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Government Recommendations and Health Behaviors: Evidence from Breast Cancer Screening Guidelines

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Abstract

We provide novel evidence on how healthcare decision-making responds to changes in government recommendations by studying the United States Preventive Services Task Force's 2009 decision to stop recommending mammogram screenings for women aged 40-49. Using a difference-in-differences identification strategy, we find that the guideline revision reduced mammography among 40-49-year-old women by 6-10 percent (from a baseline rate of 48.8 percent) relative to their older counterparts. We also identify large spillovers onto women aged 30-39 who were subsequently 25 percent less likely to receive a mammogram recommendation (from a baseline rate of 22.8 percent) and up to 60 percent less likely to receive a mammogram (from a baseline rate of 12.6 percent). These reductions were most pronounced for groups that had higher screening rates in the pre-period (i.e., non-Hispanic white women, women with health insurance, and women with a college degree). Additional analyses suggest the revision reduced overdiagnosis of early-stage tumors. Finally, we find that the 2009 update increased confusion about recommendations for preventing cancer.

JEL Codes: I18; I12
Key words: mammography; recommendation; cancer

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1. Introduction

The United States is routinely ranked last when comparing healthcare system performance among high-income countries (Commonwealth Fund 2021). It spends more on medical care than any other OECD country yet ranks 30 out of 38 for life expectancy at birth (OECD 2019, 2022). Though many factors contribute to this dubious distinction, policymakers have long argued that preventive care may be a healthcare silver bullet; by detecting and treating disease in its early stages, the hope is that preventive care can save both lives and money (White House 2012; White House 2022). As a result, public officials have sought to increase preventive care take-up by reducing the costs of these services and increasing knowledge about the associated benefits. While researchers have devoted considerable attention to understanding the effects of prices on healthcare utilization (Finkelstein et al. 2012; Kolstad and Kowalski 2012; Antwi et al. 2015; Barbaresco et al. 2015; Brot-Goldberg et al. 2017), relatively less is known about how government health recommendations affect patient and physician decision-making. Nevertheless, these policies can be found throughout the healthcare system, including recommended practice guidelines for a variety of preventive care services.[1]

In this paper, we study the impact of the 2009 update to the United States Preventive Services Task Force (USPSTF) mammogram recommendations. The USPSTF is an independent panel of medical experts appointed by the Department of Health and Human Services with the goal of making evidence-based recommendations about preventive services. While the task force has long recommended mammography for breast cancer prevention (USPSTF 1989; Woolf

[1] For example, the United States Preventive Services Task Force currently has 52 recommendations related to diseases including cancer, diabetes, obesity, and mental health disorders, among others. The Advisory Committee on Immunization Practices has recommendations for 26 vaccine-preventable diseases, including hepatitis A and B, influenza, shingles, and COVID-19.

1992), over the past several decades there have been multiple revisions to the age at which these screenings are first recommended and the suggested interval between screenings. Prior to 2009, USPSTF recommended that all women aged 40 or older receive a mammogram every 1-2 years;[2] in November 2009 they issued a revision recommending biennial mammograms for women aged 50 to 74, with no routine mammography recommended for women under the age of 50.[3] Notably, this recommendation change created disagreement between the USPSTF and other professional organizations (e.g., the American Cancer Society), which continued to recommend routine mammograms beginning at age 40.

Although in 2016 USPSTF reaffirmed their 2009 decision to recommend that routine screening begin at 50 years old, on April 30, 2024, USPSTF once again lowered the recommended starting age for mammography to 40 (USPSTF 2024). Given the ongoing debate about the appropriate age to begin mammogram screenings, it is critical to understand the role of government health recommendations in influencing this health behavior.

The November 2009 revision was motivated by updated evidence from randomized control trials that failed to detect any reduction in breast cancer mortality attributable to mammography in younger women (Nelson et al. 2009; Moss et al. 2006; Bjurstam et al. 2003), as well as concerns that younger women were being harmed due to (i) the high rate of false positives for this group, and (ii) the treatment of precancers that would have otherwise remained harmless (Elmore et al. 1998; Armstrong et al. 2007; Hubbard et al. 2011; Welch et al. 2016; Einav et al. 2020; Ryser et al. 2022). The revised recommendations were disseminated

[2] Throughout the text, we follow USPSTF's language and discuss mammography recommendations for women, though we acknowledge that there are women who do not have breasts and that not everyone with breasts identifies as a woman.

[3] The existing recommendation had been in place since 2002. Importantly, the 2009 recommendation change did not impact health insurance coverage of mammograms. See Section 2 for a detailed timeline regarding the evolution of mammogram recommendations and insurance coverage.

through publication on the USPSTF website and in a peer-reviewed medical journal (USPSTF 2022a), and we document widespread mammogram-related newspaper coverage concentrated in the week the recommendation was issued. Thus, this recommendation change, by synthesizing and publicizing the most up-to-date clinical findings, represents a shock to both physicians' and patients' information on the government's perceived value of mammography.

We first evaluate how the November 2009 USPSTF guideline revision affected mammogram screenings and related health behaviors using two sources of administrative data: the 2008-2015 American College of Radiology's National Mammography Database (NMD) and the 2008-2014 Maryland State Ambulatory Surgery and Services Database from the Healthcare Cost and Utilization Project (HCUP). We complement these administrative data sources with nationally representative survey data from the 2003-2018 National Health Interview Surveys (NHIS) and the 2003-2019 National Cancer Institute's Health Information National Trends Surveys (HINTS). Although each of these datasets has relative strengths and weaknesses, by showing robustness of our results across them we are able to increase our confidence that we are capturing meaningful changes in health behaviors arising from the updated USPSTF guidelines.

To identify policy effects, we use a difference-in-differences strategy comparing changes in mammogram screenings among women aged 40-49 to the concurrent changes for women aged 50-54. Our results show that the 2009 USPSTF guideline revision reduced mammography among 40-49-year-old women by 6-10 percent (from a baseline rate of 48.8 percent). Given that the 2009 USPSTF recommendation change recommended less frequent mammograms for women aged 50 or older, in addition to fully removing the screening recommendation for women aged 40-49, our results may underestimate the effect of the recommendation change on mammography among the younger age group. Crucially, however, by including relatively older women as a control group, we net out the common effects of factors such as the increased media coverage of mammography in the post-period (as shown in Figure 1) and any increase in preventive care use following passage of the Affordable Care Act.[4]

We also find evidence of sizable reductions in mammography among women aged 30-39, who were never recommended to receive routine mammograms during our sample period and thus were not directly affected by the updated guidelines. We document a 30-60-percent reduction in the number of annual mammogram procedures for women of this age group (from a baseline rate of 12.6 percent). Notably, at the time of the 2009 USPSTF revision, no major organization had recommended that women younger than 40 receive routine mammogram screenings for over a decade, and there is little evidence in favor of mammography for these younger women (Buckley et al. 2017; Chen et al. 2018). As such, our results are the first to provide causal evidence that raising the minimum age at which USPSTF recommends routine mammography reduces low-value care among never-recommended women. These results highlight the importance of considering how recommendations may alter the behaviors of non-targeted groups when deciding the optimal starting age at which to begin recommending routine screening.

Heterogeneity analyses by race/ethnicity, education level, and insurance status demonstrate that the response to the recommendation change varied substantially across groups. In particular, we find that those with the highest rates of mammography at baseline – non-Hispanic white women, women with health

[4] It is theoretically possible that our identification strategy could overestimate the effect of the policy change if women under the age of 50 followed the 2009 recommendation and stopped receiving mammogram screenings while those aged 50-54 defied the recommendation and began receiving more frequent mammograms. However, we show using multiple datasets that (1) estimated reductions in mammography are either larger or similar in magnitude when we alternatively use older women as the control group, and (2) mammography among 50-54-year-old women either fell (NMD, MD HCUP, BRFSS) or was unchanged (NHIS) following the 2009 USPSTF revision, indicating that this is unlikely to be the case.

insurance, and college graduates – reduced their screening rates relatively more in response to the recommendation change. Heterogeneity by observable health-related characteristics (receipt of the flu vaccine, BMI status, smoking history, and self-reported health) show a less clear pattern of effects.

We further provide suggestive evidence that the spillovers to younger women were driven by changes in physician and patient behavior. Our results show that the guideline change reduced the probability that women aged 35-39 reported receiving a mammogram recommendation from their doctor by over 7 percentage points – a 25-percent reduction relative to the pre-period mean for this group. Changes in doctor recommendations for mammography were much smaller for targeted women aged 40-49 (2.4 percentage points). We also show, however, that 40-49-year-old women responded to the recommendation change by decreasing their probability of going to the doctor in the past year by 2 percentage points. Moreover, the revised guideline seemingly generated confusion about the benefit of healthcare screenings for these women – after the USPSTF changed their recommendation, younger women were nearly 30 percent more likely to report feeling that they did not know which cancer prevention recommendations to follow. This suggests that frequent revisions to health recommendations may reduce the degree to which patients understand the guidelines, potentially undermining their credibility.

Next, we use a similar difference-in-differences model and 2002-2019 Surveillance, Epidemiology, and End Results (SEER) Program data to examine the effects of the guideline revision – and the subsequent change in mammography – on breast cancer diagnoses. After the 2009 update, we find no change in diagnoses of malignant (invasive) breast cancer for women aged 40-49 relative to the concurrent changes for older women. We do, however, find that diagnoses of non-invasive precancer ("in situ") breast tumors fell by approximately 16 percent for women aged 35-39 (the group with the largest change in mammography). Given that less than a quarter of the in situ precancers progress to life-threatening disease (Rosen et al. 1980), some cancer experts have argued that widespread screening has resulted in an overdiagnosis of these in situ precancers (Marmot et al. 2012; Francis et al. 2015; Worni et al. 2015; Benson et al. 2016; Co 2020).

These results suggest that the women who opted out of mammography following the 2009 USPSTF recommendation change were those who were least likely to be diagnosed with invasive breast cancer. This closely aligns with findings from prior work showing that the marginal women who comply with mammogram screening recommendations are less likely to have malignant breast cancer than those who do not screen (Einav et al. 2020; Kowalski 2023) and those who select into screening prior to the recommended age (Einav et al. 2020). The reduction we find in diagnoses of in situ breast tumors is also consistent with evidence from Kowalski (2023) showing that women who received mammograms were more likely to be overdiagnosed (i.e., they were more likely to be diagnosed with breast cancer that otherwise would not have caused symptoms).

Our findings contribute to several notable literatures. First, by showing that the number of screening mammograms among younger women fell in response to the recommendation change, we contribute new evidence to a literature exploring how non-binding recommendations affect health behaviors. Understanding the impacts of these types of recommendations is important given how widespread they are throughout the healthcare system.

Notably, the existing public health literature examining the 2009 USPSTF guideline revision is largely descriptive in nature and has drawn mixed conclusions on the effect it had on mammography among younger women (Howard and Adams 2012; Block et al. 2013; Pace et al. 2013; Sprague et al. 2014; Wang et al. 2014; Dehkordy et al. 2015; Jiang et al. 2015; Nelson et al. 2015; Wharam et al. 2015;

Fedewa et al. 2016; Gray and Picone 2016; Wernli et al. 2017; Brown et al. 2018).[5] Nearly all of the prior papers relied on interrupted time series or single-difference analyses (i.e., comparing mammography rates in a single baseline period versus post-treatment rates) and did not use a control group in their empirical analyses.[6] In this context, however, inclusion of a control group is critical for identifying a valid counterfactual, as it allows for the age-specific impacts of the USPSTF guideline change to be disentangled from other broad factors that are changing in the post-period and may affect mammography rates for women of all ages (such as increased media coverage of mammography or the Affordable Care Act's passage). Failure to account for these general shocks may lead to the incorrect conclusion that the USPSTF 2009 guideline change led to no change (or even an *increase*, for some sub-groups) in mammography among women aged 40-49.[7] We overcome this

[5] Most of the prior work examining the effects of the 2009 USPSTF revision limited their sample to women aged 40 or older (e.g., Howard and Adams 2012; Block et al. 2013; Wang et al. 2014; Fedewa et al. 2016; Rajan et al. 2017; Wernli et al. 2017; Brown et al. 2018) and was necessarily unable to detect reductions among younger women. However, two articles examining mammography trends over time documented reductions among women under the age of 40 (Dehkordy et al. 2015; Nelson et al. 2015).

[6] An exception to this is Block et al. (2013) who used BRFSS data from 2006, 2008, and 2010 and estimated difference-in-differences models comparing past year mammography for 40-49-year-olds versus 50-74-year-olds. They found no significant change in the full sample, which is not unexpected given that their post-period was limited to one year (2010) and their dependent variable measured changes in past year mammography. Notably, they did report a significant *increase* in past year mammography among women aged 40-49 who had a check-up in the past year, which is consistent with our finding that women in this age group causally responded to the recommendation change by altering their doctor-going behavior (see Table 4). In Section 4.2 we empirically reconcile our findings with the prior literature.

