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Who Benefits from the 2016 U.S. Preventive Services Task Force's Screening Mammography Recommendations? An Empirical and Philosophical Evaluation of Screening Mammography Guidelines Focused on Reducing False Positive Incidence

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Who Benefits from the 2016 U.S. Preventive Services Task Force's Screening Mammography Recommendations[1]?

An Empirical and Philosophical Evaluation of Screening Mammography Guidelines Focused on Reducing *False Positive* Incidence

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[1] *Final Recommendation Statement: Breast Cancer: Screening*. U.S. Preventive Services Task Force. November 2016.https://www.uspreventiveservicestaskforce.org/Page/Document/RecommendationStatementFinal/breast-cancer-screening1

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Contents

Abstract

Detecting breast cancer in its earliest stages significantly increases the likelihood of being completely cured of the disease. Early detection via cancer mammogram screening is central to breast cancer diagnosis. There is significant controversy, however, surrounding the 2016 mammogram screening recommendation issued by the U.S. Preventive Services Task Force (USPSTF). *Why?* The revised recommendation cuts the frequency of screening in half and advises women to begin routine screenings 10 years later than what previous guidelines recommended. The justification for this change was that the benefits of screening mammography increase with age, while the harms—especially the risk of a *false positive* outcome—remain constant. This research evaluates the efficacy of the USPSTF's decision to change screening recommendations to minimize the false positive frequency. Using a logistic regression model of data from the 2015 National Health Interview Survey, this analysis identifies the rate and demographic correlates of false positive results. From these findings, this research considers the ethical frameworks most appropriate for making policy recommendations in this arena. The results of this analysis show that younger women, who have a lower-risk of developing breast cancer compared to the average woman in their age group, have a statistically significant ($p<0.001$) increased risk of a false positive outcome. This paper proposes policy recommendations focused on transitioning from a selective screening framework to an individualized risk assessment framework.

Keywords

Health economics, screening mammography, breast cancer, false positive, philosophy of medicine, policy evaluation

1. Introduction

In the United States, nearly 1 in 8 women will develop invasive breast cancer over the course of their lifetime ("U.S. Breast" 2017). Breast cancer death rates for women in the US are higher than those for any other cancer, besides lung cancer ("U.S. Breast" 2017). According to the National Health Institute, breast cancer is the second-leading cause of cancer death among women in the United States and in 2015, an estimated 232,000 women were diagnosed with the disease with 40,000 deaths ("SEER Stat Factsheets" 2015). Mammograms are one type of screening tool that can be used to detect breast cancer in women, including for those women who have no signs or symptoms of the disease. Although the primary goal of screening mammography is to decrease mortality from breast cancer, it is important to emphasize that mammogram screenings are diagnostic *not* preventative. In other words, mammograms cannot prevent breast cancer incidence; they can only identify breast cancer and potential signs of breast cancer.

There are important benefits of screening mammograms, but some have argued that these benefits are modest and do not outweigh the potential harms ("Mammography" 2011). On one hand, early detection of breast cancer with screening mammography allows for the opportunity to begin treatment at an earlier stage, when the cancer may be more treatable. Screening mammography has been shown to reduce the number of deaths from breast cancer among women ages 40-74, however there is no appreciable benefit to regular screening of women under age 40 (Mandelblatt et al. 2009). In light of this finding, The National Breast Cancer Coalition (NBCC) contends that the benefits of screening mammography in reducing mortality are modest and instead emphasizes the harms associated with screening. It may be that the harms and public health costs of screening mammography may outweigh the modest benefits of the intervention.

One significant harm associated with screening is the *false positive* result. False positive results occur when radiologists identify an abnormality on a mammogram but no cancer is actually present. In this case, additional testing is usually conducted including invasive procedures like biopsies. Beyond the physical consequences, false positive results can lead to significant psychic costs including anxiety, distress, and physical discomfort (American Cancer Society, 2017). False positive results are more common in younger women, women with dense breasts, women who have had previous biopsies, women with a family history of breast cancer, and women who are taking estrogen ("Mammograms" 2016). Moreover, the chance of having a false positive result increases with the number of mammograms a woman has had ("Mammograms" 2016). It is essential that screening recommendations consider the tangible and intangible costs of screening while also ensuring its effective capture of the high-risk pool of women who are likely to develop breast cancer in their lifetime. The ultimate goal of a screening recommendation, then, should be to minimize the rate of incorrect results like the false positive, while maximizing the rate of true positives, that is, the detection of cancer from screening.

With the ultimate purpose of screening mammography in mind, this study focuses on analyzing the efficacy of the 2016 revised U.S. Preventive Services Task Force screening mammography recommendations by specifically examining *who* benefits the most from the revised recommendation. Given that a motivation for the USPSTF revision was to minimize the rate of false positive incidence, this paper assumes that the individuals who benefit the most from the USPSTF revision are those that are at a greatest risk for a false positive outcome. In particular, this study will involve conducting an empirical analysis of false positive incidence and demographic characteristics of individuals who received a mammogram in 2015 and participated

in the 2015 National Health Interview Survey, the year preceding release of the USPSTF revised guidelines.

Study Objectives and Overview

The central purpose of this study is to identify socioeconomic and demographic characteristics of female patients who are most at risk of a false positive outcome, and therefore would benefit the greatest from the U.S. Preventative Service Task Force (USPSTF) decision to modify screening recommendations from annual to biennial screenings in order to minimize the occurrence of the false positive. By conducting an empirical analysis that will identify significant demographic factors that may serve as predictors of a false positive outcome, this study will examine whether the revised USPSTF screening mammography recommendation is efficacious.

Moreover, this empirical analysis will be complemented with an ethical discussion surrounding responsibility of care and the appropriateness of approaching screening mammography recommendations from a utilitarian framework. Specifically, the philosophical evaluation will focus on the application of the prevention paradox to the U.S. government-sponsored screening mammography recommendation along with the ethical implications of using a cost-benefit framework to evaluate the effectiveness of health interventions. Given that empirical and economic analyses rarely ever include a philosophical component, a secondary purpose of this study is to understand how incorporating a philosophical discussion to an empirical analysis may serve to strengthen the results and proposed outcome of the analyses of interest.

My research question arises out of the understanding that reduced screenings result in a reduced incidence of false positive results; but the female demographic most at risk for a false positive outcome is still being understood. The false positive result incurs many associated costs, included psychological costs and costs associated with added procedures. Yet, this cost may vary for individuals based on certain demographic characteristics. Therefore, in conducting this empirical analysis, I will investigate whether screening less in order to decrease the costs and frequency of false positives, benefits individuals with certain demographic characteristics over others. In summary, I have the following objectives for this study:

1) To evaluate the efficacy of the U.S. Preventive Services Task Force's decision to change their screening recommendation from annual to biennial in order to minimize the false positive frequency.
2) Identify the rate and demographic correlates of a false positive outcome, and the patient pathway preceding a false positive outcome.
3) Investigate how closely the USPSTF recommendation aligns with certain ethical frameworks.

2. Background and Policy History

Screening Mammography

According to the American Cancer Society,[2] a mammogram is a low-dose x-ray that allows doctors, specifically radiologists, to look for changes in breast tissue. According to the American Cancer Society (ACS), the procedure of a mammogram involves a machine designed to look only at breast tissue. The machine has two plates that compress or flatten the breast to spread the breast tissue apart, since doing so gives results in a clearer picture and allows for the use of less radiation. Mammograms can often detect breast cancer early, when the abnormality is small and before a lump can even be felt. Mammograms are important diagnostic tools because treatment at an earlier stage of a cancer's progression is more likely to be successful. There are two types of mammograms: screening and diagnostic. While screening mammograms are used to examine a woman's breasts regardless of whether or not symptoms are present, diagnostic mammograms are used when changes in breast tissue have been reported or observed. This study will focus solely on the results of screening mammograms.

Screening mammograms most often show abnormal areas in the breast. As mentioned previously, mammograms are diagnostic in nature and *not* preventive, therefore they cannot protect individuals from developing breast cancer. Instead, mammograms can only identify potential abnormalities. A common analogy used to describe the purpose of screening mammograms are strep throat tests. Strep throat tests, like mammograms, are not administered in order to prevent the occurrence of sickness—in this case strep throat—but rather to diagnosis its presence as a cause of observed symptoms. Similarly, mammograms cannot protect an individual from developing breast cancer. Instead, the value of a mammogram rests in its ability to detect cancer, where the best case scenario involves early detection such that the breast cancer may be more treatable. Clinical trials, observational studies and modeling studies have demonstrated that as women age the likelihood of avoiding a breast cancer death with regular screening mammography gradually increases (USPSTF). In contrast, the harms of screening mammography appear to remain constant or to decrease with age. While both types of mammograms expose the breasts to small amounts radiation, the American Cancer Society has determined that any potential harms associated with the radiation exposure are outweighed by the benefits of early detection of breast cancer. Although it is very common to associate breast imaging with screening mammography, mammograms are only one type of screening tool. In fact, only in the last several decades, screening mammography has evolved and popularized substantially with advances in radiologic technologies that aid in the detection and diagnosis of diseases.

In analyzing mammograms, radiologists look for different types of breast changes, such as small white spots indicating calcification, lumps or tumors indicating masses, and other suspicious areas that could be signs of cancer. When possible, doctors will compare old mammograms to new ones (ACS, 2017). Findings that are not present on older mammograms may be cancerous, warranting further tests. Mammogram reports also contain an assessment of breast density, which is based on how fibrous and glandular tissues are distributed in the breast as opposed to how much of the breast is made up of fatty tissue (ACS, 2017). Dense breasts, though not abnormal, are linked to higher risk of breast cancer and can also make it more difficult to detect cancer from a

[2] American Cancer Society, Mammography Basics: https://www.cancer.org/cancer/breast-cancer/screening-tests-and-early-detection/mammograms/mammogram-basics.html

mammogram. In order to evaluate mammograms, doctors use a categorical number system of 0-6. This system is called the Breast Imaging Reporting and Data System or BI-RADS. By designating results into specific categories, doctors have a universal description of results. The BI-RADS categorization allows for accurate and consistent communication among the medical community and between the doctor and patient. A detailed breakdown of the BI-RADS categories can be found in the Appendix (*Table 1*).

