detailed results for Italy

	Current program	Differences				
		Lower	Upper	Lower & upper	Participation rate	All changes
Events						
Invitation	4 453 293	1 132 663	881 330	2 013 993	0	2 013 993
Screening	2 467 124	627 495	488 257	1 115 752	872 845	2 383 340
Recall	120 889	30 747	23 925	54 672	42 769	116 784
Breast cancer	35 821	348	515	863	596	1 764
In situ	3 687	285	555	840	615	1 779
Stage I	17 168	346	1 076	1 422	981	2 941
Stage II	9 897	-195	-542	-738	-545	-1 578
Stage III	3 124	-95	-391	-486	-343	-1 020
Stage IV	1 945	7	-182	-175	-113	-358
Breast cancer death	8 785	-89	-303	-392	-319	-849
Life years, undiscounted	-164 026	2 734	2 944	5 678	6 108	13 795
Quality-adjusted life years						
Screening	0	0	0	0	0	0
Recall	0	0	0	0	0	0
In situ	-55	-4	-8	-13	-9	-27
Stage I	-2 575	-52	-161	-213	-147	-441
Stage II	-3 464	68	190	258	191	552
Stage III	-1 406	43	176	219	154	459
Stage IV	-4 568	46	157	204	166	441
Breast cancer death	-99 999	1 550	2 028	3 578	3 794	8 638
Total	-112 068	1 651	2 382	4 033	4 148	9 622
Direct costs, EUR million						
Invitation	28	7	5	12	0	12
Screening	108	28	21	49	38	105
Recall	14	3	3	6	5	13
In situ	30	2	4	7	5	14
Stage I	322	6	20	27	18	55
Stage II	211	-4	-12	-16	-12	-34
Stage III	76	-2	-10	-12	-8	-25
Stage IV	303	-3	-10	-13	-11	-29
Total	1 091	37	23	60	36	112
Production losses, EUR million						
Screening	42	16	0	16	15	37
Recall	5	2	0	2	2	5
In situ	10	1	0	1	2	3
Stage I	97	3	0	3	6	11
Stage II	100	-4	0	-4	-6	-12
Stage III	41	-3	0	-3	-6	-9
Stage IV	97	-3	0	-3	-3	-7
Breast cancer death	872	-28	0	-28	-15	-53
Total	1 265	-14	0	-14	-5	-25

Table 11: Detailed results for Spain

	Current program	Differences				
		Lower	Upper	Lower & upper	Participation rate	All changes
Events						
Invitation	3 362 795	1 004 217	609 901	1 614 118	0	1 614 118
Screening	2 316 965	691 905	420 222	1 112 127	205 130	1 415 719
Recall	74 143	22 141	13 447	35 588	6 564	45 303
Breast cancer	25 211	377	311	688	134	883
In situ	2 548	234	251	485	103	635
Stage I	9 163	522	627	1 149	245	1 503
Stage II	8 789	-319	-191	-510	-112	-674
Stage III	3 666	-103	-275	-378	-87	-502
Stage IV	1 045	43	-101	-57	-16	-79
Breast cancer death	4 292	-64	-162	-226	-51	-297
Life years, undiscounted	-90 298	2 044	1 734	3 779	1 043	5 156
Quality-adjusted life years						
Screening	0	0	0	0	0	0
Recall	0	0	0	0	0	0
In situ	-38	-4	-4	-7	-2	-10
Stage I	-1 374	-78	-94	-172	-37	-225
Stage II	-3 076	112	67	179	39	236
Stage III	-1 650	46	124	170	39	226
Stage IV	-2 232	33	84	118	27	155
Breast cancer death	-47 945	1 055	961	2 016	569	2 764
Total	-56 316	1 165	1 138	2 303	636	3 145
Direct costs, EUR million						
Invitation	4	1	1	2	0	2
Screening	128	38	23	62	11	78
Recall	8	2	1	4	1	5
In situ	33	3	3	6	1	8
Stage I	209	12	14	26	6	34
Stage II	257	-9	-6	-15	-3	-20
Stage III	139	-4	-10	-14	-3	-19
Stage IV	283	-4	-11	-15	-3	-20
Total	1 061	39	16	56	9	69
Production losses, EUR million						
Screening	39	18	0	18	3	23
Recall	3	1	0	1	0	2
In situ	15	2	0	2	1	3
Stage I	119	11	0	11	3	15
Stage II	214	-13	0	-13	-3	-17
Stage III	116	-6	0	-6	-3	-9
Stage IV	115	-4	0	-4	-1	-6
Breast cancer death	520	-20	0	-20	-3	-24
Total	1 140	-10	0	-10	-2	-13

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