[7] For example, Wang et al. (2014) used 2006-2011 private insurance claims data and an interrupted time series model to show that for women aged 40-49, the monthly mammography screening rate was significantly *higher* in 2011 than what would have been expected if the pre-November 2009 time trends had continued. They therefore concluded that "the guideline change was associated with an increase in screening mammography rates." However, they also found that screening rates among 50-64-year-olds were significantly higher by the end of their sample period. This suggests that accounting for other factors changing during the post-period and affecting women of all ages is important to identify the targeted effect of the recommendation change. Similarly, Pace et al. (2013) used the 2005, 2008, and 2011 waves of the nationally representative National Health Interview Surveys and showed that there were no significant differences in self-reported past-year mammography between 2008 and 2011 for 40-49-year-old women. However, they also found a statistically significant (p=0.09) increase in past-year mammography for 50-74-year-old women,

limitation of the prior literature by estimating difference-in-differences models comparing changes in mammography in both administrative and survey data among women aged 40-49 to the concurrent changes occurring among women aged 50-54. These models allow us to flexibly control for common shocks which affect mammography rates for women of all ages within our samples.

There is some evidence from other contexts of the impacts of preventive care recommendations on health behaviors. Kadiyala and Strumpf (2016) showed using a regression discontinuity framework that 41-year-old women were 23 percentage points more likely to have had a recent mammogram compared to 39-year-old women prior to the updated guidelines.[8] Similarly, studying an earlier period (1991-2000) in which USPSTF and various medical organizations issued conflicting recommendations regarding mammography screening ages, Jacobson and Kadiyala (2017) found evidence that uninsured women discontinuously increased mammography at both recommended ages (i.e., 40 and 50). In contrast, insured women appeared to begin screening at the earliest recommended age. More broadly, several recent papers have found mixed evidence of whether age-targeted vaccine recommendations increase vaccine take-up (Lawler 2017; Lawler 2020; Churchill and Henkhaus 2023).

By documenting the reduction in physician mammogram recommendations following the guideline change, we also offer new evidence on a relatively unexplored economic determinant of physician behavior. Prior work has explored the roles of financial incentives (Gaynor and Pauly 1990; Gruber et al. 1999; Rizzo and Zeckhauser 2003; Clemens and Gottlieb 2014; Brekke et al. 2017; Alexander

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again suggesting that broader factors were affecting mammography. These examples highlight the importance of a valid counterfactual for identifying the effects of the USPSTF recommendation change on mammography for age-targeted women.

[8] Because their data predated the 2009 policy change, Kadiyala and Strumpf (2016) could not leverage the temporal variation in the recommended starting age for mammography and necessarily assumed that women did not otherwise discontinuously change their health behaviors when turning 40 – a focal age signaling the start of being “middle aged.”

and Schnell 2021; Schnell 2022), legal liability (Baicker and Chandra 2005; Currie and MacLeod 2008; Frakes 2013; Shurtz 2013), and professional norms (Chandra and Staiger 2007; Kesternich et al. 2015; Currie and MacLeod 2020) in shaping physician behavior. Yet there has been comparably less work on the role of government-induced information shocks. While a few papers have found that individually targeted information shocks can sway behavior (Kolstad 2013; Singh 2021),[9] there is mixed evidence on the role of information shocks generated by government-endorsed practice recommendations (Alalouf et al. 2018; Buchmueller and Carey 2018; Dubois and Tunçel 2021; Cuddy and Currie 2022). Recently, Wu and David (2022) showed that an unexpected FDA safety communication regarding the risk of minimally invasive hysterectomies shifted physicians away from the procedure, especially among those physicians least skilled at performing it.

Through analyzing changes in both mammogram screenings and breast cancer diagnoses, we add to work analyzing the efficacy of health screenings (Stewart and Mumpower 2003; Hackl et al. 2015; Abaluck et al. 2016; Welch et al. 2016; Kim et al. 2017; Glewwe et al. 2018; Conner et al. 2022; Mullainathan and Obermeyer 2022; Guthmuller et al. 2023). Prior work has shown that individuals who comply with health recommendations are more likely to engage in other beneficial health behaviors (Oster 2020). In the context of mammography, Einav et al. (2020) found that women who began mammogram screening at age 40 were less likely to have cancer than women who selected into screening earlier or those who never began screening. Similarly, Kowalski (2023) showed that women who were more likely to receive mammograms were healthier – both in terms of long-term

[9] Studying surgeon "report cards" containing information on individual and peer performance that was unrelated to patient demand, Kolstad (2013) documented improvements in surgeon quality. Likewise, Singh (2021) found that physicians were responsive to information shocks obtained through personal experience – physicians whose patients experienced complications with a particular delivery mode (i.e., vaginal or Cesarean) were more likely to switch delivery modes for the subsequent patient.

breast cancer incidence and all-cause mortality – and more likely to engage in other beneficial health behaviors. Moreover, she found that women who received mammograms were more likely to be overdiagnosed with breast cancer (i.e., they were more likely to be diagnosed with breast cancer that otherwise would not have caused symptoms). While these articles documented underlying differences among individuals who complied with recommendations to *undertake* particular health behaviors relative to those that did not comply, in our setting the compliers are those who followed the 2009 USPSTF recommendation to *delay* receiving mammogram screenings until the age of 50.

Finally, by detailing how a government recommendation affected women's decisions to undergo breast cancer screenings, we add to a broader literature documenting the economic determinants of cancer screenings. Much of the literature to date has focused on the impact of health insurance coverage and cost-sharing (Busch and Duchovny 2005; Finkelstein et al. 2012; Kolstad and Kowalski 2012; Bitler and Carpenter 2016; Bitler and Carpenter 2017; Kim and Lee 2017; Sabik and Bradley 2016; Myerson et al. 2020). Other studies have considered the role of retirement (Coe and Zamarro 2015; Frimmel and Pruckner 2020; Eibich and Goldzahl 2021), access to health clinics (Lu and Slusky 2016), awareness campaigns (Jacobsen and Jacobsen 2011), unemployment rates (Ruhm 2000), and targeted screening programs (Pletscher 2017; Buchmueller and Goldzahl 2018; Eibich and Goldzahl 2020; Bitler and Carpenter 2019). Our paper expands on this literature by highlighting the role of information – and government policies that convey it – in cancer screening decisions. Given that government recommendations are often the first line policy option for changing health behaviors, understanding the direct and spillover impacts of these policies is crucial.

The rest of the paper proceeds as follows: Section 2 describes the clinical evidence regarding mammography and cancer detection, as well as the policy history of age-targeted recommendations. Section 3 explains the administrative and survey data that we use to examine changes in mammography and related health behaviors, as well as our difference-in-differences identification strategy. Section 4 presents our results on mammography, breast cancer diagnoses, and the potential underlying mechanisms. Finally, Section 5 discusses the policy implications and limitations of our results.

2. Clinical Evidence and Policy History

Cancer is the second leading cause of death in the United States (CDC 2022), and – except for some skin cancers – breast cancer is the most diagnosed cancer, with over 280,000 expected new cases in 2022 (NCI 2022a).[10] Approximately 30 percent of all female cancers are breast cancers, and 1 in 8 US women will develop breast cancer during their lives. As the second leading cause of cancer death in women, breast cancer kills over 40,000 women each year (ACS 2022a). Moreover, with total medical costs exceeding $16.5 billion each year, breast cancer has a higher economic burden than all other cancers (Mariotto et al. 2011).[11] Reducing the female breast cancer mortality rate has been an explicit goal of the US Department of Health and Human Services for the past several decades (US DHHS 2021, 2014, 2012). Because treatment costs and mortality are higher for more advanced breast cancers, increasing early detection through routine screenings known as mammograms is also a US public health priority (US DHSS 2021; Cutler 2008).[12]

A mammogram is an X-ray examination of the breast used to detect potentially cancerous abnormalities. Mammograms are very effective at detecting breast cancer, in the sense that they have low rates of false negatives; however, they

[10] The National Cancer Institute excludes nonmelanoma skin cancers from the list of the most common cancer types.
[11] Mariotto et al. (2011) estimated the total annual medical cost of breast cancer to be $16.5 billion in 2010. They projected this value would range from $18.9-$25.6 billion in 2020.
[12] The 5-year relative survival rate is 99 percent for localized breast cancer that has not spread, 86 percent for regional breast cancer that has spread to nearby structures or lymph nodes, and 20 percent for distant breast cancer that has spread to other parts of the body (ACS 2022b).

also have high rates of false positives. False positives are particularly common for younger women and may cause unnecessary distress, follow-up procedures (e.g., biopsies), and out-of-pocket costs.[13] Additionally, there is a growing body of evidence that mammography results in the detection and treatment of early-stage tumors that would have remained harmless (Elmore et al. 1998; Armstrong et al. 2007; Hubbard et al. 2011; Einav et al. 2020; Welch et al. 2016; Ryser et al. 2022).

The out-of-pocket monetary costs for screening mammograms are likely to be low during our sample period, due to widespread adoption of insurance coverage mandates. At the start of our sample period, almost every state mandated mammography benefits for qualified health insurance plans, including "baseline" mammogram screenings for 35-39-year-old women, biennial mammograms for women aged 40-49, and annual mammograms for women aged 50 or older (Bitler and Carpenter 2016; American Cancer Society 2025). Notably, although health insurance coverage of "baseline" mammograms for 35-39-year-old women is common, there is little evidence in favor of mammography for 35-39-year-old women (Buckley et al. 2017; Chen et al. 2018), and during our sample period none of the major organizations (American Cancer Society, American College of Radiology, or the USPSTF) recommended mammograms prior to age 40 for women of average risk.[14]

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[13] For example, Ho et al. (2022) estimated the average false positive rate of digital mammography to be 9 percent. Rates are significantly higher for women aged 40-49 (10.8%) versus women aged 50-59 (8.2%) and 60-69 (5.7%). This gradient is explained in part by the fact that denser breasts result in higher rates of false positives, and younger women have denser breast tissue (Sprague et al. 2014; Mandelson et al. 2000; Kerlikowske et al. 2015).

[14] Between 1980 and 1992 the American Cancer Society did recommend a baseline mammogram for women aged 35-39 (Dodd 1993; American Cancer Society 2023), and it was during this period that the vast majority of insurance mandates were adopted that required coverage of a "baseline" mammogram for 35-39-year-old women. While comparing new mammograms to prior mammograms may improve accuracy (Roelofs et al. 2007), when ACS removed their recommendation in 1992, routine mammography beginning at age 40 was viewed as serving as a "logical replacement" to "baseline" mammography at ages 35-39 (Dodd 1993).

It is also the case that under the Affordable Care Act private insurers are required to cover mammogram screenings without cost-sharing for women aged 40 or older, effective for plan years beginning on or after August 1, 2012 (USPSTF 2019). For physicians, reimbursement is also relatively low: in 2022, physicians received approximately $40 per mammogram under the Medicare Physician Fee Schedule, and the facility received $90.67 (CMS 2022).

The United States Preventive Services Task Force (USPSTF) issued their first set of mammography recommendations in 1996, initially recommending that women aged 50-69 receive a mammogram every 1-2 years.[15] At that time, they did *not* recommend routine screening for women aged 40-49, stating that there was "conflicting evidence…regarding clinical benefit from mammography" for women in that age group (USPSTF 1996). After conducting a meta-analysis of the existing evidence, in 2002 USPSTF reversed course and recommended routine mammography every 1-2 years for women aged 40 or older (USPSTF 2002).

In November 2009, USPSTF updated their 2002 meta-analysis to incorporate new clinical evidence from two more recent trials (Bjurstam et al. 2003; Moss et al. 2006). Based on this evidence, USPSTF stopped recommending routine screening for women aged 40-49, concluding that the cost of "false-positive results and unnecessary biopsies is larger" than the benefits of averted breast cancer deaths attributable to mammogram screenings for these younger women. They also noted that these women would be at heightened risk for "treatment of noninvasive and invasive breast cancer that would otherwise not have become a threat to their health, or even apparent, during their lifetime." At the same time, USPSTF also reduced

[15] The USPSTF mammography recommendations do not apply to women who have a genetic risk for breast cancer (i.e., to women who have one of the two genes, *BRCA1* and *BRCA2*, associated with breast cancer). However, the USPSTF only recommends *BRCA* screening for women with a known history of breast, ovarian, tubal, or peritoneal cancer, and less than 10 percent of women with breast cancer have a *BRCA* mutation (Long and Ganz 2015). The 2016 USPSTF mammogram recommendation also acknowledged that women aged 40-49 with a familial history of breast cancer "may benefit more than average-risk women from beginning screening in their 40s."

the frequency of its recommendation for women aged 50-74 to biennial screening (USPSTF 2009). In 2016, USPSTF again updated their meta-analysis and then reaffirmed their 2009 recommendations (Nelson et al. 2016; USPSTF 2016).

However, a recent revision in April 2024 once again lowered the recommended starting age for mammography to 40 (USPSTF 2024). Unlike the 2009 recommendation change, which was driven primarily by new clinical trial evidence, the 2024 revision appears to largely be motivated by concerns about persistent racial disparities in breast cancer mortality, particularly the higher mortality rates observed among Black women (Pace and Keating 2024). For women overall, the estimated balance of benefits and harms from initiating screening at age 40 instead of age 50 remained relatively unchanged between 2016 and 2024 (Trentham-Dietz et al. 2024, USPSTF 2016).[16] The 2024 recommendation, however, explicitly emphasizes the potential for a relatively larger reduction in breast cancer mortality among Black women as a justification for lowering the recommended starting age to 40 (USPSTF 2024). Table 1 summarizes the recommendation changes.