Despite the many risk factors for breast cancer, fewer than 1 in 10 women who are called back for additional testing are diagnosed with cancer (ACS, 2017). Often the cause of the follow-up is to clarify any areas of concern via more x-rays or an ultrasound, sometimes breast images were not clear and need to be retaken or dense breast tissue may have made analysis difficult. Follow-up requests are more common after a woman's second mammogram, when there is a previous mammogram available for comparison. Follow-up is also more common in women who have not undergone menopause (ACS, 2017). In the case that the follow-up shows no suspicious signs of cancer, then the outcome is a false positive. Alternatively, if the follow-up reveals additional issues that raise questions or concerns, then a biopsy is sometimes ordered. If the subsequent biopsy shows no signs of cancer, then the result is also considered a false positive. Since a biopsy is often the only way to isolate cancer from other tissue abnormalities, this invasive procedure—which requires removing a small piece of breast tissue to be checked under microscopy—is relatively common.

Screening Mammography Limitations

Although mammograms are considered by the medical community to be the most reliable screening test available, mammograms have limits. As shown in *Figure 1*, there are four possible outcomes of a mammogram.

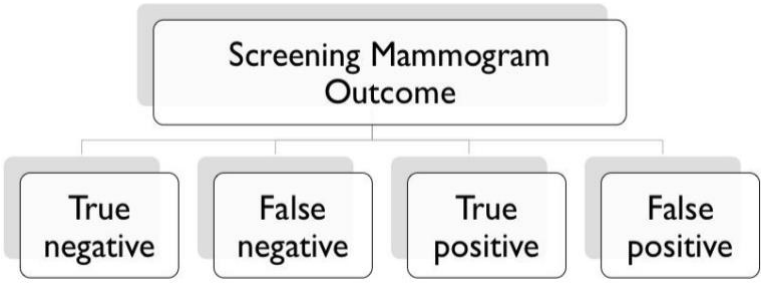

Figure 1: Screening Mammogram Outcomes

While true positive and true negative results correctly identify the existence, or lack thereof, of cancerous tissue, false positive and false negative results occur when a mammogram or radiologist falsely identifies or fails to identify breast cancer. False negative outcomes result when a patient is incorrectly reported to *not* have breast cancer when they do, while a false positive outcome results from a patient being incorrectly assumed to have breast cancer or signs of breast cancer when they actually do not. Given these outcomes, in addition to maximizing the detection of breast cancer, screening mammography recommendations must try to minimize the costs and harms (including psychological costs) of screenings that result from incorrect results like false positives and false negatives.

The USPSTF found adequate evidence that:

> screening for breast cancer with mammography results in harms for women aged 40-74 years. The most important harm is the diagnosis and treatment of noninvasive and invasive breast cancer that would otherwise not have become a threat to women's health, or even apparent, during her lifetime (that is, overdiagnosis and overtreatment). False positive results are common and lead to unnecessary and sometimes invasive follow-up testing, with the potential for psychological harms (such as anxiety).

According to the American Cancer Society *Limitations of Mammograms* webpage,[3] given that mammography sometimes leads to follow-up examinations, including biopsies, when there is no cancer (a false positive result), a false positive outcome most often follows a woman's initial screening mammogram. Factors that may increase the likelihood of a false positive include the use of postmenopausal hormone therapy and having more mammographically dense breast tissue (ACS, 2017). On average, of the women who are encouraged to have further testing following a mammogram, 95% are ultimately shown not to have cancer. According to another US study, about one-half of women experience a false positive result and about 19% undergo biopsy but do not have cancer (Elmore et al, 1998). Given that the overall rate of breast cancer incidence is low, this high rate of false positive incidence following additional testing is unsurprising.

The U.S. Preventive Services Task Force

The U.S. Preventive Services Task Force (USPSTF) is an independent panel of clinicians and scientists commissioned by the Agency for Healthcare Research and Quality, an agency housed under the Department of Health and Human Services. According to the U.S. Preventive Services Task Force's *Final Recommendations Statement on Breast Cancer Screening*,[4]

> The USPSTF makes recommendations about the effectiveness of specific preventive care services for patients without obvious related signs or symptoms. It bases its recommendations on the evidence of both the benefits and harms of the service, and an assessment of the balance. The USPSTF does not consider the costs of providing a service in this assessment. The USPSTF recognizes that clinical decisions involve more considerations than evidence alone. Clinicians should understand the evidence but individualize decision-making to the specific patient or situation. Similarly, the USPSTF notes that policy and coverage decisions involve considerations in addition to the evidence of clinical benefits and harms.

Despite the screening mammography guidelines regularly released by the U.S. Preventive services Task Force, there is significant controversy surrounding what age and how often women should get mammograms. In 2002, the U.S. Preventive Services Task Force (USPSTF) recommended screening mammography every 1-2 years for women beginning at age 40 years. Seven years later,

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[3] American Cancer Society, Limitations of Mammograms: https://www.cancer.org/cancer/breast-cancer/screening-tests-and-early-detection/mammograms/limitations-of-mammograms.html

[4] *Final Recommendation Statement: Breast Cancer: Screening*. U.S. Preventive Services Task Force. November 2016.https://www.uspreventiveservicestaskforce.org/Page/Document/RecommendationStatementFinal/breast-cancer-screening1

on November 16, 2009, the USPSTF released new recommendations for breast cancer screening (Hendrick et al, 2011). The revised statement recommended a change to biennial mammography beginning at age 50 and ending at age 74 years on the basis that both annual and biennial screening reduce mortality, but with biennial, the negative impacts are reduced ("Screening for Breast Cancer"). The newest guidelines state the following:

> The USPSTF recommends against routine screening mammography in women aged 40 to 49 years. The decision to start regular, biennial screening mammography before the age of 50 years should be an individual one and take into account patient context including the patient's values regarding specific benefits and harms. The USPSTF recommends biennial screening mammography for women between the ages of 50 and 74 years ("Screening for Breast Cancer", emphasis added).

In making this new recommendation, the USPSTF was informed by a systematic review of published randomized clinical trials (Nelson et al, 2009) and the Cancer Intervention and Surveillance Modeling Network (CISNET) modeling studies, which showed that despite a significantly larger number of mammograms required when screening is started at age 40 versus age 50 years, the result was only small gains in detection (Mandelbatt et al, 2009).[5] *Table 2* provides a visual representation of these findings.

Recommendations by the USPSTF carry considerable weight. According to the Kaiser Family Foundation, The U.S. Healthcare Reform Act, in its original form, included a specific recommendation that "only USPSTF recommendations with a grade of A or B would receive Medicare of Medicaid funding. An 'A' or 'B' letter grade indicates that the panel finds there is high certainty that the services have a substantial or moderate net benefit" ("Preventative Services Covered" 2015). The 2009 USPSTF report gave the recommendation that women 50-74 years should receive a biennial screening a B rating. If their recommendations were followed, only women ages 50-74 years would have insurance coverage to have a mammogram once every 24 months. Medicare recipients would also not be covered for screening mammography after the age of 74 years. Moreover, "many third-party insurers follow Medicare's lead in deciding which radiologic studies they will reimburse. Some states, such as Colorado, have tied funding for screening mammography to USPSTF recommendations" (Hendrick et al, 2011). Therefore, the implications of the USPSTF recommendations are significant in that they could lead to Medicare and insurers funding only biennial screening for women 50–74 years old while shutting out women under age 50 from access to coverage for screening mammograms.

Historically, "the decision to recommend screening mammography has hinged on randomized controlled trials (RCT) results showing a statistically significant survival benefit overall or for specific age groups" (Hendrick et al, 2011). In its 2009 screening mammography recommendation, the USPSTF examined RCT data on screening mammography, as analyzed and summarized in a detailed report by the Oregon Evidence-Based Practice Center at the Oregon Health and Science University (Nelson et al, 2009). Moreover, the meta-analysis prepared specifically for the 2009 USPSTF guidelines shows "a statistically significant benefit for women 39–49 years old alone, 50–59 years old alone, and 60–69 years old alone" (Hendrick et al, 2011). However, the USPSTF decided to "depart from this standard of medical decision making, instead

[5] A more detailed summary of the evidence considered by the USPSTF for the revised screening mammography recommendations can be found in the literature review.

focusing on the 'number needed to invite' to screening mammography in justifying its decision against screening women 40–49 years old with mammography" (Hendrick et al, 2011). Ultimately, the USPSTF estimated that "it would require inviting 1,904 women ages 40–49 years to save one life and concluded that this was too many women screened for one life saved" (Hendrick et al, 2011).

This thesis will further analyze the justification and evidence considered for the USPSTF revised recommendations in the ethical discussion. In their most recent recommendation, the USPSTF concludes that "while there are harms of mammography, the benefit of screening mammography outweighs the harms by at least a moderate amount from age 50-74 years and is greatest for women in their 60's" (*Table 2*) (USPSTF 2016). The statement also adds that "for women in their 40's, the number who benefit from starting regular screening mammography is smaller and the number experiencing harm is larger compared with older woman" (USPSTF 2016). As a result:

> Women in their 40s must weigh a very important but infrequent benefit (reduction in breast cancer deaths) against a group of meaningful and more common harms (overdiagnosis and overtreatment, unnecessary and sometimes invasive follow-up testing and psychological harms associated with false positive test results, and false reassurance from false-negative test results). Women who value the possible benefit of screening mammography more than they value avoiding its harms can make an informed decision to begin screening ("Final Recommendation Statement" 2016).

Although it is difficult to precisely measure the extent of the benefits and harms associated with beginning screening at age 40 rather than age 50, minimal research and modeling has been done to predict the relative tradeoffs. According to a study conducted by CISNET in which modeling studies were used to predict the lifetime benefits and harms of screening with contemporary digital mammography at different starting and stopping ages and screening intervals, results showed that the incidence of prevented breast cancer deaths when beginning screening age 40 rather than age 50 is insignificant (<1), yet the false positive incidence and rate of unnecessary follow-up biopsies is almost two-fold (USPSTF). Once again, *Table 2* displays the results of the study by comparing the median and range across the models for predicted lifetime benefits and harms of screening biennially from ages 50 to 74 years with screening biennially from ages 40 to 74 years (USPSTF).

Variable	Ages 40–74 y	Ages 50–74 y
Fewer breast cancer deaths, *n*	8 (5–10)	7 (4–9)
Life-years gained, *n*	152 (99–195)	122 (75–154)
False-positive tests, *n*	1529 (1100–1976)	953 (830–1325)
Unnecessary breast biopsies, *n*	213 (153–276)	146 (121–205)
Overdiagnosed breast tumors, *n*	21 (12–38)	19 (11–34)

Table 2: Lifetime Benefits and Harms of Biennial Screening Mammography per 1000 Women Screened: Model Results Compared with No Screening, values reported are medians (ranges). *Source*: USPSTF 2017

Current Environment

Because of the uncertainty surrounding the benefits and harms of screening mammography, there has been significant resistance to reducing the frequency and decreasing the age range for screening. One of these is the American Cancer Society, which in 2003 recommended annual screenings from age 40 and continued regardless of a woman's age.
Moreover, despite the USPSTF recommendation, currently all Marketplace health plans, which are mandated by the 2010 ACA, and many other plans, must cover breast cancer mammography screenings every 1-2 years for women over age 40 without charging a copayment or coinsurance, even if a woman has not met her yearly deductible ("Preventive Care Benefits for Women"). Given the contentious nature of the ACA, healthcare plans face the danger of only covering screening mammograms based on the USPSTF guidelines. Consequently, the revised guidelines may limit access to mammography for 22 million women between ages 40 and 49 ("USPSTF Guidelines" 2016). For this reason, there exists a significant divergence between the screening recommendations issued by the federal government, the screening recommendations that insurers are willing to cover, and the screening recommendations that the general public is recommended to follow.

3. Literature Review

Risk Factors of Breast Cancer

According to the Center for Disease and Control (CDC), the risk for breast cancer is due to a combination of factors. The main factors that influence risk are sex—being a woman—and getting older. Most cases of breast cancer are found in women who are 50 years old and older (CDC, 2017). Although some women will develop breast cancer without risk factors of which they are aware, research has defined notable risk factors that can be used to predict the likelihood of breast cancer incidence. These include: age, genetic mutations, early menstrual period, late or no pregnancy, starting menopause after age 55, a sedentary lifestyle, being overweight or obese, having dense breasts, using combination hormone therapy (i.e. estrogen and progesterone hormone replacements), taking oral contraceptives (e.g. birth control pills), personal history of breast cancer, personal history of certain non-cancerous breast diseases, family history of breast cancer, previous treatment using radiation therapy, women who took the drug diethylstilbestrol (DES), and alcohol (CDC, 2017) Although these risk factors may be used to help predict the likelihood of developing cancer, it is important to note that most women have one or more of these risk factors, but still never develop cancer in their lifetime.

Moreover, the rate of women that develop breast cancer in their lifetime varies, depending on their race and ethnicity. *Figure 2* shows how many women out of 100,000 got breast cancer each year during the years 1994-2014. Accordingly, white woman had the highest rate of getting breast cancer, followed by Black, Hispanic, Asian/Pacific Islander, and American Indian/Alaskan Native women (CDC, 2017). However, the rate of women dying from breast cancer also varies depending on race and ethnicity. Although White women are more likely to develop breast cancer, according to the CDC, black women have been shown to be more likely to die of breast cancer than any other racial group (*Figure 3* Appendix).

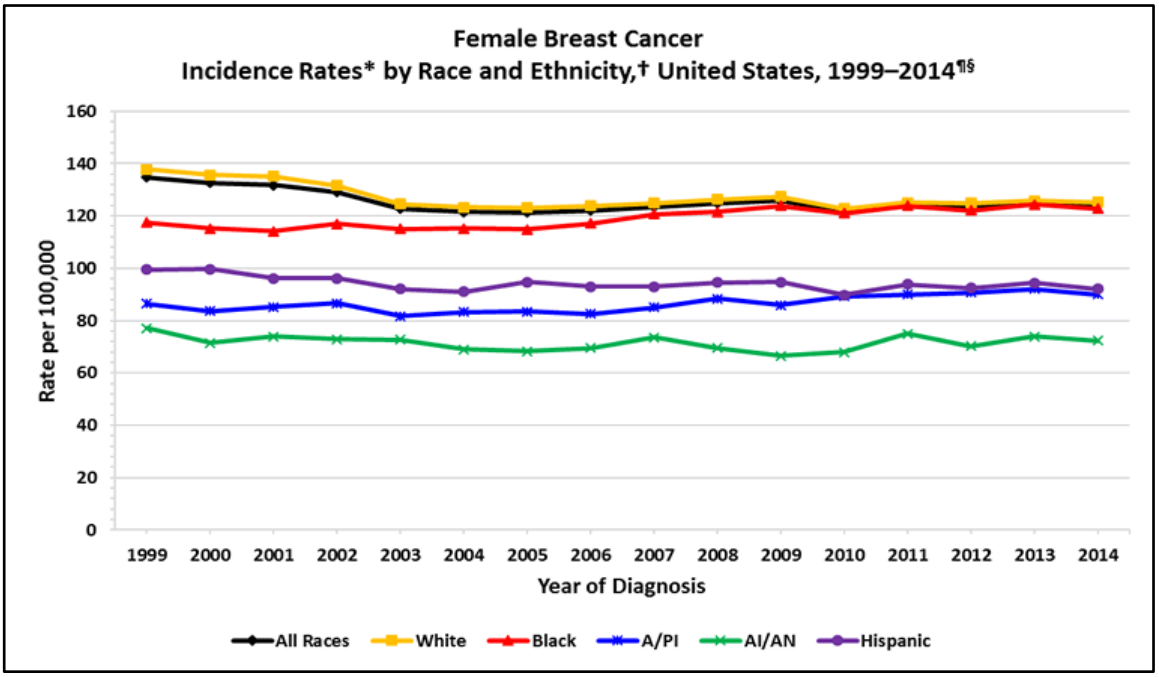

Figure 2: Female Breast Cancer Incidence Rates in the United States by Race and Ethnicity (1999-2014). *Source*: CDC's National Program of Cancer Registries and National Cancer Institute's Surveillance, Epidemiology, and End Results program.

According to the USPSTF, "race and ethnicity are factors that have prompted concern because of a growing disparity in breast cancer mortality rates. Moreover, "although White women have historically had higher incidence rates than African American women, incidence rates have come close to converging as of 2012 (128 vs. 124 cases per 100,000 women per year, respectively)" (DeSantis et al, 2015). Despite the similar incidence rates, more African American women die each year from breast cancer than White women, specifically about 31 vs. 22 breast cancer deaths per 100,000 women per year, respectively (Howlader et al, 2014). However, the reason for the disparity in breast cancer mortality between White and African American women is not evident. Some research studies argue that it may be attributed to a differences in biology—"African American women are disproportionately affected by more aggressive and treatment-resistant forms of breast cancer (that is, cancer with adverse histologic features, such as poorly differentiated tumors and triple-negative phenotypes)" (Bauer et al, 2007 and Carey et al, 2006). Unfortunately, according to the USPSTF, "these types of cancer may be the least likely to be positively affected by screening programs, because they can grow so rapidly that they develop and spread entirely within the timespan between screening examinations" (USPSTF).

The disparity in mortality rates between Whites and African Americans may also be due to socioeconomic differences and health system failures (USPSTF). Multiple studies have shown an association between African American race and experiencing delays in receiving health care services for cancer, not receiving appropriate treatment, or not receiving treatment at all (Brawley 2009 and Griggs et al, 2007 and Roetzheim et al, 1999). However, according to the USPSTF, African American women are also substantially underrepresented in randomized controlled trials

of mammography screening; therefore, there is no high-quality evidence to conclude that screening African American women more often or earlier than already recommended for the overall population of women would result in fewer breast cancer deaths or a greater net benefit (USPSTF).

Risk Factors of a False Positive Result

Research has shown that women ages 40 to 49 made up the largest percentage of false positive mammogram results with a recommendation for more imaging (33.1%) ("False-Positive Mammogram" 2015). Women with dense breasts were also more likely to have false positive results (Henderson et al, 2015). However, it is important to note that just because a mammogram is abnormal does not imply breast cancer. Instead, the majority of abnormal mammograms have benign causes. Causes of false positive occurrence include inaccurate interpretations and faulty readings. Given that each woman's breast looks different on a mammogram, breast imaging may prove less accurate for some women than others. Other situations that put a woman at greater risk for a false positive mammogram include "dense breast tissue, calcification, and benign cysts or other masses" (Hook, 2010). False positive results from screening mammograms have also helped fuel the debate on the value of breast cancer screening. One particular study suggests that women who receive false positive results may be more likely to delay or avoid future mammograms (Dabbous et al, 2017). Therefore, false positive incidence may have an impact on cancer outcomes if women who have experienced false positive results avoid future mammogram screenings and then later develop breast cancer. Consequently, those comparing the costs and benefits of screening mammograms must be aware of the indirect costs of false positive outcomes as well.

Dalton et al's (2006) population-based Danish study showed an increased risk of being diagnosed with breast cancer for women with less education, lower disposable income, residence in rural areas, and having no access to organized mammography screening. Apart from the access to screening, these effects of social inequality were significant only for postmenopausal breast cancers. As expected, access to mammography screening is an important factor for breast cancer stage at diagnosis. Tosteson et al (2014) found that anxiety was significantly higher for women with false positive mammograms as was future screening intention. Women who were younger and in poorer health were also more likely to have a false positive outcome. Although the risk factors for breast cancer and the consequences of false positive outcomes are researched extensively, the demographic risk factors associated with false positive outcomes are still being understood. Therefore, this thesis focuses on identifying the demographic correlates of false positive incidence from screening mammography.

Ultimately, having a better understanding of the characteristics of women who are at the highest risk of a false positive outcome can inform best practice to reducing the risk of false positive occurrence. Moreover, identifying risk factors associated with a false positive result will reveal the female demographic that benefits the most from the revised and controversial USPSTF guidelines, given that a primary consideration for the revisions was to reduce false positive incidence associated with screening mammography.

4. Data and Methods

Assembling the Data Set

In order to identify the rate and demographic correlates of false positive incidence, data on individual screening mammography cases was required. The National Health Interview Survey reported this data, therefore this analysis utilizes the 2015 National Health Interview Survey[6] given that it reports screening mammography cases directly preceding the implementation of the revised USPSTF screening mammography guidelines. Specifically, the 2015 NHIS cancer adult dataset was merged with the 2015 NHIS adult file dataset in order to merge demographic characteristics of screened women with data on specific screening mammography outcomes. The National Health Interview Survey (NHIS) is a cross-sectional household survey conducted by the Center for Disease Control and Prevention. The NHIS dataset provides a wide range of information about the health of the U.S. population. Importantly, the NHIS collects information on the health of the U.S. population using a multistage area probability design that permits a representative sampling of households (Jatoi et al, 2006). Since the aim of this study was to discern any association between demographic characteristics and false positive mammograms in a random sampling of the U.S. population, the 2015 NHIS provided adequate data in its cancer module.