At the time of the USPSTF 2009 guideline revision, there was not a clear consensus among medical professionals about the appropriate age to begin mammogram screenings.[17] The American College of Radiology (2009) called the updated guidelines "ill-advised and dangerous," and a survey found that nearly 60 percent of physicians reported that the revised guidelines were not applicable to their patients (Hinz et al. 2011). Similarly, the American Cancer Society (ACS)

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[16] Notably, this (modest) benefits-to-harms ratio was used in 2016 to inform the recommendation of individual decision making for mammography screening among women aged 40-49 (Pace and Keating 2024).

[17] There was, however, longstanding public support for mammogram screenings. For example, a nationally representative survey found that over 40 percent of adults would consider it irresponsible for an 80-year-old to forgo mammography (Schwartz et al. 2004), and a separate study found that over half of adults would undergo a cancer screening that did not reduce the chance of cancer death or extend the length of life (Scherer et al. 2019).

contradicted the USPSTF recommendation, releasing a 2009 statement affirming routine breast cancer screenings for women aged 40-49, with ACS's chief medical officer Dr. Otis W. Brawley stating, "[t]his is one screening test I recommend unequivocally, and would recommend to any woman 40 and over, be she a patient, a stranger, or a family member" (ACS 2009). However, in 2015 the American Cancer Society raised its recommended starting age for mammography from 40 to 45 years old (ACS 2015).

As previously noted, the explicit audience for USPSTF guidelines are primary care physicians (USPSTF 2022a), with official dissemination occurring via publication online and in a peer-reviewed medical journal. Descriptive evidence presented in Figure 1, however, suggests that the 2009 update to the USPSTF mammography guidelines was disseminated much more broadly. Panel A shows that there was an intense (though short-lived) spike in mammogram-related newspaper coverage coinciding with the timing of the recommendation; Panel B shows a similarly timed spike in internet search activity for the term "mammogram."

3. Data and Methodology

3.1 Mammography Data: National Mammography Database

To examine the relationship between the November 2009 USPSTF recommendation change and mammography behavior, we draw on several complementary data sources. We first use facility-reported mammography data from the 2008-2015 American College of Radiology's National Mammography Database (NMD). The NMD was established in 2008 with the dual aims of improving mammography performance quality and facilitating research (American College of Radiology 2024). These data have been used extensively in the medical literature (e.g., Grimm et al. 2022; Berg et al. 2020; Lee et al. 2017), including to assess mammography-related policy changes (Bahl et al. 2016). Our sample contains the number of screening mammograms performed each year by single year of patient age.

A key advantage of these data is that they are administratively reported, though facility participation in the database is voluntary. By participating in the NMD, facilities receive performance feedback, including national and regional benchmark information. Barriers to participation are relatively low, as facilities are already required to collect the relevant metrics for annual audits under the federal Mammography Quality Standards Act and data collection and submission is automated for many existing commercial software (American College of Radiology 2024). Notably, Lee et al. (2016) found that patient characteristics and performance measurements for facilities that participated in the NMD between 2008 and 2012 were generally consistent with other nationally representative estimates.

Facility participation in the NMD has increased substantially over time (Lee et al. 2016). To ensure that changes in the composition of reporting facilities do not influence our results, we limit the sample to the ten distinct facilities that were continuously reporting from Q1 2008 through Q4 2015. These facilities are relatively high-volume facilities: we observe a total of 611,419 screening mammograms during our sample period, with a facility mean annual number of approximately 7,643.[18]

Table 2 documents the facility and patient characteristics in these data. The majority of the reported mammograms were performed at either community hospitals (42.3 percent) or freestanding centers (40.5 percent). The sample is drawn largely from suburban areas (70.5 percent), and these facilities are in the Midwest (42 percent), South (29.9 percent), and West (28.2 percent) Census regions. No

[18] Appendix Figure 1 plots the number of mammograms in our sample from each year of the NMD data. For context, based on data collected by the FDA, in 2009, there were 8,713 certified mammography facilities and they performed a total of 37,321,810 mammograms (FDA 2025). While these figures do not distinguish between screening and diagnostic mammograms, approximately 88.5 percent of mammograms are screening mammograms (Allison et al. 2015).

facilities in our sample are in the Northeast region.[19] Most of the mammograms were done in facilities performing at least 5,000 mammograms per year (79.7 percent). Patient race and ethnicity is not always reported (40.6 percent and 29.2 percent, respectively). However, among the individuals for whom we have racial information, the majority were white (89.3 percent), with Black individuals comprising the second largest group (9.4 percent). For robustness we also conduct analyses using a sample of 19 facilities that continuously reported from Q1 2009 through Q4 2015 (total observed mammograms of 1,269,784, with a facility mean annual number of approximately 9,547), and we report the characteristics of these facilities in Appendix Table 1.[20,21]

Figure 2 plots the number of observed screening mammograms that were performed each year on women aged 40-44, 45-49, and 50-54 in the NMD sample (Panel A). We observe a clear reduction in the number of mammograms reported for women aged 40-44 coincident with the 2009 USPSTF recommendation. In contrast, the number reported for women aged 45-49 and 50-54 appear to follow a smoother trend around the policy change. Interestingly, though during our sample

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[19] In the appendix, we use an alternative sample that has a shorter pre-period but includes facilities from the Northeast.

[20] Appendix Table 2 reports the summary statistics from the NMD sample analyzed by Lee et al. (2016). Our analytic sample is generally in line with the sample used for their analyses with a few key exceptions. First, patient race is missing over 26 percent less frequently in our dataset than in Lee et al. (2016). Second, while only 14 percent of our sample comes from metropolitan facilities, over 60 percent of the mammograms in their sample are performed at facilities in metropolitan areas. Third, our sample generally comes from facilities that perform fewer mammograms. While 20 percent of our data are from facilities performing fewer than 5,000 mammograms, only 5 percent of Lee et al.'s (2016) sample was from facilities of this size. As a result, while an average facility in our data performed approximately 7,643 mammograms annually, the mean facility in Lee et al. (2016) performed 13,804.

[21] Appendix Table 3 reports summary statistics from the nationally representative Breast Cancer Surveillance Consortium (BCSC). Between 1996 and 2019, an average facility performed 1,821 mammograms annually, which is considerably smaller than the average facility in our NMD sample or Lee et al. (2016). Appendix Figure 2 plots trends using publicly available BCSC data. While not well-suited for our analyses, because they only included data on women aged 40 or older in 10-year age groups for the following year groupings: 2005-2008, 2009-2010 (spanning the pre- and post-periods), 2011, 2012, 2013, 2014, and 2015-2017, the trends are qualitatively similar to the trends in the NMD sample.

period they were never recommended to receive a mammogram, there is also a sharp reduction in the number of mammograms in our data performed on women aged 35-39 (Panel B).

3.2 Mammography Data: Maryland HCUP State Ambulatory Surgery and Services Data

Although the NMD data provide information about screening mammograms conducted at a diverse set of facilities across the United States, a limitation of those data is that facilities must select into reporting. To demonstrate that our findings are not being driven by selective participation of facilities, we complement the NMD data with Maryland State Ambulatory Surgery and Services Data (SASD) from the Healthcare Cost and Utilization Project (HCUP) for 2008-2014. The SASD database was designed to provide encounter-level data for ambulatory surgeries that occur at hospital-owned ambulatory surgery facilities (AHRQ 2025b). However, states may also include encounters for other outpatient services (e.g., observation stays, imaging, chemotherapy, etc.) and from other facilities, including other outpatient facilities or non-hospital owned facilities.

Ideally, we would draw on HCUP SASD data from a range of states, though we are limited to Maryland due to HCUP data availability and budgetary considerations.[22] Crucially for our purposes, since 2007 Maryland SASD has included all outpatient records from hospital-owned facilities, including those

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[22] To assess the feasibility of including data from additional states we reviewed the HCUP SASD File Composition documentation and the year- and state-specific Core summary statistics for all 16 states with SASD data available via HCUP during the year of policy adoption (2009). Of these states, only three (Kentucky, Maine, and Maryland) reported providing their complete outpatient file to HCUP to be released in the SASD files. Review of the summary statistics also confirmed that these were the only three states with records of what we deemed to be a sufficient number of mammography procedures. For example, in 2009, Kentucky had 184,509 records with a mammography-related procedure code, Maine had 163,559, and Maryland had 81,602. The next two highest were New Jersey (4,143) and New York (200). Unfortunately, the HCUP SASD files for Maine and Kentucky were prohibitively expensive.

physically attached to a hospital and stand-alone facilities (AHRQ 2025a). We therefore begin our analyses in 2008 to avoid changes in sample composition associated with this transition.[23] We identify screening mammograms in the outpatient records using the CPT Codes G0202 ("screening mammography, digital") and 77057 ("mammogram, screening"). We then collapse the data so that each observation contains the count of observed screening mammograms at the single year of age-calendar year level.

Descriptive statistics for the MD HCUP data are presented in Appendix Table 4. For women aged 30-54, we observe a total of 168,782 screening mammograms between 2008 and 2014.[24] Approximately 55 percent of these mammograms are for non-Hispanic white women, 33 percent for non-Hispanic Black women, and 4 percent for Hispanic women. Private insurance is the expected primary payer for the majority of these screenings (75.6 percent). As with the trends in the NMD, Figure 2 shows a clear reduction in the number of mammograms reported for women aged 40-44 (Panel C) and 35-39 (Panel D) coincident with the 2009 USPSTF recommendation. These raw data also show suggestive evidence of smaller declines in the number of mammograms for women aged 45-49 and 50-54.

[23] Summary statistics provided by HCUP show that the number of records in the Maryland annual SASD file increased starkly between 2006 and 2008 (980,442 in 2006, to 2,002,783 in 2007, to 3,331,111 in 2008). From 2008 until the end of our sample (2014), the number of annual visits recorded is remarkably stable – varying only between 3,331,111 (2008) and 3,595,168 (2014).

[24] To benchmark the share of Maryland screening mammograms present in these data, we divided the number of mammograms observed in the 2008 HCUP data (the first year of our sample) by the female age-specific population estimate obtained from the SEER population database. We then compared these observed rates to the share of Maryland women in the 2008 BRFSS that reported receiving a mammogram in the past year. We note that we use the BRFSS data for this calculation, as opposed to the NHIS, because the public-use BRFSS data includes state identifiers. We estimate that the MD HCUP data capture 6.3-6.8 percent of the reported BRFSS mammograms for women aged 40-54. However, our calculation likely *underestimates* the true proportion of the screening mammograms captured in the MD HCUP data for two reasons. First, the BRFSS survey question does not distinguish between screening and diagnostic mammograms. Second, prior evidence shows that unscreened women tend to over-report having had a screening (Anderson et al. 2019).

3.3 Mammography Data: National Health Interview Surveys

We also obtain self-reported information on mammography screening from the 2003-2018 National Health Interview Surveys (NHIS).[25] The NHIS is a nationally representative survey that collects detailed information from face-to-face interviews of approximately 87,500 people each year. In these data, women were asked whether they have ever had a mammogram, as well as questions about the timing of their most recent mammogram. From these questions, we construct several dichotomous outcomes. First, we generate *Mammogram in Past Year*, which is equal to 1 if the woman reported receiving a mammogram within the last year and 0 if her most recent mammogram was more than a year ago or she reported never receiving a mammogram. Because the 2009 USPSTF recommendation change removed the screening recommendation for women aged 40-49 *and* recommended less frequent mammograms for women aged 50 or older, we would expect past year mammography to fall across both age groups. As such, we also construct indicators for *Mammogram in Past Two Years* and *Mammogram in Past Three Years*. While *Mammogram in the Past Two Years* and *Mammogram in the Past Three Years* are intended to account for the fact that the 2009 revision also recommended that women in the comparison group (i.e., aged 50-54) receive less frequent mammograms, it is worth noting that since these outcomes have longer lookback periods, some women may be answering about mammograms that occurred when they were in the treated group (i.e., aged 40-49). We show in the appendix that our results are robust to excluding from the sample women for whom the lookback period includes years prior to turning age 50.

Because the NHIS data are nationally representative, we can use them to calculate age-specific screening rates during the pre- and post-periods. We plot these rates in Appendix Figure 3, and we present trends in these outcomes in Figure

[25] Breast cancer screening information is available in the 2003, 2005, 2008, 2010, 2013, 2015, and 2018 survey waves.

3. Consistent with the administrative data, we observe reductions in all mammography measures for women aged 30-49, with no evidence of reductions among the 50–54-year-old women. Importantly, the trends suggest that these reductions among relatively younger women occurred following the November 2009 update to the guidelines. We report additional mammography rates from the NHIS data in Appendix Table 5.[26]

3.4 Opinions on Care: Health Information National Trends Survey

We explore how the 2009 USPSTF mammogram recommendation affected targeted women's views on cancer recommendations, satisfaction with their input into healthcare decision making, and trust in the healthcare system using the 2003-2019 Health Information National Trends Survey (HINTS). These nationally representative data are collected by the National Cancer Institute to measure cancer-related knowledge and attitudes among adults aged 18 or older and include demographic characteristics such as age, race/ethnicity, educational attainment, marital status, and health insurance coverage. Thus, we can separately examine changes in outcomes for targeted women (aged 40-49) compared to the associated changes experienced by their older counterparts (aged 50-54).