Within the NHIS dataset, basic health and demographic information is collected on all household members, adults aged 18 or order, and children aged 1-17 years in the family core, adult core, and child core components of the NHIS, respectively—although this study only focuses on women aged 18 or older. In 2015, 33,672 adults with cancer completed the NHIS Adult Cancer survey. Out of these, 18,601 females completed the survey. Since this study focuses on the screening mammography outcomes of women, the dataset used in the analysis only includes females. Questions ranging from family history, physical activity, diet, demographics, height and weight, medical conditions, health behaviors, and health care access were asked. In the specific cancer module, questions related to screening mammography history and family history of breast cancer were asked.

Research Design

This study is concerned with evaluating the particular demographic characteristics that are significant to predicting a particular patient pathway that results in a false positive outcome. For this reason, three nearly identical logit regression models were run using three different samples in the screening mammography patient pathway. Accordingly, each stage addresses a different question regarding the effect of demographic characteristics on screening mammography outcomes:

(1) *First Sample:* What are the demographic correlates of the decision to receive a mammogram (controlling for initial risk assessment)?

[6] 2015 National Health Interview Survey. *Source*: https://www.cdc.gov/nchs/nhis/nhis_2015_data_release.htm

(2) *Second Sample:* Of those who get a mammogram what are the demographic correlates of receiving a recommendation for additional tests following initial mammogram (controlling for initial risk assessment)?
(3) *Third Sample:* Of the women who followed up with additional testing, what are the demographic correlates of a false positive outcome (controlling for initial risk assessment)?

Three logit regression models were run on three different samples based on these defined screening mammography patient pathways. Out of 33,672 adults, 10,887 women responded "yes" when asked if they had ever received a mammogram (1). Out of the women who had received a mammogram, 989 were recommended for follow up testing out of which 82 failed to follow the recommendation (2). Out of the women who had follow up testing, 888 reported their outcome in the survey, out of which 103 were diagnosed with cancer after following up and 785 females had a false positive outcome (no cancer diagnosis after follow up testing) (3). Data were analyzed for all three samples in three separate regression models.

Economic Models

Data Descriptions

Table 4 summarizes the descriptions of the 13 independent variables used in the economic models for this analysis. The independent explanatory variables include general demographic characteristics as well as breast cancer risk factors as control variables. In preparing the dataset, many of the variables were recoded to fit a binary framework. Specific information regarding how variables were transformed can be found in the "Variable Description" section of *Table 4*. Summary statistics for the following variables can be found in the Appendix (*Tables 17-19*).

Variable	Instrument Variable Name	Variable Reference Name	Variable Description
Have you ever had a mammogram?	MAMHAD	**Mamm_Had**	Binary variable (Yes=1, No=1) and dependent variable representing Sample 1 and stage 1 of the screening mammography patient pathway.
Recommended to have more tests after most recent mammogram?	MAMABN1	**Followup_Recc**	Binary variable (Yes=1, No=0) where more tests may include another mammogram, a sonogram, an MRI, a biopsy, or something else to check for problems in your breast. Female sample adults who have ever had mammogram and were advised to follow up with testing
As a result of these additional tests after your mammogram(s) were you diagnosed with cancer?	MAMCAN1	**Cancer_Diagnosis**	Binary variable (Yes=1, No=0), used as proxy for false positive outcome if no cancer diagnoses post additional testing (where if False positive=0, Cancer=1)
Reason for not following recommendation to have more tests	MNOTFOL1	**No_Followup**	Female sample adults 30+ who have ever had a mammogram and did not follow recommendation to have more tests
Region residing in the United States	REGION	**Region**	Categorical variable representing region of the United States where female patient resides (1= Northwest, 2=Midwest, 3=South, 4=West)
Race	HISCODI3	**Race**	Race categorical variable (1=White, 2=Hispanic, 3=Black, 4=Asian, 5=Other)
Age	AGE_P	**Age**	Continuous variable where the minimum age of a female is 18 years and maximum age is 85
Marital Status	R_MARITL	**Marital_Status**	Categorical variable representing marital status of female patient (1=married, 2=widowed, 3=divorced/separated, 4=never married/single, 5=living with partner, 6=unknown)
Highest level of school completed	EDUC1	**Education**	Categorical variable representing highest level of educational attainment (1=less than high school, 2=GED or equivalent/high school graduate, 3=some college, no degree, 4=associate degree (occupational, technical, vocational, and academic program), 5=Bachelor's degree, 6=above Bachelor's degree/Postgraduate degree level, 7=unknown)
Risk of breast cancer compared to average woman	GTCBOM	**Cancer_Risk**	Categorical variable comparing personal risk of breast cancer compared to the average women in the female patient's age group (1=More likely, 2=Less likely, 3=About as likely, 9=Unknown). This variable is used as a proxy for all risk factors of breast cancer given that it assesses average risk based on such factors while holding age constant
Breast MRI to follow up test to mammogram	MFOLLO02	**MRI**	Female sample adults 30+ who have ever had a mammogram and was recommended to have MRI as a follow up (Yes=1, No=0, Unknown=9)
Additional mammogram as follow up test to mammogram	MFOLLO03	**Add_Mamm**	Female sample adults 30+ who have ever had a mammogram and was recommended to have additional mammogram as a follow up (Yes=1, No=0, Unknown=9)
Biopsy to follow up tests to mammogram	MFOLLO04	**Biopsy**	Female sample adults 30+ who have ever had a mammogram and recommended to have biopsy as a follow up (Yes=1, No=0, Unknown=9)

Table 4: Independent and dependent variables and corresponding variable descriptions used in all three economic models. *Source*: 2015 National Health Interview Survey

First Model (Sample 1)

In the original 2015 NHIS cancer survey, a woman was asked ‘‘*Have you ever had a mammogram*?’’ Out of 15,602 females that responded to this question, 10,887 women replied that they had (69.78%), while the remaining 4,715 females reported otherwise. The first logit regression model uses this sample and a binary response to the original question (1=Yes 0=No) as the left-handed dependent variable. This model focuses on understanding the demographic correlates of a women’s likelihood of getting a mammogram. It is important to note that in addition to following a logit model, this model also uses Stata’s margins command to estimate and interpret marginal effects at the means.

$$Mamm\_Had_c = \beta_0 + \beta_1 (Cancer\_Risk_c) + \beta_2 (Age) + \beta_3 (Race_c) + \beta_4 (Marital\_Status_c) + \beta_5 (Education_c) + \beta_6 (Region_c) + \varepsilon$$

Second Model (Sample 2)

In the original survey, after having answered “Yes” to the initial question “*Have you ever had a mammogram?*” women were asked the follow-up question “*After your MOST RECENT mammogram, were you advised to have more tests?*” If the patient had follow up testing then they were designated a “1” in the binary code, independent of the type of testing they had, if they were not recommended for follow up testing, they were designated as “0” in the binary code. Out of the 10,887 females who had a mammogram, 9,898 (91%) were not recommended for a follow-up while 989 (9%) were recommended for additional testing after an initial mammogram. This logit regression model uses Stata’s margins command to estimate and interpret marginal effects at the means.

$$Followup\_Recc_c = \beta_0 + \beta_1 (Cancer\_Risk_c) + \beta_2 (Age) + \beta_3 (Race_c) + \beta_4 (Marital\_Status_c) + \beta_5 (Education_c) + \beta_6 (Region_c) + \varepsilon$$

Third Model (Sample 3)

In the original survey, if individuals followed up with additional testing after being advised to do so, they were asked “*as a result of these additional tests after your mammograms(s), were you diagnosed with cance*r?” If the answer was “No” then they were designated with a “0” in the binary code and this outcome represented a false positive outcome. If the answer was “Yes” then they were designated a “1” in the binary code. Out of the 888 females that followed through with additional testing, 103 were diagnosed with cancer while 785 were not. As a result, false positive incidence in this dataset occurred in approximately 88% of females who had follow up testing and in approximately 7.2% of females who had a mammogram. As in the previous stages, in addition to following a logit model, this model also uses Stata’s margins command to estimate and interpret marginal effects.

$$Cancer\_Diagnosis_c = \beta_0 + \beta_1 (Cancer\_Risk_c) + \beta_2 (Age) + \beta_3 (Race_c) + \beta_4 (Marital\_Status_c) + \beta_5 (Education_c) + \beta_6 (Region_c) + \varepsilon$$

5. Data Analysis and Visualization

Predicting the Likelihood of Receiving a Mammogram (Sample 1)

In examining the demographic predictors associated with a woman's response to whether or not she had a mammogram, several characteristics stood out including age, marital status, and educational attainment level. Approximately 82% of females in the dataset who were assessed to be *more likely* than the average woman in their age group to develop breast cancer (e.g. higher individual risk assessment), had mammograms. Of the women that were *less likely* than the average woman in their age group to develop breast cancer, around 76% had a mammogram not holding any other factors constant (*Table 5*). This is to say, a woman's likelihood of receiving a mammogram increased with her personal risk of developing breast cancer compared to the average woman in her age group, not controlling for several other factors (*Table 5*).

Mamm_Had	Risk				
	High-Risk	Low-Risk	Medium Risk	Unknown Risk	Total
No	**297**	**1335**	**1724**	**1359**	**4715**
Row freq	6.30%	28.31%	36.56%	28.82%	100%
Column freq	18.30%	23.58%	27.54%	66.03%	30.22%
Yes	**1326**	**4326**	**4536**	**699**	**10887**
Row freq	12.18%	39.74%	41.66%	6.42%	100%
Column freq	81.70%	76.42%	72.46%	33.97%	69.78%
Total	**1623**	**5661**	**6260**	**2058**	**15602**
Row freq	10.40%	36.28%	40.12%	13.19%	100%
Column freq	100%	100%	100%	100%	100%

Table 5: Cross tabulation of a woman's response to whether or not she had a mammogram and her personal risk of developing breast cancer compared to the average woman in her age group.

Importantly, around 12% of White females in the dataset had a higher risk of developing breast cancer compared to the average woman in their age group. However, 43% of White females were less likely than the average woman in their age group to develop breast cancer. By contrast, only 8% of Hispanic females were high-risk, and only 8% of Black females were high-risk.