As with the NHIS data, the HINTS data contain information on whether women reported ever receiving a mammogram. For our purposes, a key advantage of these surveys is that they also asked whether women felt that there were "so many recommendations about preventing cancer" that it made it difficult to know which ones to follow, whether they felt that their doctor always involved them in their healthcare decision-making, and whether they trusted health information from

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[26] To the best of our knowledge, out of the three main datasets that we use to examine mammography screening (NHIS, NMD, and HCUP), only NHIS has been previously used to look at the effects of the 2009 USPSTF recommendation change (Fedewa et al. 2016; Pace et al. 2013). Prior work also used the BRFSS data that we use as a supplementary data source, though the findings were mixed (Block et al. 2013; Gray and Picone 2016).

doctors and government agencies. Although these questions allow us to explore potentially important consequences of the 2009 USPSTF recommendation, they contain a relatively small sample; for women aged 40-54, the HINTS mammography sample is 21 percent of the size of our NHIS sample. We report the summary statistics from these data in Appendix Table 6.[27]

3.5 Cancer Data: Surveillance, Epidemiology, and End Results Program

We obtain information on breast cancer diagnoses from the 2002-2019 National Cancer Institute's Surveillance, Epidemiology, and End Results (SEER) Program. Our data include the universe of breast cancer diagnoses for women collected from 17 cancer registries in 12 states, covering nearly 27 percent of the US population (NCI 2022b). These data include information on age at diagnosis, state of residence, and diagnosis year. They also include detailed information on tumor location, size, and behavior (e.g., in situ, malignant), as well as months of survival following diagnosis (measured as of 2019). We differentiate between in situ and malignant tumors, given evidence that many in situ precancers do not progress or become malignant (invasive) tumors (Rosen et al. 1980; Marmot et al. 2012; Francis et al. 2015; Worni et al. 2015; Benson et al. 2016; Co 2020). Summary statistics are provided in Appendix Table 8; trends in breast cancer incidence are presented in Appendix Figure 4.

3.6 Empirical Strategy: Difference-in-Differences

While the trends offer descriptive evidence that the 2009 USPSTF mammography recommendation reduced mammography among younger women, we empirically test this relationship using a difference-in-differences strategy. Using the NMD and

[27] An additional limitation of the HINTS data is that the set of survey questions varies across survey waves, so the underlying sample varies slightly across outcomes. We show in Appendix Table 7 the set of years each question is included. Further, the mammography questions are only asked of women aged 35 and older, and so we are unable to examine effects for women aged 30-34, unlike in the NMD, HCUP, and NHIS data.

Maryland HCUP data on the number of screening mammograms among women aged 30-54, we estimate the following specification:

$$M_{agt} = \alpha + \sum_{g=30\text{-}34}^{45\text{-}49} \beta^{g} \cdot \text{AGE GROUP}_{g} \times \mathbf{1}\{2009\ \text{USPSTF}\}_{t} + \theta_{a} + \tau_{t} + \varepsilon_{agt} \qquad (1)$$

where the dependent variable, M_{agt}, is the natural log of the number of mammograms performed for women aged *a,* in 5-year age group *g* (for $g \in \{30\text{-}34, 35\text{-}39, 40\text{-}44, 45\text{-}49\}$), in a given year *t*. The coefficients of interest, β^{g}, measure the differential age-group specific change in the log number of mammogram procedures following the November 2009 USPSTF recommendation, relative to the change observed among women aged 50-54. The vector of age fixed effects, θ_{a}, accounts for time-invariant age-specific attitudes toward mammography, and we flexibly control for broad shocks to mammography by including a vector of year fixed effects, τ_{t}.

Because the 2009 USPSTF revision recommended less frequent mammograms for women aged 50 or older, in addition to fully removing the screening recommendation for women aged 40-49, this empirical specification may underestimate the effect of the recommendation change on mammography among younger women. However, if women under the age of 50 followed the 2009 recommendation and stopped receiving mammogram screenings while those aged 50 or older defied the recommendation and began receiving more frequent mammograms, then this specification could overstate the effect of the recommendation change. While theoretically possible, we note that the descriptive trends for both administrative datasets reveal reductions in the number of mammograms for women of all ages, including those aged 50-54 (see Figure 2, Panel A and Panel C). Likewise, our survey data indicates that mammography fell among women under the age of 50 and remained largely unchanged for those aged 50 or older (see Figure 3).

Crucially, however, by including relatively older women as a control group, we net out the common effects of factors such as the increased media coverage of mammography in the post-period (as shown in Figure 1) and any increase in preventive care use following passage of the Affordable Care Act. While almost every state mandated mammography benefits for qualified health insurance plans at the start of our sample period (Bitler and Carpenter 2016; American Cancer Society 2025), the Affordable Care Act further required that screening mammograms be covered without patient cost sharing for women aged 40 and older. Because the ACA went into effect in September 2010 – less than one year after the November 2009 USPSTF guideline revision – research examining only trends in annual mammography will be unable to isolate the effects of the USPSTF recommendation change from the effects of the ACA. To date, the evidence on the impacts of the ACA on mammography is mixed (Nelson et al. 2015; Alharbi et al. 2019; Courtemanche et al. 2019).

When using our survey datasets, we employ a similar specification but additionally leverage our ability to account for demographic and geographic characteristics. Specifically, we estimate the following equation:

$$M_{iagst} = \alpha + \sum_{g=30\text{-}34}^{45\text{-}49} \beta^{g} \cdot \text{AGE GROUP}_{g} \times \mathbf{1}\{\text{2009 USPSTF}\}_{t} + X_{iagst}'\gamma + \theta_{a} + \tau_{st} + \varepsilon_{iagst} \quad (2)$$

where the dependent variable, M_{iagst}, is the mammogram-related outcome of interest (mammogram in past year, in past two years, or in past three years) for respondent *i,* age *a,* in age group *g*, in geographic area *s*, and time *t*. As above, we note that since the updated guidelines also recommended that older women reduce their mammogram frequency from annually to biennially, we expect the estimated treatment effect on past year mammography among younger women to be biased towards zero. However, we also expect that this bias should be much smaller when examining the share reporting a mammogram during the past two years and the past three years, as these outcomes should have been relatively less affected by the recommendation change for women aged 50-54.

We include a vector of individual-level characteristics, X_{iagst}, to account for demographic traits potentially related to the decision to receive a mammogram, including indicators for race/ethnicity (white, Black, Hispanic, and Asian with 'other' omitted), educational attainment (less than high school, high school graduate, and some college with college graduate omitted), marital status (married, divorced, widowed, and separated with never married omitted), and health insurance coverage (any coverage with no coverage omitted). Our survey datasets include observations from after the American Cancer Society raised its recommended age for women to begin mammogram screenings from 40 to 45 years old (October 2015). We control for this policy change with a binary variable that takes on the value of one for all women aged 40 and above until October 2015; after October 2015 the variable remains one for women aged 45 or older, but changes to zero for those aged 40-44 (ACS 2015).

For analyses using the NHIS and HINTS datasets we respectively include Census region-year-month or Census region-year fixed effects (τ_{st}), as these are the most granular geographic and time variables available. In robustness analyses using data from the 2002-2019 Behavioral Risk Factor Surveillance System, we are able to include state-year-month fixed effects to account for all state-level economic and policy changes occurring at the year-month level (e.g., ACA Medicaid expansion or state breast cancer awareness campaigns).[28]

[28] During our sample period, the BRFSS underwent a redesign in a way that was anticipated to be correlated with health behaviors (Morbidity and Mortality Weekly Report 2012). Given this limitation, we do not report results using these data in the main text, although we report them in the appendix for completeness. Trends using the BRFSS data are presented in Appendix Figure 5 and show reductions in past year mammography for 40-49-year-old women and 50-54-year-old women after the USPSTF recommendation change.

The fact that treatment occurred at the age-group level (i.e., those under the age of 50 and those aged 50 or older) implies that we have two clusters, which presents a challenge for statistical inference (Cameron et al. 2008; Cameron and Miller 2015; Abadie et al. 2017). To address this complication, we follow MacKinnon and Webb (2018) and implement a subcluster wild bootstrap procedure that clusters standard errors at the finer five-year age group-year level.[29] We also report heteroskedastic robust standard errors for all specifications.

4. Results

4.1 Effects on Mammography

We begin by examining the relationship between the November 2009 USPSTF recommendation and the number of mammograms performed for women ages 30-54, using the administrative data. The dependent variable in Figure 4 is the natural log of the number of mammograms performed for women of each age group. Women aged 50-54 are the omitted (control) group. The dark grey circles denote the estimates obtained from the NMD data, while the light grey triangles denote the estimates obtained from the Maryland HCUP data.

Figure 4 shows that the 2009 USPSTF guidelines resulted in a statistically significant 8 percent reduction in the number of mammogram procedures for women aged 40-44, with an estimated 6-10 percent reduction among women aged 45-49.[30] These estimates are remarkably consistent across the two datasets. More strikingly, we detect a near 60 percent reduction in the number of procedures for women aged 35-39, and a less precisely estimated 19-50 percent reduction among

[29] When the number of treated clusters is small, unrestricted (i.e., no null hypothesis imposed) wild cluster bootstraps tend to over-reject the null, whereas restricted (i.e., null hypothesis imposed) wild cluster bootstraps tend to under-reject the null (MacKinnon and Webb 2018). While we only report restricted (null imposed) *p*-values throughout the tables to save space, the corresponding unrestricted *p*-values were practically identical, increasing our confidence in the statistical inference. These additional statistics are available upon request.

[30] Appendix Figure 6 presents results where the effect is allowed to vary by single-year-of-age.

30-34-year-olds. We show in Appendix Tables 9 and 10 that these results are robust to including older women in the control group (column 2), replacing the dependent variable with the inverse hyperbolic sine of the number of mammograms (column 3), and using a Poisson specification (column 4).[31] We also show in Appendix Figure 7 that the NMD results are robust to alternatively using a larger sample of facilities that continuously reported screenings from 2009-2015.

What might explain this change among 30-39-year-old women? As previously mentioned, routine mammography was never recommended by USPSTF for these women during our sample period. Nor had any major organization recommended women under the age of 40 routinely receive a mammogram since 1992. However, despite the lack of clinical justification, many existing state laws continued to require that insurers cover "baseline" mammograms for women aged 35-39. As such, one possibility is that these younger patients continued to receive baseline mammograms – either by their own requests or at the recommendation of their providers – though it went against the existing recommendation. By increasing the likelihood that women began receiving regular mammogram screenings at age 50, rather than age 40, the 2009 USPSTF revision may have lowered the perceived clinical value to obtaining an initial screening at ages 35-39 (Brennar 2003; Sumkin et al. 2003). Another possibility is that patients under 40 years old and their healthcare providers may have been using the 40-year-old threshold as an anchor when making healthcare decisions (e.g., a woman may always choose to begin screening two years prior to the official recommended age).

[31] Recent work has drawn attention to the difficulty in interpreting estimates in which the outcome variable has zeros and the dependent variable is natural log transformed (Mullahy and Norton 2023; Chen and Roth 2024). While this is not an issue when we are examining changes in the number of mammograms (as we always have a nonzero number of mammograms for each age-by-year observation), we do encounter zeros in the outcome for our analyses of breast cancer. Thus, for completeness and for comparability of our estimates across datasets, we show that our mammography results are also robust to using an inverse hyperbolic sine transformation (which is defined at zero) or a Poisson specification that accounts for the count nature of the data.

By updating the starting age to 50, the 2009 USPSTF guidelines would have increased the gap between a younger woman's age and the threshold, generating spillovers onto these younger women.

In Figure 5 we estimate an event study specification where the coefficients of interest capture the relative difference between the targeted group (women aged 40-49) and the non-targeted group (women aged 50-54) around the recommendation change. We plot these estimates for both the NMD (Panel A) and Maryland HCUP data (Panel B).[32] The estimates for 40-49-year-olds (black triangles) show that following the updated recommendation, there were approximately 7 percent fewer mammograms performed for these women relative to slightly older women. We also plot estimates comparing changes in the number of procedures for 30-39-year-olds to changes in the number for 50-54-year-olds (grey circles). Consistent with the prior figure showing large reductions in mammography among younger women who had never been recommended to begin mammogram screening, the event study estimates reveal more than a 30 percent reduction in the number of mammograms performed for women aged 30-39. In the event studies using the NMD, we find no evidence of differential pre-trends in the number of mammograms performed for younger women relative to the 50-54-year-old comparison group. In the Maryland HCUP data, however, we do estimate a positive and significant coefficient for 2008, though the estimates are considerably smaller in absolute magnitude than the changes we observe in the post-period.

[32] We also estimated models at the age-year-quarter level to obtain additional pre-period observations. Consistent with the annual data, Appendix Figure 8 shows that the reductions in mammography were limited to the post-period. In the NMD, smaller cell sizes (<20) are suppressed, resulting in missing values at this more granular level of observation. To account for this, for each age and year we took the difference between the total number of mammograms in the year and the sum of non-suppressed mammograms at the year-quarter level. We then assigned each missing quarterly observation the average number of unaccounted for mammograms in that year. Our dependent variable remains ln(Number of Mammograms) in this analysis. In the MD HCUP data, there are zeroes at the age-year-quarter level, so our dependent variable is ln(Number of Mammograms + 1).