Given the output of the binary logit regression model (*Model 1*) for Sample 1, there are several important points to note (*Table 9*). There was a significant negative effect of risk-level on likelihood of having a mammogram. That is to say, compared to individuals that were at a higher risk than average of developing breast cancer, women who were at a lower risk than average of developing breast cancer were 7.5% less likely to have had a mammogram holding all other factors constant ($p<0.000$). Women who were equally at risk of developing breast cancer as the average woman in their age group were also almost 7% less likely to have had a mammogram than high risk women, holding all other factors constant ($p<0.000$). Most significantly, women with an unknown risk of developing breast cancer were 62% less likely to have had a mammogram than their high-risk counterparts, holding all else constant ($p<0.000$). Therefore, it can be inferred that a females' individual risk of developing breast cancer has a significant effect on likelihood of receiving a mammogram. Reasons for this effect will be discussed later. Evidently, it seems that a

woman's likelihood of having a mammogram significantly increases if she is at a higher risk or aware of her personal risk of developing breast cancer in her lifetime (*Table 9*).

Age was another significant predictor of a woman's response to whether or not she had a mammogram. A woman's likelihood of having a mammogram increases by almost 2% every year, holding all other factors constant ($p<0.000$). This means that a woman's likelihood of receiving a mammogram increases by 20% every 10 years. Given the social norm surrounding routine mammogram screenings for women, it comes as no surprise that as a woman ages, she is more likely to have had a mammogram than her younger counterparts, regardless of her personal risk of developing breast cancer (*Table 9*). Marital status was yet another significant predictor of a female's likelihood of having had a mammogram. Widowed women were 20% less likely to have had a mammogram than their married counterparts ($p<0.000$) while single women were also about 4% less likely to have had a mammogram compared to their married counterparts ($p<0.000$). Race was not a significant predictor of a woman's likelihood of having had a mammogram, however according to the results of the model (*Table 9*), it appears that Black women were 2% more likely than White females to have received a mammogram, holding risk of developing breast cancer along with other characteristics constant ($p<0.036$). Moreover, Asian women were 3% less likely than White women to have had a mammogram ($p<0.006$). Hispanic women were not significantly more or less likely than White women to have received a mammogram.

Although the effect of the region a woman resides on her likelihood of receiving a mammogram was statistically significant holding all else constant (*Table 9*) the effect size was small (*Table 8*). According to *Table 8*, 68-72% of women in every region in the United States received a mammogram. Moreover, the difference in the likelihood of having received a mammogram based on region is small (<5%). Nonetheless there may be important reasons for why region of residence may have a significant effect on the likelihood that a woman has received a mammogram—holding all other factors constant—including variations in access to or quality of healthcare.

Mamm_Had	Region				
	Northwest	Midwest	South	West	Total
No	**752**	**961**	**1727**	**1275**	**4715**
Frequency	27.32%	30.03%	31.36%	30.78%	30.22%
Yes	**2001**	**2239**	**3780**	**2867**	**10887**
Frequency	72.68%	69.97%	68.64%	69.22%	69.78%
Total	**2753**	**3200**	**5507**	**4142**	**15602**
Frequency	100.00%	100.00%	100.00%	100.00%	100.00%

Table 8: Cross tabulation of a woman's response to whether or not she had a mammogram and the region of the United States where she reportedly resides.

	Delta-Method					
	dy/dx	Std. Error	z	p>|z|	[95% Confidence Interval]	
Risk						
Low-Risk	-0.0753262	0.008188	-9.20	0.000	-0.0913745	-0.0592779
Avg Risk	-0.0694304	0.0077259	-8.99	0.000	-0.084573	-0.0542879
Unknown Risk	-0.6208862	0.0154563	-40.17	0.000	-0.6511799	-0.5913924
Age	0.0176325	0.000347	50.81	0.000	0.0169324	0.0183127
Race						
Hispanic	0.00196	0.0110209	0.18	0.859	-0.0196406	0.0235607
Back	0.0202875	0.0106036	1.91	0.056	-0.0004951	0.0410702
Asian	-0.0545149	0.01965441	-2.77	0.006	-0.0930362	-0.0159936
Other	0.0302906	0.0301269	1.01	0.315	-0.028757	0.0893382
Marital Status						
Widowed	-0.2091877	0.0196924	-10.62	0.000	-0.2477841	-0.1705914
Divorced/Separated	0.009381	0.0083673	1.12	0.626	-0.007019	0.025781
Never Married/Single	-0.036706	0.0110437	-5.13	0.000	-0.0783512	-0.0350608
Living with Partner	-0.019833	0.0155888	-1.27	0.203	-0.0503864	0.0107204
Unknown	-0.133893	0.0819096	-1.63	0.102	-0.2944327	0.0266468
Education						
GED/high school grad	0.0369448	0.015779	2.34	0.019	0.0060171	0.0678725
some college, no degree	0.0828639	0.0157703	5.25	0.000	0.0519547	0.1137731
associate degree	0.0840676	0.0164335	5.12	0.000	0.0518585	0.1162768
Bachelor's degree	0.0824127	0.0157387	5.24	0.000	0.0515655	0.11326
above Bachelor's degree	0.1027663	0.0161716	6.35	0.000	0.0710705	0.1344621
Unknown	-0.0075508	0.063953	-0.12	0.906	-0.1328964	0.1177947
Region						
Midwest	-0.0497703	0.0116804	-4.26	0.000	-0.0726635	-0.0268771
South	-0.0373943	0.010319	-3.62	0.000	-0.0576194	-0.0171696
West	-0.0384601	0.0108689	-3.54	0.000	-0.0597627	-0.0171574
Note: dy/dx for factor levels is the discrete change from the base level.						

Table 9: Logit regression model with robust standard errors and marginal effects where the dependent variable is a female's binary response to whether or not she had a mammogram. Independent explanatory variables include personal risk of developing cancer, age, race, marital status, educational attainment, and region of residence.

Predicting the Likelihood of a Recommendation for Additional Testing (Sample 2)

If women responded, "Yes" to having had a mammogram, they were then asked the follow-up question of whether or not they were recommended for additional testing after the initial mammogram. A second model was examined in order to identify socioeconomic and demographic

characteristics that could predict a woman's likelihood of being recommended for follow up testing (*Table 12*). A preliminary analysis of the data showed that around 20% of high risk women were recommended for additional testing, while only 6% of low-risk women and almost 9% of average-risk women were recommended for follow up testing (*Table 10*). Moreover, close to 10% of White females, 9% of Hispanic females, 7% of Black females, and 10% of Asian females in the dataset were recommended for additional testing (*Table 11*).

Followup_Recc	Cancer_Risk				
	High-Risk	Low-Risk	Avg Risk	Unknown Risk	Total
No	1,065	4,040	4,147	646	9,898
Yes	261	286	389	53	989
Total	**1,326**	**4,326**	**4,536**	**699**	**10,887**

Table 10: Cross tabulation of personal risk of breast cancer compared to the average women in the female patient's age group and a woman's response to whether or not she was recommended for additional/follow-up testing.

Followup_Recc	Race					
	White	Hispanic	Black	Asian	Other	Total
No	6,578	1,316	1,445	455	104	9,898
Yes	6951	129	113	43	9	989
Total	**7,273**	**1,445**	**1,558**	**498**	**113**	**10,887**

Table 11: Cross tabulation of race and a woman's response to whether or not she was recommended for additional/follow-up testing.

According to the results of the model predicting likelihood of being recommended for additional testing (*Table 12*), a female's personal risk of developing breast cancer was once again a significant variable ($p<0.001$). Specifically, a woman who is less likely than the average woman in her age group to develop breast cancer is about 12% less likely than women at a higher risk than average to be recommended for a follow up, holding all else constant ($p<0.000$). A woman who is at average risk is 10% less likely than her high-risk counterpart to be recommended for additional testing, holding all else constant ($p<0.000$). For this reason, it is evident that holding all other characteristics constant, a woman's likelihood of being recommended for follow-up testing increases with her personal risk of developing breast cancer.

Age was another significant predictor of likelihood of follow-up in Sample 2. Specifically, the older a woman is, the less likely she is recommended for a follow-up, although the effect size is small (β <0.001). With regards to race, comparison between Black females and White females regarding the likelihood of follow-up was the only significant effect. In particular, Black females are about 2% less likely to be recommended for a follow-up than White females ($p<0.024$). Marital status was an insignificant predictor of the likelihood of being recommended for follow-up as was region of residence (*Table 12*). Educational attainment level, however, was a significant predictor

of the likelihood of being recommended for additional testing. As it appears, the higher the educational attainment of a female, the more likely she is compared to her lesser educated counterparts to be recommended for additional testing, holding all else constant ($p<0.002$).

	Delta-Method					
	dy/dx	Std. Error	z	p>|z|	[95% Confidence Interval]	
Risk						
Low-Risk	-0.1172754	0.0113738	-10.31	0.000	-0.1395677	-0.0949831
Avg Risk	-0.1036158	0.0112815	-9.18	0.000	-0.1257271	-0.0815044
Unknown Risk	-0.1064382	0.0148848	-7.15	0.000	-0.135612	-0.0772645
Age	-0.00122	0.0002135	-5.71	0.000	-0.0016384	-0.0008016
Race						
Hispanic	-0.0046715	0.0085284	-0.55	0.584	-0.0213869	0.0120439
Black	-0.0168635	0.0074465	-2.26	0.024	-0.0314583	-0.0022687
Asian	-0.0121519	0.0117651	-1.03	0.302	-0.0352112	0.0109073
Other	-0.0167785	0.0233854	-0.72	0.473	-0.0626129	0.029056
Marital Status						
Widowed	-0.0061762	0.008403	-0.73	0.462	-0.0226457	0.0102934
Divorced/Separated	-0.0049485	0.0065106	-0.76	0.447	-0.017709	0.0078119
Never Married/Single	0.0042075	0.00915	0.46	0.646	-0.0137262	0.0221411
Living with Partner	0.0043628	0.0143312	0.30	0.761	-0.0237258	0.0324515
Unknown	-0.052788	0.02989026	-1.77	0.077	-0.1112	0.005624
Education						
GED/high school grad	0.0158529	0.0086508	1.83	0.067	-0.0011023	0.0328081
some college, no degree	0.0130454	0.0089397	1.46	0.144	-0.0044761	0.0305669
Associate degree	0.0185285	0.0100997	1.53	0.067	-0.0012665	0.0383235
Bachelor's degree	0.0294541	0.0096569	3.05	0.002	0.010527	0.0483812
above Bachelor's degree	0.0325037	0.0105537	3.08	0.002	0.0118188	0.0531885
Unknown	-0.0474347	0.0193263	-2.45	0.014	-0.0853136	-0.0095559
Region						
Midwest	-0.0163427	0.0082059	-1.99	0.046	-0.0324259	-0.002595
South	-0.0086429	0.0077242	-1.12	0.263	-0.0237521	0.0064962
West	-0.0011856	0.0082012	-0.14	0.885	-0.0172597	0.0148886
Note: dy/dx for factor levels is the discrete change from the base level.						