Taken together, we believe that these results provide compelling evidence that the November 2009 USPSTF recommendation change significantly reduced mammography among women aged 30-49, relative to their 50-54-year-old peers.

Next, we explore whether the reduction in the number of mammograms performed on women aged 30-49 that we detect in the administrative data is also present in the nationally representative NHIS data. Results using these data are presented in Figure 6; we also report age-specific estimates in Appendix Figure 9.[33] Because women aged 50-54 (our omitted group) were also recommended to get less frequent mammograms, we report results where the dependent variable is an indicator for having a mammogram during the past year (circles), the past two years (triangles), and the past three years (squares).[34]

Consistent with the results from the NMD and Maryland HCUP data, we detect large reductions in the likelihood that women in their late 30s reported receiving a recent mammogram. We estimate that 35-39-year-old women were 4.3-8.9 percentage points less likely to have had a recent mammogram. During the pre-period 16.4 percent of these women reported receiving a mammogram during the past year, 43.9. percent reported receiving a mammogram during the past two years, and 46.3 percent reported receiving a mammogram during the past three years. As

[33] We find a similar pattern of results when using data from the 2002-2019 Behavioral Risk Factor Surveillance System and employing a difference-in-differences specification that accounts for state-level time-varying policies through the inclusion of state-by-year fixed effects (Appendix Figure 10). As previously mentioned, during our sample period, the BRFSS data underwent a redesign that was anticipated to be correlated with health behaviors, which is why we use the NHIS data in our main analysis.

[34] Since the NHIS outcomes ask women about mammograms that occurred during the past year, the past two years, and the past three years, some of the 50-54-year-old women in the comparison group may be answering about screenings that occurred when they were in the treated group. To test how this may influence our results, in Appendix Figure 11 we restrict our sample to exclude (i) 50-year-old women when the outcome is *Mammogram in the Past Year*, (ii) 50- and 51-year-old women when the outcome is *Mammogram in the Past Two Years*, and (iii) 50-52-year-old women when the outcome is *Mammogram in the Past Three Years*. Reassuringly, the results are practically unchanged. We also show in Appendix Figure 11 that our results are robust to dropping the period after the ACS recommendation change in October 2015.

a result, our estimates imply that the USPSTF 2009 revision reduced mammography among women aged 35-39 by 17.3-26.2 percent relative to the pre-period mean.[35] In contrast, we estimate a 1-2 percentage point reduction among women aged 40-49. Prior to the recommendation change, 49.1 percent of these women reported receiving a mammogram during the past year, 63.0 percent reported receiving a mammogram during the past two years, and 69.1 percent reported receiving a mammogram during the past three years. These figures imply that the USPSTF revision was associated with a 2-4 percent reduction in mammography for women aged 40-49 relative to the pre-period means. Although these estimates are not statistically significant, they are similar in magnitude – though less precisely estimated – to the reduction observed in the NMD and HCUP data (approximately 6-8 percent).

As a sensitivity check, in Figure 7 we show that our mammography results across all three datasets (NMD, HCUP, and NHIS) are robust to using women aged 55-59, 60-64, or 65-69 as our control group, rather than those aged 50-54. For the administrative datasets, the results using alternative control groups generally show larger reductions in mammography for women aged 30-49 than our baseline estimates. The magnitudes of the NHIS estimates are relatively stable regardless of the choice of control group. We also estimate small reductions for those aged 50-54, which is consistent with the fact that the 2009 guideline revision also recommended that this age group receive less frequent mammograms. Overall, this exercise suggests that our main results are likely conservative estimates of the change in screening mammography that occurred following the 2009 revision to the USPSTF guidelines.

[35] We also report these results and the relevant pre-treatment means in Appendix Table 11.

4.2 Reconciling Our Results with Prior Literature

The fact that we detect a reduction in mammography among 40-49-year-old women runs counter to the mixed findings in some prior work (Howard and Adams 2012; Block et al. 2013; Pace et al. 2013; Sprague et al. 2014; Wang et al. 2014; Dehkordy et al. 2015; Jiang et al. 2015; Nelson et al. 2015; Wharam et al. 2015; Fedewa et al. 2016; Gray and Picone 2016; Wernli et al. 2017; Brown et al. 2018). One possible explanation for the difference in findings is that some of the existing literature used survey datasets with only one year of post-period data (e.g., Howard and Adams 2012; Block et al. 2013). Because the surveys asked women about their mammography history during the past year, women may have been reporting mammograms that they received prior to the November 2009 USPSTF revision.

To test whether the use of a longer post-period explains the difference between our findings and that of prior work, we first limit our sample to women aged 40-54 (i.e., we exclude women aged 30-39 who were not typically studied in prior work). In Appendix Table 12 we show that analyses using survey measures of mammography from the NHIS only show evidence of a reduction in mammography when including several years of post-period data. This is consistent with the idea that the lookback period of the outcome variable in these data causes a lag in our ability to detect an effect. On the other hand, results using our two administrative datasets, presented in Appendix Figure 12, show a significant reduction in mammography for women aged 40-49, regardless of the length of our post-period.[36]

[36] The fact that we detect a reduction in mammography in two sources of administrative data contrasts with Wang et al. (2014) who used data on privately insured individuals and an interrupted time series specification and concluded that – following an initial reduction in the months following the 2009 USPSTF revision – mammography increased for women aged 40-49 and those aged 50-64. However, aggregate data collected by the FDA as part of the Mammography Quality Standards Act shown in Appendix Figure 13 clearly shows a reduction in the number of mammograms performed.

Another possible explanation for the differing results is that some prior work compared mammography rates before and after the recommendation change without using a control group and therefore were unable to account for secular trends in mammography that affected both younger and older women. In Appendix Table 13 we show that estimates from single-difference specifications (as employed in the prior literature) yield mixed results across all three of our datasets (columns 2-5). In contrast, when using a control group in a difference-in-differences specification, we consistently find reductions in mammography following the 2009 revision to the USPSTF recommendations (column 1). Overall, these exhibits highlight the importance of (i) using a sufficiently long post-period when survey questionnaires ask about behavior during the past year and (ii) including a control group to account for secular trends and contemporaneous changes.

4.3 Heterogeneity

In Figure 8, we use the NHIS survey data to explore potential heterogeneity in the effects of the 2009 USPSTF recommendation change along several dimensions, including health insurance coverage (Panel A), race/ethnicity (Panel B), and educational attainment (Panel C).[37] Appendix Figures 14-16 plot the trends for recent mammography by age and demographic group. We note that there are meaningful differences in mammography along these dimensions. Prior to the recommendation change, insured women were nearly 20 percentage points more likely to report having had a recent mammogram. Similarly, non-Hispanic white women and college-educated women were over 5 percentage points more likely to have had a recent mammogram than non-white women and those without a college degree, respectively (see Appendix Table 5).

[37] Appendix Table 14 shows that there were no differential changes in the demographic composition of our sample that was coincident with 2009 USPSTF recommendation change.

Figure 8 indicates that the 2009 USPSTF recommendation change resulted in some convergence in the levels of screening across these dimensions, as the groups with the highest rates of mammography at baseline reduced their screening rates relatively more. We find that the 2009 change reduced the probability that insured women aged 30-49 reported receiving a recent mammogram by 2.2-3.9 percentage points (6.1-7.7 percent). In contrast, the point estimates for uninsured women are opposite signed and statistically insignificant. We also detect a statistically significant 2.9-4.5 percentage point (8.6-9.1 percent) reduction among white women aged 30-49 compared to a statistically insignificant 0.6-1.5 percentage point (1.6-3.6 percent) reduction among their non-white counterparts. Finally, we estimate a statistically significant 3.5-4.3 percentage point (7.7-9.7 percent) reduction among college-educated women aged 30-49 compared to a statistically insignificant 0.3-1.6 percentage point (1.0-3.5 percent) reduction among similarly aged women without a college degree. Appendix Figure 17 shows that these patterns persist when only examining 40-54-year-old women.[38]

We next explore heterogeneity across four health-related dimensions – receipt of the flu vaccine, BMI status, smoking history, and self-reported health – as prior evidence shows that women who comply with health recommendations are typically healthier than average (Einav et al. 2020; Oster 2020; Kowalski 2023). In our data, it is indeed the case that prior to the November 2009 recommendation change, women aged 50-54 who self-reported being in better health, receiving a recent flu vaccine, and not having a history of smoking were 8-17 percentage points more likely to have had a past year mammogram than their similarly aged but less healthy counterparts (see Appendix Figures 19-21). Screening rates were similar,

[38] Appendix Table 15 examines changes in mammography for women with and without a maternal history of breast cancer. We are unable to reject that the estimated effects for these two groups differ from one other, likely due to the small number of women in our sample with maternal history of breast cancer (1,185 women). Appendix Figure 18 shows similar reductions in mammography among women with and without a history of maternal breast cancer.

however, across BMI status. For 30-49-year-old women we see a much different pattern: while women in this age range who reported receiving a recent flu vaccine were approximately 10 percentage points more likely to report having had a past year mammogram, screening rates were similar across the three other health dimensions we examine (self-reported health, smoking history, and BMI status).

The results from these heterogeneity analyses are presented in Figure 9. Interestingly, we do not observe a clear relationship between changes in mammogram screenings and other health behaviors. The results show that the 2009 USPSTF recommendation change was associated with a reduction in mammography among women in worse self-reported health and those who reported *not* receiving a flu shot during the prior year, suggesting that it was less healthy women who followed the updated recommendation to delay screening. Yet we also detect larger reductions in mammography among women *without* a history of smoking (i.e., the healthier group) relative to those with a history of smoking. One potential explanation for this pattern is that the well-known connection between smoking and various types of cancer (Viscusi 1990; Botteri et al. 2008; Iodice et al. 2008; Lortet-Tieulent et al. 2016) reduced the willingness of women with a history of smoking to follow the recommendation and forgo a cancer screening, even though smoking is only associated with a modest increase in breast cancer risk (Xue et al. 2011; Gaudet et al. 2013). Finally, we find no evidence of a differential response to the 2009 USPSTF recommendation change based on BMI status.

Next, we examine heterogeneity in the impacts of the recommendation change based on age at the time of the update to account for the possibility that women who began mammography when they turned 40 – prior to the updated guidelines – may have been less inclined to cease their regular screenings compared to women who turned 40 after the recommended starting age was raised to 50. Table 3 separately considers women aged 40-49 who turned 40 after the recommendation change (Panel A) and women aged 40-49 who had already turned 40 prior to the recommendation change (Panel B). We find suggestive evidence that women who turned 40 after the recommendation change were 2.0-2.9 percentage points less likely to have had a recent mammogram, though the estimates are imprecisely estimated. Meanwhile, the point estimates for 40-49-year-old women who had already turned 40 prior the recommendation change are smaller in magnitude and statistically insignificant. Overall, Table 3 suggests that some 40-49-year-old women who had already begun mammogram screenings continued to receive them following the recommendation change.

4.4 Additional Results

The 2009 USPSTF guidelines were primarily intended to guide physician behavior regarding mammogram screenings. However, given how broadly the recommendation change was disseminated (see Figure 1), the update may have also made targeted women less likely to engage with the healthcare system. We test these pathways in Table 4. Column 1 shows that, following the 2009 update, women younger than 50 years old were approximately 2 percentage points less likely to have had a healthcare visit during the prior year compared to their 50-54-year-old counterparts. To increase confidence that the estimated reduction in healthcare visits is not being driven by an underlying trend in engagement with the healthcare system, in Figure 10 we show that the change was unique to women. There was no change in healthcare utilization among similarly aged men (Panel A).[39] Moreover, we find that this reduction was driven by 40-44-year-old women (Panel B), suggesting that some women who would otherwise have visited a physician to receive their mammogram screenings chose to forgo visits to their healthcare providers altogether.

[39] Appendix Figure 22 shows that this result is robust to excluding 30-39-year-olds from the sample.

Returning to Table 4, column 2 indicates that these women were 2.4-3.7 percentage points less likely to report that they were recommended a mammogram screening during the past year, though the estimate is more pronounced when including 30-39-year-old women within the sample (Panel A). Indeed, in Figure 11 we find that 35-39-year-old women were 7.8 percentage points less likely to report that they had been recommended a mammogram during the prior year – a 25 percent reduction relative to the pre-period mean.[40] We also find smaller less-precisely estimated reductions for 40-49-year-old women. This pattern is consistent with the USPSTF guidelines being intended to shape primary care physicians' practicing behaviors (USPSTF 2022b) and may in part explain the large mammography spillovers we documented for younger women.

By changing the age at which women were recommended to begin mammogram screenings, the shock generated by the 2009 USPSTF recommendation may have affected women's perceptions of their care quality and their view of government health recommendations. On one hand, women near the threshold may have felt confused by the decision to raise the recommended starting age and, subsequently, lost faith in government health recommendations more broadly. On the other hand, it is possible that this change signaled to women that the recommendations were based on the best available clinical evidence. We test these possibilities in Table 5 using the 2003-2019 HINTS data.

Consistent with the NHIS estimates, column 1 shows that women younger than 50-years-old were 5 percentage points less likely to report ever having had a mammogram following the 2009 revision, regardless of whether we do (Panel A)

[40] Appendix Figure 23 shows that the pattern is unchanged if we limit the sample to women who reported having a recent doctor visit. Appendix Figure 24 plots the descriptive trends and estimated effects by single-year-of-age. The pattern is qualitatively similar, though the effects are less precisely estimated.

or do not (Panel B) include 35-39-year-old women in the sample.[41] In column 2, we find suggestive evidence that targeted women were less likely to report that they were always involved as much as they would like in their healthcare decision-making process, though the results are not statistically significant. Meanwhile, column 3 shows a statistically significant 7.8-8.9 percentage point (28-32 percent) increase in the likelihood that women younger than 50-years-old reported that there were so many cancer recommendations that it made it difficult to know which ones to follow. Column 4 does not reveal a significant change in the likelihood that women trusted information from their doctors, though column 5 offers some evidence that targeted women were less likely to trust information from a government health agency. Overall, Table 5 suggests that the updated guidelines may have increased younger women's confusion regarding cancer prevention.

4.5 Effects on Breast Cancer Incidence

With the prior evidence indicating that the 2009 USPSTF mammography recommendations were successful in reducing mammography screening among women younger than 50 years old, we now test whether this recommendation affected subsequent breast cancer diagnoses. For these analyses, we use SEER data collapsed to the 5-year age group-registry-race-year level, such that each observation contains the count of cases diagnosed in a given year and registry area for a 5-year age-by-race (white/non-white) group.

Our results are presented in Figure 12. The triangles plot the estimates from a regression where the dependent variable is the natural log of the number of in situ precancerous cases; the circles plot the estimates where the dependent variable is the natural log of the number of malignant cases. Consistent with our prior results

[41] Women under the age of 35 were not asked mammogram-related questions in the HINTS. Due to the limited number of observations, we report estimates for whether women reported ever having received a mammogram as a coarse measure of mammography.

showing the largest reductions in mammogram recommendations and mammography occurred for women aged 35-39, Figure 12 shows an approximately 16 percent reduction in the number of in situ precancerous cases diagnosed in 35-39-year-old women.[42]

For context, we compare our findings to those of Einav et al. (2020), which used a structural model to estimate the effect of moving the recommended age to begin mammogram screenings from 40 to 45 years old. Their findings suggest that this policy would result in a 20 percent decline in the number of mammograms and a 6 percent reduction in diagnoses of in situ tumors for women aged 40-44, with no changes in invasive cancer diagnoses. Notably, their model explicitly assumed that raising the recommended age would reduce mammography only among targeted women (i.e., those ages 40-44) and, as a result, it was this age group that was estimated to experience the reduction in diagnoses of in situ precancer tumors. While our findings show that raising the recommended age to begin mammogram screenings from 40 to 50 years old had the largest impact on screenings among 35-39-year-olds (as opposed to the targeted age group), it is the case that, conditional on a change in screenings, the relative change in breast cancer diagnoses that we estimate is strikingly similar to the estimate in Einav et al. (2020). For 35-39-year-old women, we find an approximately 60 percent reduction in mammography (Figure 4) and a 16 percent reduction in diagnoses of in situ tumors. As with Einav et al. (2020), we find no significant change in diagnoses of later stage invasive breast cancers.

We conduct several supplemental analyses to further characterize the impact of the 2009 recommendation change on breast cancer outcomes.[43] Analyses

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[42] Appendix Figure 25 plots the event study estimates for in situ and malignant breast cancer diagnoses for each age group (30-34, 35-39, 40-44, and 45-49) relative to those aged 50-54.

[43] Appendix Table 16 reports the estimates, standard errors, and wild bootstrapped p-values for every evaluated outcome (ln(in situ cases+1), ln(malignant cases+1), 5-year mortality rate, share

examining tumor size suggest that tumors were somewhat larger at diagnosis: Appendix Figure 26 shows a reduction in the share of diagnosed breast cancers that were less than 2 centimeters, consistent with the idea that reduced screenings delay diagnoses. In Appendix Figure 27 we present results for analyses examining the impact on mortality within 5 years of diagnosis. Across all age groups we find no statistically significant changes in the 5-year mortality rate.[44] Overall, these results suggest that the 2009 USPSTF recommendations reduced the overdiagnosis of in situ precancers which would likely have otherwise remained harmless (Welch et al. 2016; Einav et al. 2020; Ryser et al. 2022) and are consistent with the USPSTF's review of clinical evidence which failed to find a statistically significant reduction in breast cancer mortality in younger women attributable to mammography (USPSTF 2009).

5. Conclusion

While mammogram screenings are generally viewed as effective tools for detecting breast cancer in its early stages – thereby increasing the chance of survival – there is considerable controversy surrounding the appropriate age at which to begin these screenings. As a result, the United States Preventive Services Task Force has altered their mammography guidelines multiples times over the last several decades, first recommending that women aged 40-49 receive mammogram screenings in 2002, dropping that recommendation in 2009, and reinstating it in 2024.

In this paper, we provide evidence that the 2009 USPSTF recommendation significantly reduced the number of screening mammograms among targeted

<2cm, share 2-5 cm, share 5+cm). Appendix Table 17 then shows the robustness of our main in situ estimate to alternative samples and specifications.

[44] These results are robust to alternatively omitting 30-34-year-old women, as opposed to 50-54-year-old women (available upon request), given the possibility that fewer diagnoses at ages 40-49 might generate more diagnoses and higher mortality at older ages.

women aged 40-49 by 6-10 percent. More strikingly, our results also show that the recommendation change had substantial spillovers onto younger women aged 35-39, who had approximately 60 percent fewer screening mammograms after the revision. Importantly, we document reductions in mammography using two sources of administrative data and several survey datasets.

We also provide evidence of the mechanisms underlying these effects. Our results show that, following the recommendation change, physicians were 2.4 percentage points less likely to recommend mammography to the targeted women, with even larger reductions for younger women who were never recommended to receive a mammogram by USPSTF. Women aged 40-44 also responded to the guideline revision by modestly decreasing healthcare visits. These results suggest that the USPSTF revision resulted in changes in both physician and patient behavior.

Interestingly, we further document an increase in the likelihood that younger women reported feeling that there are "so many recommendations about preventing cancer," that it is hard to know what to follow. We hypothesize that this confusion was driven both by the numerous revisions to the USPSTF cancer screening guidelines, as well as the fact that the 2009 revision created inconsistencies in the recommendations across major medical organizations. This result is particularly timely, given that USPSTF once again lowered the recommended mammography starting age to 40 years old (USPSTF 2024) while the American Cancer Society currently recommends screenings begin at age 45.[45]

Finally, using data from National Cancer Institute's Surveillance, Epidemiology, and End Results Program 2002-2019, we find a 16 percent reduction in the number of in situ precancerous diagnoses among women aged 35-39, without

[45] The American Cancer Society does state that women aged 40-44 should have the option to start screenings. See https://www.cancer.org/cancer/types/breast-cancer/screening-tests-and-early-detection/american-cancer-society-recommendations-for-the-early-detection-of-breast-cancer.

any detected change in malignant cancer diagnoses. These findings are consistent with the arguments made by some cancer experts that in situ precancerous growths are over-diagnosed and over-treated (Marmot et al. 2012; Francis et al. 2015; Worni et al. 2015; Benson et al. 2016; Co 2020) and that increasing the recommended age to begin mammography would help reduce the unnecessary diagnosis of these cancers (Elmore et al. 1998; Armstrong et al. 2007; Hubbard et al. 2011; Einav et al. 2020; Welch et al. 2016; Ryser et al. 2022).

The prior public health literature had drawn mixed conclusions on the effect of the 2009 USPSTF guideline revision on mammography among younger women (Howard and Adams 2012; Block et al. 2013; Pace et al. 2013; Sprague et al. 2014; Wang et al. 2014; Dehkordy et al. 2015; Jiang et al. 2015; Nelson et al. 2015; Wharam et al. 2015; Fedewa et al. 2016; Gray and Picone 2016; Wernli et al. 2017; Brown et al. 2018). However, nearly all the prior papers did not use a control group in their empirical analyses and were therefore unable to disentangle the age-specific policy impacts from the effects of common shocks affecting mammography rates for women of all ages. We overcome this limitation of the prior literature by estimating difference-in-differences models comparing changes in mammography among women aged 40-49 to the concurrent changes occurring among women aged 50-54. Importantly, we find robust declines in mammography among relatively younger women in a range of administrative and survey data sources.

These results can help inform what to expect as a result of the April 2024 update to the USPSTF recommendations, which once again recommends that women begin biennial mammography screenings at age 40. If we assume a symmetric response to the recommendation changes, our findings show that this revision will increase mammography among younger women. Although a key motivation for the 2024 revision was the potential for benefits from increased screening of 40-49-year-old Black women (due to their higher breast cancer mortality burden), our heterogeneity results suggest that the 2024 recommendation change will primarily increase screenings among non-Hispanic white women.

We are more cautious, however, in drawing conclusions about the likely impacts of this screening change on the overall rate of breast cancer diagnoses. Notably, in the past decade, there has been an uptick in the incidence of malignant breast cancer among women under the age of 50 (ACS 2024), and this increase is largely attributed to increased bodyweight and changes in childbearing (ACS 2024; BSCS 2025b). Moreover, there has been a shift in screening technology from digital mammograms to digital breast tomosynthesis (known as DBT or 3-D mammography). While DBT is associated with increased cancer detection relative to digital mammography (Rafferty et al. 2016; Conant et al. 2019; Ho et al. 2022), it also has a slightly higher rate of overdiagnosis than digital mammography (Hendrick and Monticciolo 2024).

Our results show that the 2009 recommendation change only reduced diagnoses of non-invasive in situ breast cancers, and only among women aged 35-39. This result is consistent with the fact that in situ breast cancer is "almost exclusively diagnosed during screening" (ACS 2024) and, therefore, should be more responsive to changes in screening practices than diagnoses of invasive breast cancer. This result, and the fact that the new screening technology (DBT) has slightly higher rates of overdiagnosis relative to the predominant technology in 2009 (digital mammograms), suggests that diagnoses of in situ precancers will likely increase among women aged 35-39 due to the 2024 recommendation change. However, since DBT is relatively more effective at identifying malignant cancers, we may also expect a resulting increase in these diagnoses among younger women. We believe that this remains an important area for future research.

This study is subject to some limitations. For one, although we use multiple sources of administrative data (NMD and Maryland HCUP data), neither is nationally representative. Yet we show that the reduction in mammograms among relatively younger women also occurs in nationally representative survey data, providing confidence that our results are not due to sample selection. Additionally, while we found a reduction in in situ precancer diagnoses among the targeted women, the relative recency of the policy change prohibits us from examining longer run outcomes, such as long-run mortality, that are important considerations for drawing conclusions about how the updated guidelines will affect welfare. Despite these limitations, our study highlights the important and previously overlooked relationship between the 2009 USPSTF recommendations and a broad set of mammography-related outcomes.

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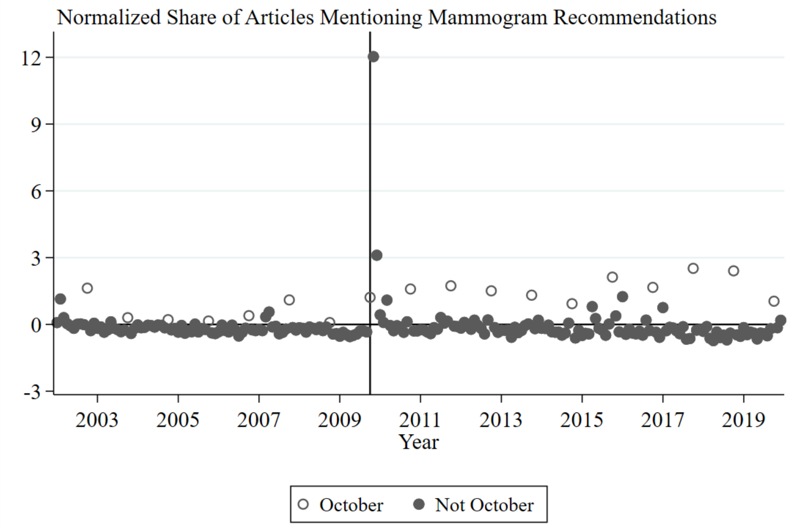
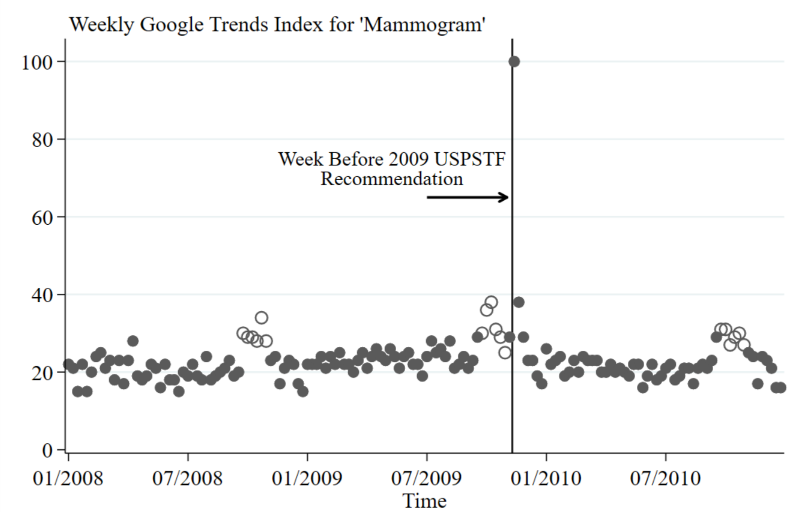
Figure 1: Trends in Media Coverage and Internet Search Activity