Table 12: Logit regression model with robust standard errors and marginal effects where the dependent variable is a binary response to whether or not a female was recommended for additional/follow up testing after an initial mammogram.

Predicting the Likelihood of a False Positive (Sample 3)

If a woman responded, "Yes" to being recommended for additional testing after an initial mammogram, and if she followed through with the additional testing, she was asked the follow-up question of whether or not the additional testing resulted in a cancer diagnosis. Out of the women who had follow up testing, 888 reported their outcome in the survey out of which 103 were diagnosed with cancer after follow-up and 785 females had a false positive outcome (no cancer diagnosis after follow-up testing). 82 women reported that they did not follow-up with additional testing despite being recommended for it (*Table 13*). Out of these women, almost 25% reported they did not follow-up because it was too expensive and/or their insurance did not cover the cost, about 20% reported they put it off or did not get around to it, and 5% reported it was too unpleasant, painful, or embarrassing. 34% cited some other reason (*Table 13*).

No_Followup	Frequency	Percent	Cumulative Frequency
No reason/never thought about it	14	17.07%	**17.07%**
Put if off/didn't get around to it	16	19.51%	**36.59%**
Too expensive/no insurance/cost	20	24.39%	**60.98%**
Too painful, unpleasant, or embarrassing	4	4.88%	**65.85%**
Other reason	28	34.15%	**100%**
Total	**82**	**100%**	

Table 13: Reported reasons for why women did not follow-up with recommendation to pursue additional testing after initial mammogram.

Of the women who did follow through with the recommended additional testing, those that were most likely to have a false positive outcome had a lower than average personal risk of developing breast cancer, as expected (*Table 14*). That is, 73% of high-risk females, 94% of low-risk females, and 94% of average-risk females had a false positive outcome (*Table 14*). Given that, in general, the rate of cancer incidence is low, it was expected that the majority of women who got a follow up would have a false positive outcome (88%).

Cancer_Diagnosis	Cancer_Risk				
	High-Risk	Low-Risk	Avg Risk	Unknown Risk	Total
No (False Positive)	173	237	333	42	785
Yes	63	16	20	4	103
Total	**236**	**253**	**353**	**46**	**888**

Table 14: Cross tabulation of personal risk of breast cancer and a woman's response to whether or not she was diagnosed with cancer after additional testing, where a negative diagnosis was considered a false positive outcome.

Of the women who had a false positive outcome, about 70% were White, 13% were Hispanic, 12% were Black, and 5% were Asian (*Table 15*). According to Model 3, holding all other factors constant, a female's personal risk of developing breast cancer was significant to whether or not she had a false positive outcome. As shown in *Table 16*, women who were at a lower risk of developing breast cancer compared to the average woman in their age group were significantly less likely to have a positive cancer diagnosis and therefore more likely to have a false positive outcome compared to their high-risk counterparts ($p<0.000$). Age was another significant predictor of a false positive outcome, holding all other factors constant. Since a woman was more likely to have a positive cancer diagnosis as she ages, it can be said that a woman's likelihood of having a false positive outcome decreases as she ages (*Table 16*).

Race was only significant as it concerned the comparison between Black females and White females. In particular, Black females were 6% less likely to have a cancer diagnosis than White females, and therefore more likely than White females to have a false positive outcome ($p<0.001$). Marital status, educational attainment level, nor region of residence were found to be significant predictors of a female's likelihood of having a false positive outcome, holding all other factors constant (*Table 16*).

Cancer_Diagnosis	Race					
	White	Hispanic	Black	Asian	Other	Total
No (False Positive)	548	102	93	36	6	785
Yes	79	13	5	4	2	103
Total	**627**	**115**	**98**	**40**	**8**	**888**

Table 15: Cross tabulation of race and a woman's response to whether or not she was diagnosed with cancer following additional/follow-up testing. A false positive outcome results from a negative cancer diagnosis (No=0) after follow-up testing.

	Delta-Method					
	dy/dx	Std. Error	z	p>|z|	[95% Confidence Interval]	
Risk						
Low-Risk	-0.19508	0.0313225	-6.23	0.000	-0.256471	-0.1336891
Avg Risk	-0.1964599	0.0305256	-6.44	0.000	-0.2562891	-0.1366308
Unknown Risk	-0.173819	0.0475083	-3.66	0.000	-0.2669336	-0.0807044
Age	0.0035244	0.0007118	4.95	0.000	0.0021293	0.0049195
Race						
Hispanic	-0.0129505	0.0270076	-0.48	0.632	-0.0658845	0.0399834
Black	-0.0611088	0.0184624	-3.31	0.001	-0.0972943	-0.024932
Asian	-0.0146649	0.0366193	-0.40	0.689	-0.0864374	0.0571076
Other	0.1261388	0.1406845	0.90	0.370	-0.1495978	0.4018754
Marital Status						
Widowed	-0.0044381	0.022798	-0.19	0.846	-0.491214	0.0402452
Divorced/Separated	-0.0131646	0.0187596	-0.70	0.483	-0.0499326	0.0236035
Never Married/Single	0.0660096	0.0444909	1.48	0.138	-0.0211909	0.1532101
Living with Partner	0.0176865	0.0599989	0.29	0.768	-0.0999092	0.13525822
Unknown	-	-	-	-	-	-
Education						
GED/high school grad	-0.0501211	0.0371856	-1.35	0.178	-0.1230036	0.0227613
some college, no degree	-0.025386	0.040313	-0.63	0.529	-0.01043981	0.0536261
Associate degree	-0.0371485	0.0400773	-0.93	0.354	-0.1156986	0.0414017
Bachelor's degree	-0.041474	0.0395113	-1.05	0.294	-0.1189147	0.0359666
above Bachelor's degree	-0.0480629	0.0402327	-1.19	0.232	-0.1269175	0.0307918
Unknown	-	-	-	-	-	-
Region						
Midwest	0.0259921	0.0232446	1.12	0.263	-0.0195664	0.071507
South	0.021341	0.0205661	1.04	0.299	-0.0189678	0.0616497
West	0.0324481	0.0221222	1.47	0.142	-0.0109106	0.0758068
Note: dy/dx for factor levels is the discrete change from the base level.						

Table 16: Logit regression model with robust standard errors and marginal effects where the dependent variable is a binary response to whether or not a female was diagnosed with cancer following additional/follow up testing after an initial mammogram.

6. Discussion

Discussion of Empirical Results

Overall, results show demographic characteristics that can serve as significant predictors of a false positive result. Moreover, there are demographic characteristics that are significant predictors of health outcomes in the patient pathways preceding a false positive outcome including the likelihood of having had a mammogram and being recommended for additional testing following an initial mammogram. Personal risk of developing breast cancer was one predictor that remained significant across all three samples of the patient pathway. Women at a higher risk than average of developing breast cancer were more likely to have had a mammogram, more likely to be recommended for follow-up testing, and more likely to be diagnosed with cancer, as expected. If a woman has a high risk of developing breast cancer—due to family history or other risk factors—she is likely to be extra cautious regarding her breast health, this includes scheduling regular screenings. The reverse of this outcome also holds true as well: women who are less likely to be at risk of developing breast cancer compared to the average woman in their age group were less likely to have had a mammogram, less likely to have been recommended for follow-up testing, and more likely to have had false positive outcome, holding all other factors constant. Younger women, in general, have lower breast cancer incidence rates. If these low-risk women are nonetheless getting routine screenings, it is expected that they will be at a higher risk of incurring a false positive outcome. This significant relationship between personal risk of breast cancer and health behavior was expected, and served as a justification for the 2016 revision to the USPSTF guidelines.

Region of residence had a significant effect on a woman's likelihood of having had a mammogram. In particular, women from the Northwest were significantly more likely than women from the Midwest, South, and West to have received a mammogram. There are several potential reasons for this difference in effect, however the most likely cause is due to regional differences in access to healthcare and preventative health services. Another significant predictor of a female patient's health outcomes was marital status. Single women, whether widowed or never married, were less likely to have a mammogram than their married or partnered counterparts. Several reasons could account for this outcome. For one, spousal/partner support can serve as a source of encouragement to follow recommendations for routine mammograms. Health insurance may also play a role in this health outcome. Married women may have the support of their partner's health insurance to cover mammogram screenings, while widowed or single women may not. Marital status *only* served as a significant predictor of the likelihood that a woman had a mammogram, not the likelihood that she would be recommended for follow-up testing or whether she would have a false positive outcome. Since the risk of a false positive outcome increases with a woman's frequency of screenings and because women that are single or widowed are less likely to have mammograms, these women—by default—are less likely to incur a false positive outcome. This assertion is not definitive, but rather just one possible explanation for why single or widowed women have a less apparent risk for a false positive outcome (*Table 15*), though this overall effect was insignificant ($p>0.846$).

Race was not entirely predictive excluding the outcome of Black females compared to White females. Black females were 2% more likely than white females to have had a mammogram ($p<0.036$), but about 2% less likely to be recommended for additional testing ($p<0.024$), and 6%

more likely to have a false positive outcome if they were recommended for additional testing, holding all other factors constant ($p<0.001$). One explanation for this outcome is that White women have, on average, the highest rate of getting breast cancer followed by Black women (CDC, 2017)—therefore, Black women are more likely to have a higher likelihood of incurring a false positive when compared to White women since their overall rate of breast cancer incidence is lower.

Educational attainment level was a significant predictor of a woman's health behavior. Women that were more highly educated were more likely to have had a mammogram and more likely to be recommended for follow-up/additional testing, although educational attainment had no significant effect on a woman's likelihood of having a false positive outcome. One explanation for this is that educated women are more likely to also be knowledgeable about their health and, as a result, are more likely to practice healthy behaviors including routine breast screenings. These women may be more knowledgeable about screening recommendations than their less educated counterparts. On another note, educated women are also more likely to have higher incomes and therefore they are more likely to be able to afford routine mammograms—whether through their health insurance or out-of-pocket.