(A)

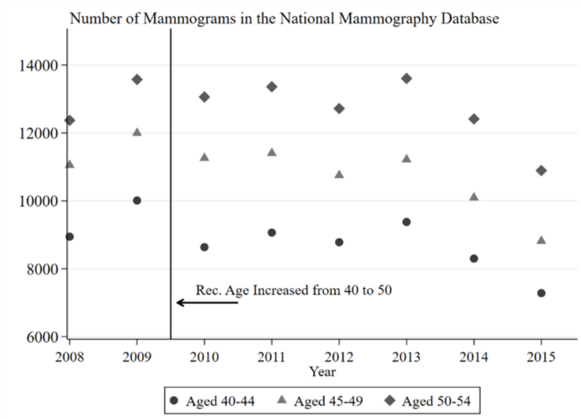


(B)

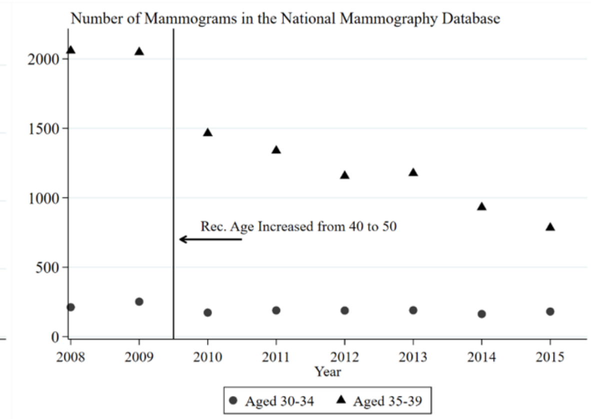
Source: ProQuest U.S. Newsstream 2002-2019; Google Trends 2008-2010

Note: Panel A plots the share of articles mentioning 'mammogram recommendation' or 'mammogram guideline.' For ease of interpretation, the share has been normalized to be mean 0 with a standard deviation of 1. The grey circles plot the value for every month and the open circles for the months of October (National Breast Cancer Awareness Month). Panel B plots the weekly Google Trends Index for the term 'mammogram' from January 1st, 2008, through December 31st, 2010. The grey circles plot the value for every non-October week and the open circles plot the values during the month of October. To construct the index, Google takes a random sample of all searches. From this sample, Google divides the number of searches for the word 'mammogram' by the total number of searches. The week when this value is maximized is set equal to 100, and the remaining values are determined by taking the ratio of the weekly search ratio to the maximum search ratio. The index does not contain information on the age of the individuals performing the searches.

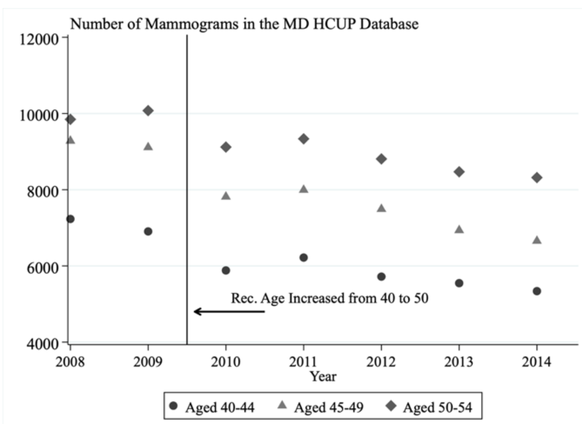
Figure 2: Age-Specific Screening Mammogram Counts in the Administrative Data



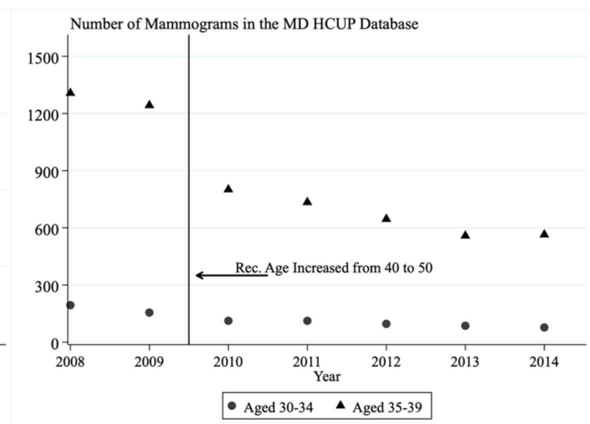
(A) NMD, Ages 40- 54



(B) NMD, Ages 30-39



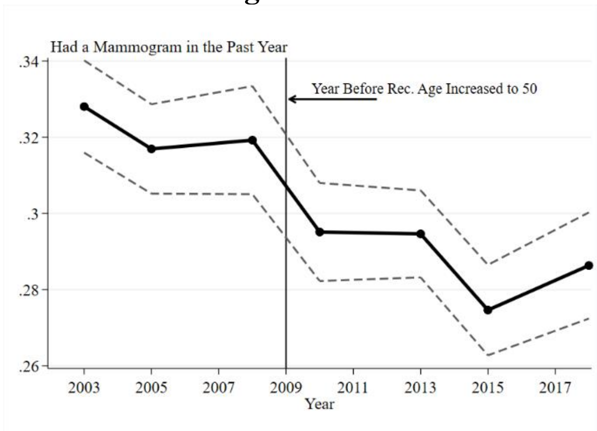
(C) MD HCUP, Ages 40- 54



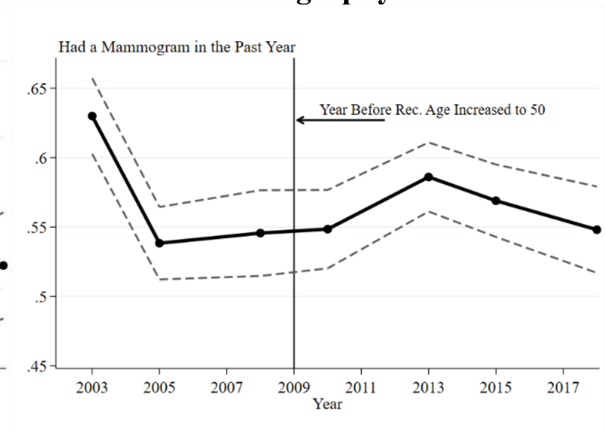
(D) MD HCUP, Ages 30-39

Sources: National Mammography Database 2008-2015, Maryland HCUP State Ambulatory Surgery and Services Databases, 2008-2014
Notes: Panels A and C plot the number of mammograms for women aged 40-44 (circles), women aged 45-49 (triangles), and women aged 50-54 (diamonds), for the NMD and Maryland HCUP data, respectively. Panels B and D plot the number of mammograms for women aged 30-34 (circles) and women aged 35-39 (triangles), for the NMD and Maryland HCUP data, respectively.

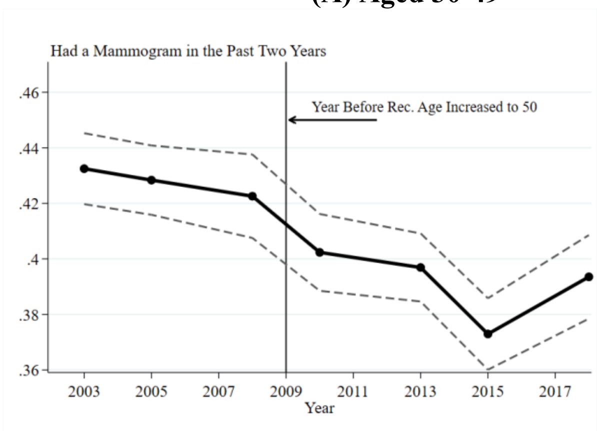
Figure 3: Trends in Measures of Recent Mammography



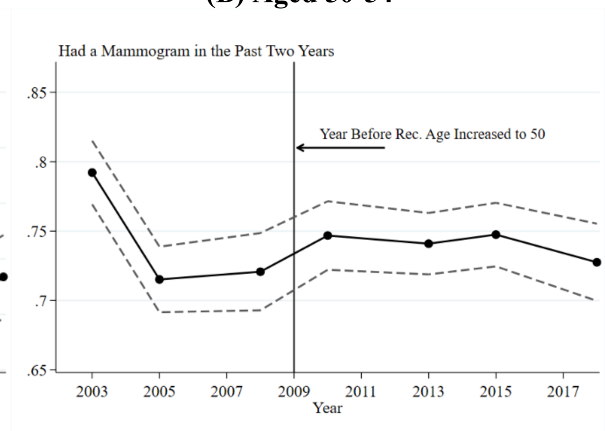
(A) Aged 30-49



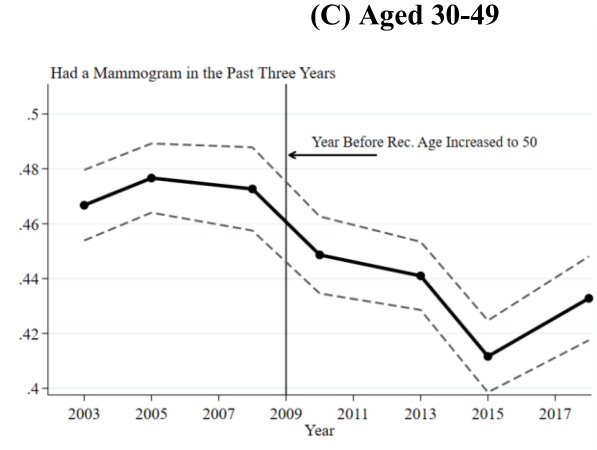
(B) Aged 50-54



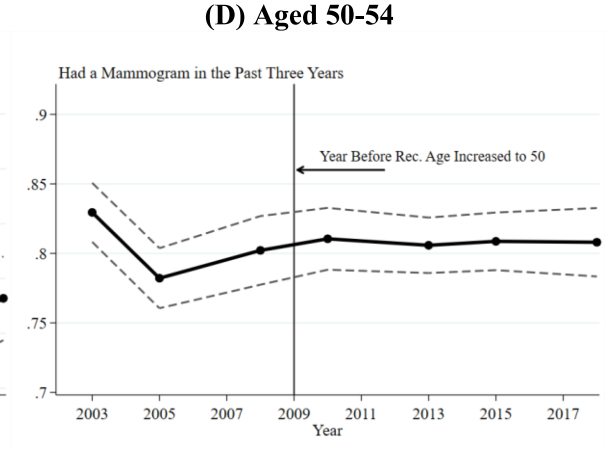
(C) Aged 30-49



(D) Aged 50-54



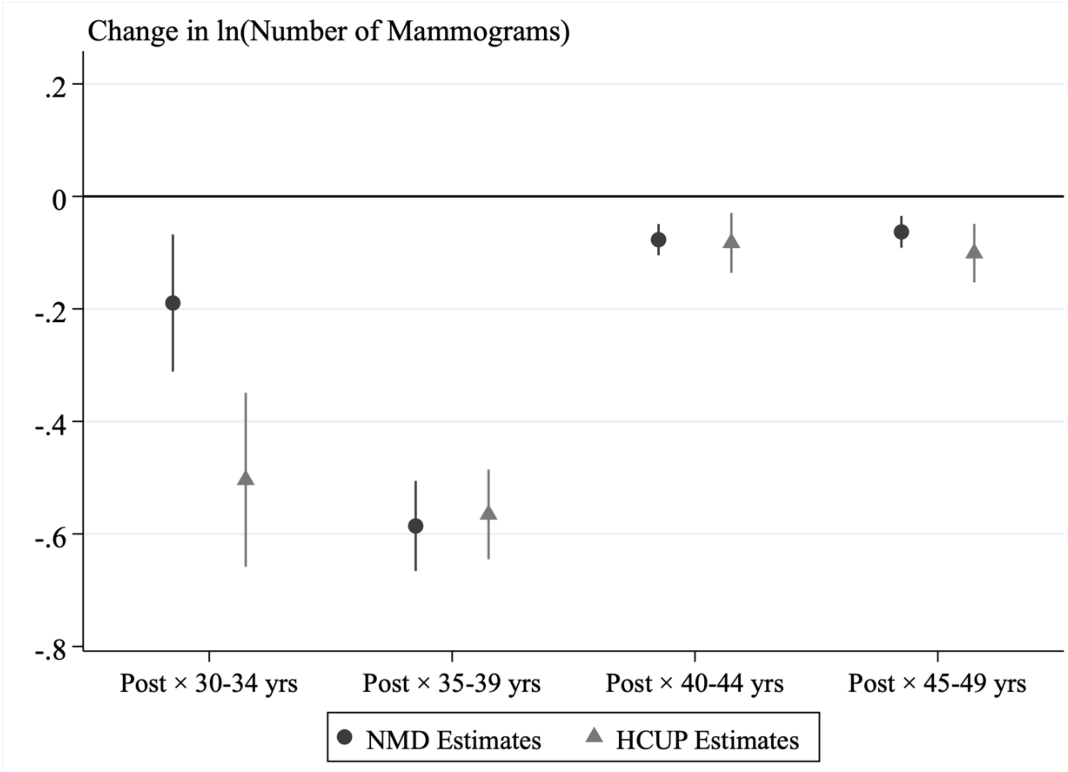
(E) Aged 30-49



(F) Aged 50-54

Source: National Health Interview Survey 2003-2018
Note: Panels A and B plot the share of women reporting that they had a mammogram during the past year, Panels C and D during the past two years, and Panels E and F during the past three years. Panels A, C, and E examine women aged 30-49, while Panels B, D, and F examine women aged 50-54. The solid line denotes the sample mean, while the dashed lines represent the corresponding 95 percent confidence intervals. The estimates use the sample weights.