Age was by far the most significant variable across all stages of the patient pathway, holding all other factors constant. Arguably, age is the most significant driver of a woman's reasons for getting a mammogram. As she ages, however, she is less likely to be called in for a mammogram (though not as significantly so), and finally she is more likely than her younger counterparts to be diagnosed with cancer after additional testing. Such an outcome was expected because as woman age, their number of screening mammograms increases. The more mammograms a woman has had, the easier it is for a doctor to interpret a mammogram report when there are past mammograms to use as a comparison. For this reason, the need for a follow-up to clarify results may decrease. Alternatively, then, younger women who have less experience with screening mammograms are at a higher risk for a false positive outcome. Such an outcome is expected as it served as the primary justification for why the USPSTF revised their recommendations to starting routine screenings 10 years later than their previous recommendation advised, in order to reduce the false positive incidence in young women.

Therefore, it appears as though the data prove consistent with the guidelines advised by the USPSTF. Those benefiting most from the revision are females that are at a greatest risk of a false positive outcome. According to the models run in this analysis, women most at risk of a false positive outcome include young women that are at a lower risk of developing cancer than the average women in their age group. In delaying routine mammograms to age 50, instead of 40, the USPSTF intends to reduce the false positive incidence in young, low-risk women who are most at risk for this outcome.

Philosophical Discussion

As determined from the empirical analysis, the revised USPSTF recommendations benefit women who are younger and at a lower risk of developing breast cancer. It is for these women that annual screenings starting 10 years later than advised by the ACS, minimizes their likelihood of receiving a false positive outcome. The USPSTF reported that "the likelihood of avoiding a breast cancer death with regular screening mammography increases with age [...] however, the harms of screening mammography either remain constant or decrease with age. Therefore, the balance of benefits and harms improves with age" (USPSTF). As a result, for women in their 40s, the

percentage who benefit from starting regular screening mammography is smaller and the percentage experiencing harm is larger compared to older women. This fact is consistent with the results determined from the empirical analysis: younger women burden the costs of false positives at a higher rate than older women do. Several philosophical questions arise out of this result including those pertaining to the responsibility of care and the ethics of valuing societal risk over an individual's personal risk acceptance when defining recommendations that affect individual health outcomes.

Prevention Paradox

For one, the USPSTF follows a selective screening framework given that their recommendations pertain to women that fit a certain demographic criterion. This type of selective screening framework should not be considered to be the best approach for decreasing the incidence of breast cancer related deaths. Though seemingly utilitarian in nature, this framework falls short for several reasons. Consider the *prevention paradox*. In introducing the prevention paradox to this discussion, it is important to once again emphasize that screening mammograms are not preventative. However, although screening mammography does not prevent breast cancer incidence, it can and often does prevent breast cancer related death. As defined by the World Health Organization's *World Health Report*[7], the prevention paradox states that preventing small risks in large populations may avoid more adverse health outcomes than preventing large risks in a smaller number of high risk individuals. In the case of screening mammography guidelines, then, it addresses the question of whether tailoring a recommendation that focuses on preventing breast cancer related deaths in a smaller number of high risk individuals—as the USPSTF selective screening guidelines does—has a greater benefit to health outcomes than tailoring recommendations to prevent smaller risks in large populations—as a more universal screening recommendation does.

The USPSTF functions under the notion that recommendations should be focused on preventing larger risks in a smaller number of high risk individuals, which is why the guidelines advise starting routine screenings at age 50 instead of age 40. However, there remains a number of otherwise low risk individuals who will still develop breast cancer in their lifetime—whether from environmental or other unpredictable factors. The prevention paradox supports population-based interventions rather than those aimed at selective, high-risk individual targets to ensure that those low-risk individuals who will—despite being at low-risk—develop breast cancer can still get screened and maximize their chances of preventing breast cancer related death. For this reason, a selective screening framework may not be as effective as a more inclusive screening framework.

Rose's theorem further affirms this idea: a large number of people exposed to a small risk may generate many more cases than a small number exposed to high risk (Rose, 1992). Therefore, in order to minimize breast cancer related deaths at the population level, it does not make sense to completely shut out low risk individuals—women ages 40-50—out of which a percentage of these women will still go on to develop breast cancer in their lifetime even as low-risk individuals. As a result of the prevention paradox and the current USPSTF screening mammography guidelines, there exists a philosophical disconnect. The USPSTF framework may not be maximizing benefits of screening mammography while minimizing its harms to the extent that was presupposed.

[7] World Health Organization, Chapter 6 World Health Report: http://www.who.int/whr/2002/chapter6/en/index1.html

Beneficence and Patient Autonomy

Nonetheless, there exist significant detriments to approaching screening mammography from a utilitarian framework—valuing the overall prevention of cancer-related deaths at the lowest cost. The USPSTF screening mammography guidelines do not entirely account for individuals who, despite being outside of the recommended criteria for a mammogram, would individually benefit more from a mammogram for reasons such as minimizing anxiety from not getting screened. These individuals may find it costlier to *not* get screened rather than incurring a false positive outcome. Since the overall aggregate benefits and harms of screening mammography are difficult to determine, patient autonomy should be a central factor in determining whether a woman decides to get a mammogram or not.

Chief among the objections to the USPSTF recommendations was that the panel had insufficiently valued patients' lives or allowed cost considerations to influence recommendations (Plutynski, 2012). In a sense, the USPSTF guidelines show an inconsideration for patient autonomy and beneficence. As Norman (2012) notes, "since this time of intervention is performed on healthy individuals, the ethical requirements in the cases of screening programs are very high, because the risks of damage are not balanced, against real suffering (a clinically manifested disease), but are anchored in a potential future of illness and death." Given the exclusive nature of the USPSTF guidelines: non-maleficence (do not harm) and beneficence (The desire to promote patient's wellbeing) become difficult to adhere to for health practitioners, especially when what is deemed *best* for an individual patient may not align with what is recommended by screening mammography guidelines. This result can have an increasingly dangerous outcome if screening mammography guidelines dictate coverage requirements for screening mammography.

By narrowing the parameters of screening eligibility, selective screening may be a worse framework for screening mammography than even a universal screening one given the violation of patient autonomy and beneficence. In contrast, universal screening allows for an entire population to be screened to ensure no cancer goes undiagnosed, albeit generating unnecessary costs as it does. However, despite the benefits of universal screening over selective screening there still exists one framework that may still prove more reliable: individual risk assessment.

Given the variance in breast cancer risk and personal risk acceptance, surveillance and primary prevention adapted to each patient's individual risk level may be the most effective screening mammography recommendation framework. Moreover, this framework may be also prove the most effective use of resources for preventing, detecting, and improving breast cancer survival (Pharoah et al, 2008). This risk-level specific standard of care is continually garnering evidence of its effectiveness to produce a population-level reduction in breast cancer mortality. An individual risk assessment framework involves a shared decision between the doctor and her patient regarding when and how often to get screened. Clinical providers discuss personalized risk information with patients while patients discuss their personal risk acceptance, addressing questions like whether or not they would be willing to incur a false positive outcome to alleviate any concerns regarding their breast health. Such an approach to cancer surveillance and prevention is consistent with trends towards patient-centered care ("Institute of Medicine/Committee on Quality Health Care in America") and individualized medicine (Hamburg et al, 2008). In this way, individual risk assessment can be characterized as a tool for individuals who can then be encouraged to take responsibility for their own health (Anderson et al, 2012).

Quantifying the Value of Human Life

The USPSTF's screening mammography guidelines bring to light another very controversial philosophical discussion, this time centered on quantifying the value of human life. This discussion is not confined to the USPSTF's framework; however, it is a discussion that arises out of justifying a cost-benefit framework as a basis for recommending preventative care. Cost-benefit analyses translate all relevant considerations into monetary terms. Therefore, in the case of the USPSTF guidelines, the costs of screening mammography: from additional testing, to overdiagnosis, misdiagnosis, and psychological costs, were quantitatively compared to its benefits: including the saving of human lives and prevention of breast cancer. These considerations are all presented in terms of dollars. Proponents of cost-benefit analysis make two basic arguments in its favor:

> First, use of cost-benefit analysis ostensibly leads to more "efficient" allocation of society's resources by better identifying which potential regulatory actions are worth undertaking and in what fashion. Advocates of cost-benefit analysis also contend that this method produces more objective and more transparent government decision-making by making more explicit the assumptions and methods underlying regulatory actions (Heinzerling et al, 2002).

However, such a task is implausible in practice. For one, cost-benefit analyses cannot produce outcomes that maximize benefits to society when the process of reducing life, health, and the natural world to monetary values is inherently flawed (Heinzerling et al, 2002). Moreover, cost-benefit analysis implicitly equates the risk of death with death itself, when these two things should be accounted for separately in forming regulations for preventative services. Cost-benefit analysis also ignores the fact that "citizens are concerned about risks to their families and others as well as themselves, that market decisions are generally very different from health-related decisions, and of the incomparability of many different types of risks to human life" (Heinzerling et al, 2002). The kinds of problems which arise in attempting to define the value of human life in monetary terms also arise in evaluating the benefits of protecting human health.

This is not to say that cost-benefit analyses cannot be a useful decision-making *aid*. It certainly should be used as a tool for assessing decisions that affect populations. However, when it comes to screening recommendations and an individual's health, the value of human life should be a consideration placed upon the individual and not on the government. That is, a personal cost-benefit assessment should take precedence over a government-sponsored cost-benefit when deciding about a personal plan for getting screened. The value individuals place on life, or rather on the risk of death, is certainly dependent on factors that the government cannot be responsible for deciding on. The effectiveness of cost-benefit assessment, then, is that of distributive justice and to force considerations of the issue of placing values on health outcomes (Heinzerling et al, 2002)—therefore to promote the cause of efficiency in health care. In this way, ethics and economics need not necessarily have polarizing perspectives when evaluating health interventions, let alone screening mammography recommendations. A health intervention that has no consideration of economics can be equally as dangerous as a health intervention without ethical considerations: since "without a wider use of economics in healthcare, inefficiencies will abound and decisions will be made less explicitly and hence less rationally than is desirable [...] the price of inefficiency in explicitness and irrationality in health care is paid in death and sickness" (Mooney, 1980).

Methodological Biases in Evidence

There are several methodological issues raised in cancer screening. Some of these include: the potential biases that may infect a trial of screening effectiveness, the problem of base rates in communicating risk, and the trade-offs involved in a judgement of screening effectiveness (Plutynski, 2012). Furthermore, a recently published systematic review in the British Medical Journal on the adverse effects of cancer screening, found that only a third of randomized controlled clinical trials was concerned in measuring and controlling for potential harms of screening intervention (Norman, 2012):

> This article is very important because it has a direct effect upon the practice of health professionals, who cannot address security parameters on cancer screening interventions with their patients, since there is an information selection bias that emphasizes only the positive aspects of screening, for lack of controlling and monitoring of potential harms in most screening clinical trials (Norman, 2012).

From an ethical stance, this uncertainty undermines the patients' ability to practice autonomy, by creating false empowerment, since women do not have a more complete view on the potential harms and benefits of breast cancer screening programs (Norman, 2012). In order to secure patient autonomy, there is a need for the research and justification behind guidelines to be more transparent. Moreover, the language explaining relevant research findings and shortcomings should be neutral and accessible, so that individuals can make informed decisions about their own health.

7. Conclusions

Policy Recommendations

In recognition of the results of the philosophical and empirical analysis, several policy recommendations should be implemented in order to alleviate any recurring controversy surrounding the revisions to the USPSTF guidelines. It is important to recognize that changes in recommendations have been met with controversy partly because the public is not aware of the reasons for the revisions—that is to minimize a woman's risk of having a false positive outcome. Therefore, information, education and communication (IEC) campaigns educating women on the causes for the revisions and on the research behind screening mammography recommendations should be set in place. The research—including shortcomings—behind interventions should be neutral and accessible so that a wide audience may interpret these findings in order to make better informed decisions regarding their health.

In addition, interventions should be implemented focusing on an individualized risk assessment framework of screening. That is, women should consult their physicians and discuss options for screening before following through with any particular screening recommendation. This form of screening differs from selective screening, in that low-risk women would also have the option of being screened per their choosing and despite the existence of a recommendation that excludes them from the risk pool. This form of screening also differs from a universal screening framework in that it minimizes added costs of overdiagnosis, misdiagnosis, and unnecessary testing that are a symptom of screening all individuals regardless of risk factors.

Moreover, healthcare plans face the danger of only covering screening mammograms based on the USPSTF guidelines. The revised guidelines may limit access to mammography for 22 million women between ages 40 and 49 ("USPSTF Guidelines" 2016). By assigning breast cancer screening a "C" grade for women under 50, insurance companies will no longer be required to offer screenings without a copay, which was previously guaranteed by the Affordable Care Act. Given that coverage of preventive services without copays increases the likelihood that low-income and minority women receive important health care services, such as mammography, this recommendation may serve to increase the health disparity in the United States. Therefore, the future of screening mammography coverage is contentious and potentially life-threatening if not approached with careful consideration of the pool of women who will be without access to preventive services if they lose coverage for routine screening mammograms.

Shortcomings and Future Research

The most significant shortcoming is the fact that data were extracted from a national survey. Therefore, all responses were reported by individuals who completed the survey and should subsequently not be taken as definitive. Omitted variable bias is another potential shortcoming given that there were several factors that could not be controlled for such as income or other potential predictors of health behavior. Such variables that were not included in the regression were either not asked in the 2015 National Health Interview Survey or they were excluded due to many missing observations.

Future research should look more closely at the relationship examined in this analysis but with a dataset that is not based on observations that are self-reported. Moreover, future research should look at whether or not the USPSTF revised recommendations significantly impacts breast cancer related outcomes. Future research should also look at understanding the *true* cost of a false positive and whether or not a false positive outcome affects health behaviors in the future. Given that the dataset comes from a national-level survey, although the results can be considered generalizable to the national population, they should not be interpreted as necessarily causal considering the source of the data was a self-reported survey and therefore is subject to response bias.

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9. Appendix

Category	Definition	What it means
0	Additional imaging evaluation and/or comparison to prior mammograms is needed.	This means the radiologist may have seen a possible abnormality, but it was not clear and you will need more tests, such as another mammogram with the use of spot compression (applying compression to a smaller area when doing the mammogram), magnified views, special mammogram views, or ultrasound. This may also suggest that the radiologist wants to compare your new mammogram with older ones to see if there have been changes in the area over time.
1	Negative	There's no significant abnormality to report. Your breasts look the same (they are symmetrical) with no masses (lumps), distorted structures, or suspicious calcifications. In this case, **negative** means nothing bad was found.
2	Benign (non-cancerous) finding	This is also a negative mammogram result (there's no sign of cancer), but the radiologist chooses to describe a finding known to be benign, such as benign calcifications, lymph nodes in the breast, or calcified fibroadenomas. This ensures that others who look at the mammogram will not misinterpret the benign finding as suspicious. This finding is recorded in your mammogram report to help when comparing to future mammograms.
3	Probably benign finding – Follow-up in a short time frame is suggested	The findings in this category have a very high chance (greater than 98%) of being benign (not cancer). The findings are not expected to change over time. But since it's not proven to be benign, it's helpful to see if the area in question does change over time. You will likely need follow-up with repeat imaging in 6 months and regularly after that until the finding is known to be stable (usually at least 2 years). This approach helps avoid unnecessary biopsies, but if the area does change over time, it still allows for early diagnosis.
4	Suspicious abnormality – Biopsy should be considered	Findings do not definitely look like cancer but could be cancer. The radiologist is concerned enough to recommend a biopsy. The findings in this category can have a wide range of suspicion levels. For this reason, some, but not all, doctors divide this category further: **4A:** Finding with a low suspicion of being cancer **4B:** Finding with an intermediate suspicion of being cancer **4C:** Finding of moderate concern of being cancer, but not as high as Category 5
5	Highly suggestive of malignancy – Appropriate action should be taken	The findings look like cancer and have a high chance (at least 95%) of being cancer. Biopsy is very strongly recommended.
6	Known biopsy-proven malignancy – Appropriate action should be taken	This category is only used for findings on a mammogram that have already been shown to be cancer by a previous biopsy. Mammograms may be used in this way to see how well the cancer is responding to treatment.

Table 1: Breast Imaging Reporting and Data System, Source: https://www.cancer.org/cancer/breast-cancer/screening-tests-and-early-detection/mammograms/understanding-your-mammogram-report.html

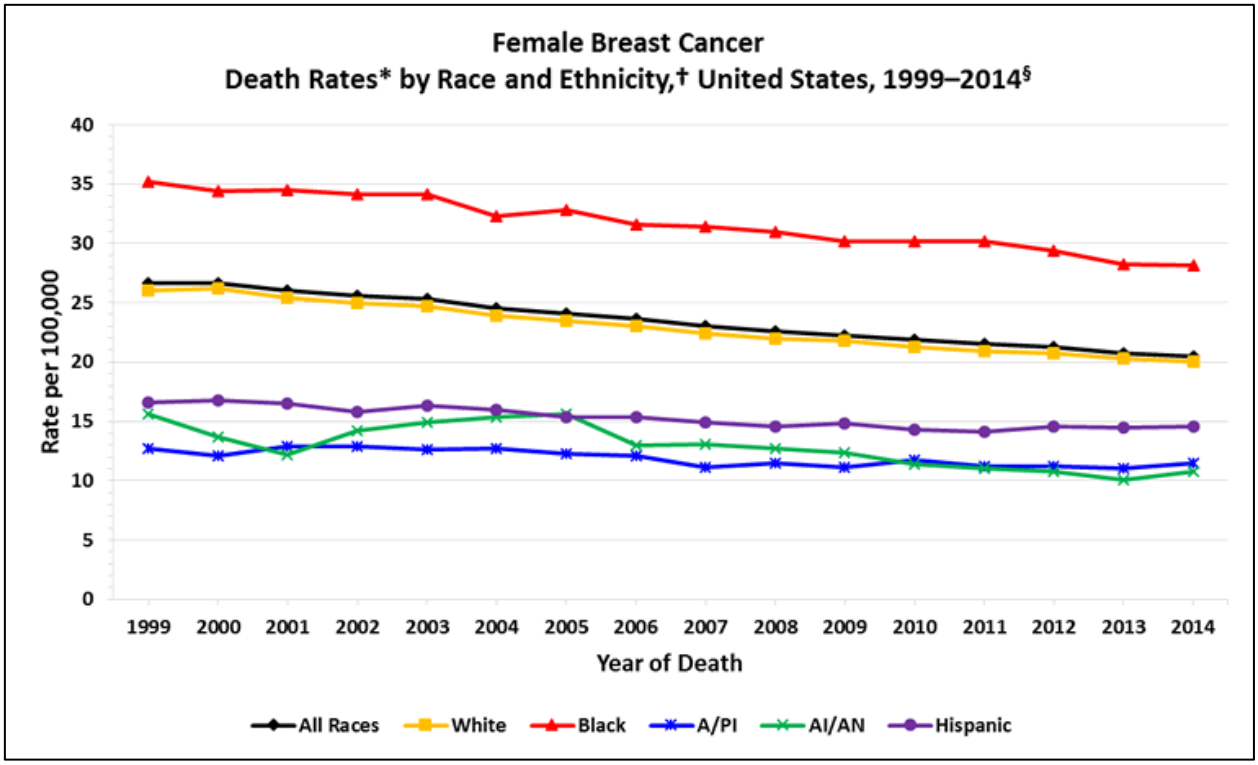

Figure 3: Female Breast Cancer Death Rates in the United States by Race and Ethnicity (1999-2014). *Source*: CDC's National Program of Cancer Registries and National Cancer Institute's Surveillance, Epidemiology, and End Results program.

Variable	Observation	Mean	Std. Dev	Min	Max
Mamm_Had	15,602	-	-	0	1
Risk	15,602	-	-	1	9
Age	15,602	55.70305	15.81841	30	85
Race	15,602	-	-	1	5
Marital_Status	15,602	-	-	1	6
Education	15,602	-	-	1	7
Region	15,602	-	-	1	4

Table 17: Model 1 (*Sample 1*) Summary statistics. *Source*: 2015 NHIS

Variable	Observation	Mean	Std. Dev	Min	Max
Followup_Recc	10,887	-	-	0	1
Risk	10,887	-	-	1	9
Age	10,887	60.32589	12.35243	30	85
Race	10,887	-	-	1	5
Marital_Status	10,887	-	-	1	6
Education	10,887	-	-	1	7
Region	10,887	-	-	1	4

Table 18: Model 2 (*Sample 2*) Summary Statistics. *Source*: 2015 NHIS

Variable	Observation	Mean	Std. Dev	Min	Max
Cancer_Diagnosis	888	-	-	0	1
Risk	888	-	-	1	9
Age	888	56.86036	12.35243	30	85
Race	888	-	-	1	5
Marital_Status	888	-	-	1	6
Education	888	-	-	1	7
Region	888	-	-	1	4

Table 19: Model 3 (*Sample 3*) Summary Statistics. *Source*: 2015 NHIS