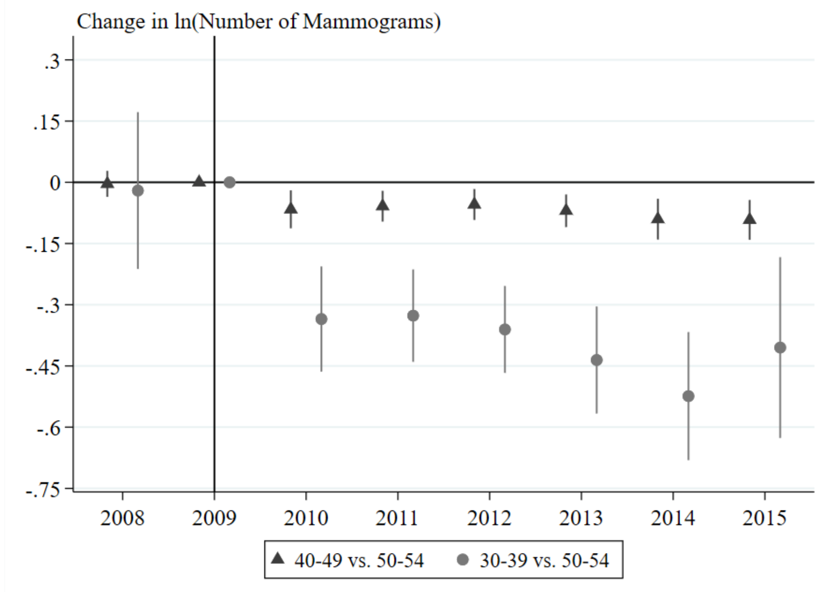
Figure 4: Age-Specific Effects on Mammography Using Administrative Data



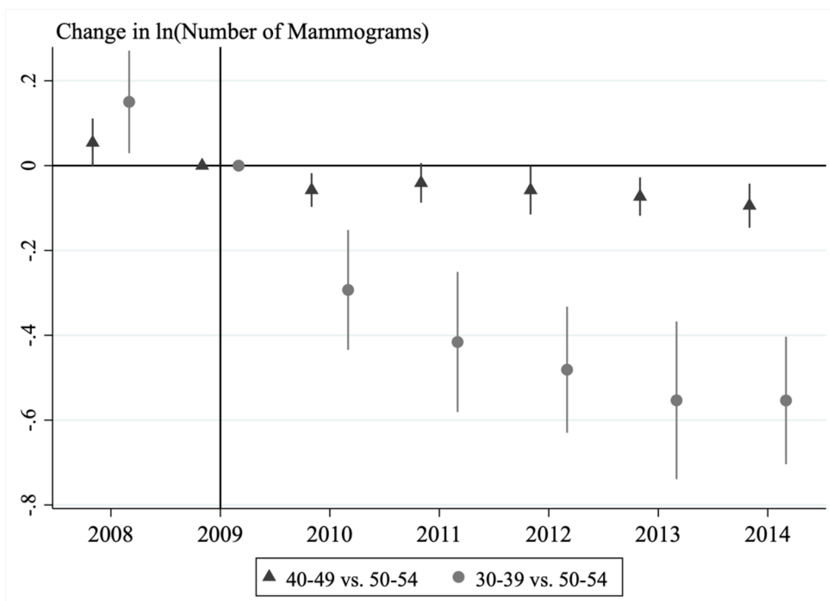
Sources: National Mammography Database 2008-2015, Maryland HCUP State Ambulatory Surgery and Services Databases 2008-2014

Note: The dependent variable is the natural log of the number of mammograms performed each year. The independent variables of interest are indicators for the five-year age groups interacted with an indicator for the post-recommendation period, with ages 50-54 as the omitted (control) group. The regression controls for age fixed effects and year fixed effects. The vertical bars denote 95 percent confidence intervals using heteroskedastic robust standard errors.

Figure 5: Event Study Estimates Using Administrative Data



(A) National Mammography Database

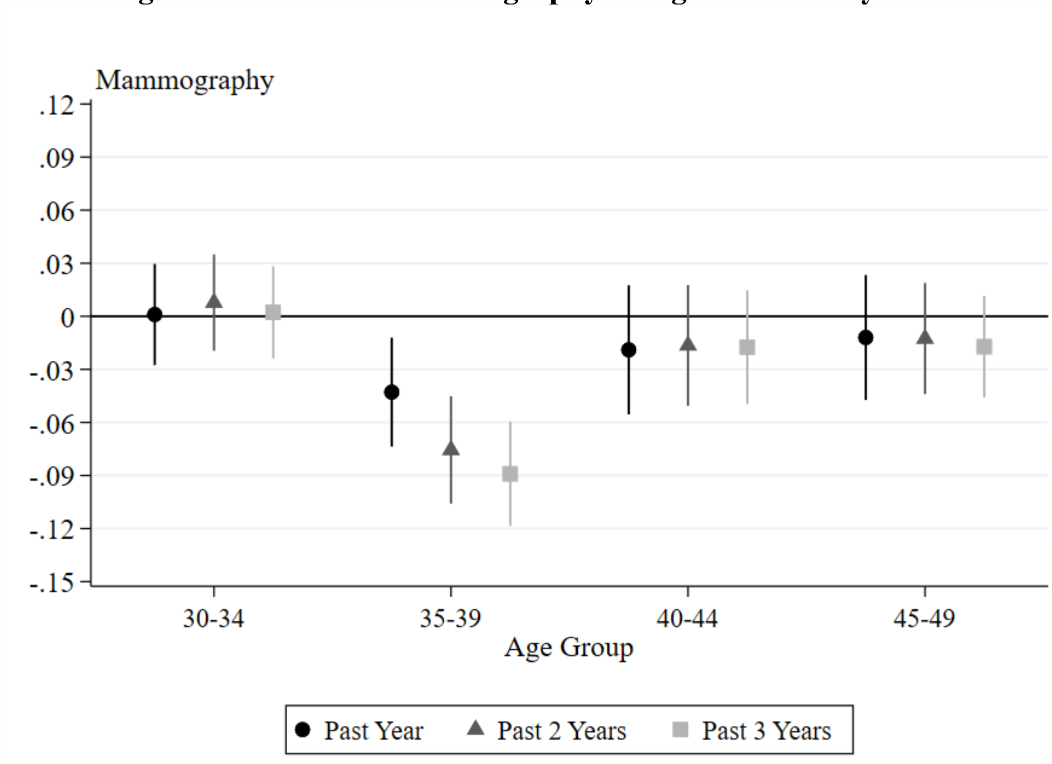


(B) Maryland HCUP Data

Sources: National Mammography Database 2008-2015, Maryland HCUP State Ambulatory Surgery and Services Databases 2008-2014

Note: The dependent variable is the natural log of the number of mammograms performed each year. The triangles denote the percent change in mammograms performed for women aged 40-49 compared to women aged 50-54 after controlling for age and year fixed effects. Meanwhile, the circles denote the percent change in mammograms performed for women aged 30-39 compared to women aged 50-54. The vertical bars denote 95 percent confidence intervals using heteroskedastic robust standard errors.

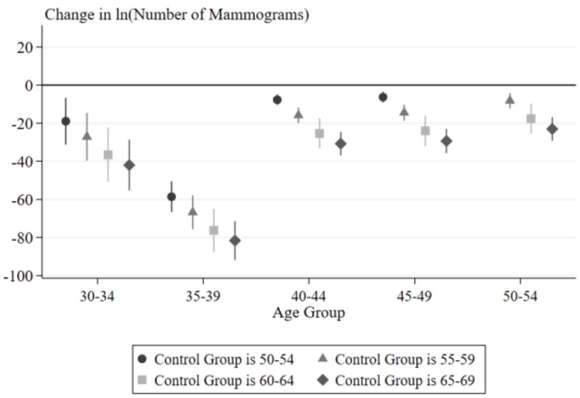
Figure 6: Effects on Mammography Using NHIS Survey Data



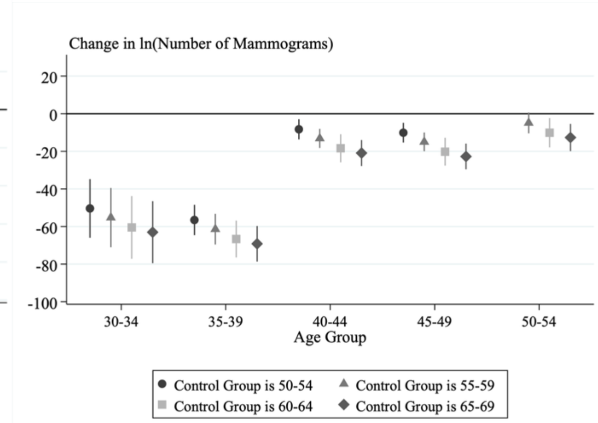
Source: National Health Interview Survey 2003-2018

Note: The markers plot the point estimates, and the lines represent the corresponding 95 percent confidence intervals using heteroskedastic robust standard errors. The black circles denote the results from a regression where the dependent variable is an indicator for having had a mammogram during the prior year, the grey triangles during the prior two years, and the light grey squares during the prior three years. The sample includes adults aged 30-54. The independent variables of interest are indicators for the five-year age groups interacted with an indicator for the post-recommendation period, with ages 50-54 as the omitted (control) group. The estimates use the sample weights.

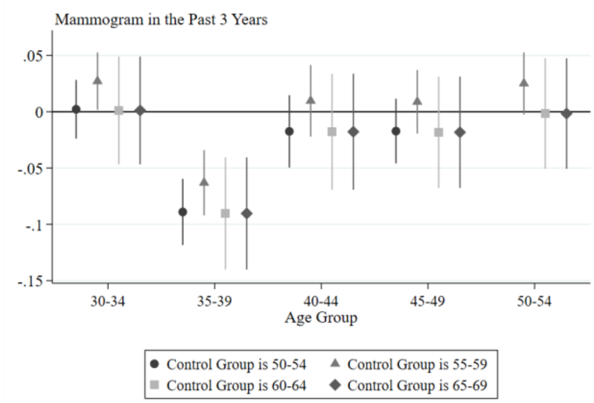
Figure 7: Robustness of Results to Alternative Control Groups



(A) NMD



(B) MD HCUP

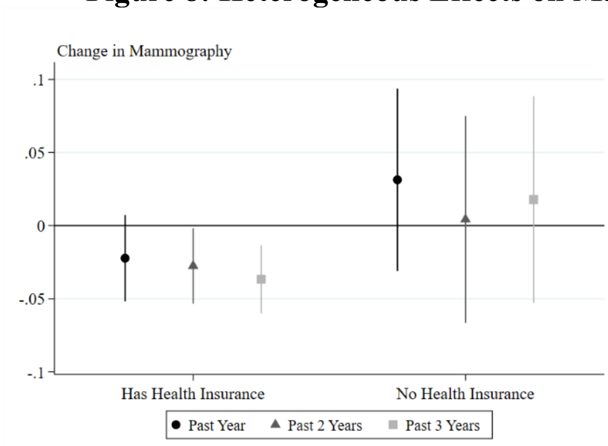


(C) NHIS

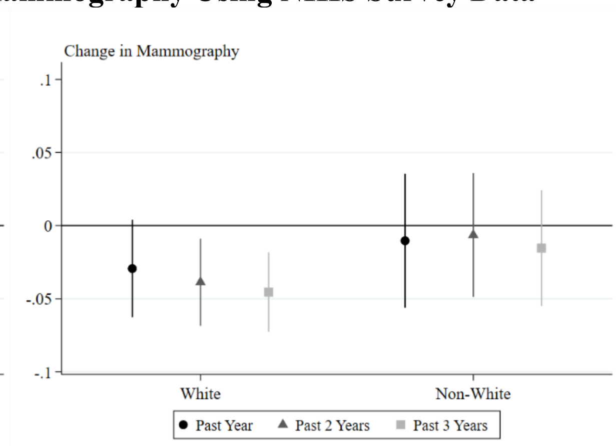
Sources: National Mammography Database 2008-2015, Maryland HCUP State Ambulatory Surgery and Services Databases 2008-2014, National Health Interview Survey 2003-2018

Note: The dependent variable in Panels A and B is the natural log of the number of mammograms for women of each age. The dependent variable in Panel C is an indicator for whether the respondent reported receiving a mammogram during the past three years. The circles denote estimates where the control group is women aged 50-54, the triangles denote estimates where the control group is women aged 55-59, the triangles denote estimates where the control group is women aged 60-65, and the triangles denote estimates where the control group is women aged 65-69. Panel C uses the sample weights.

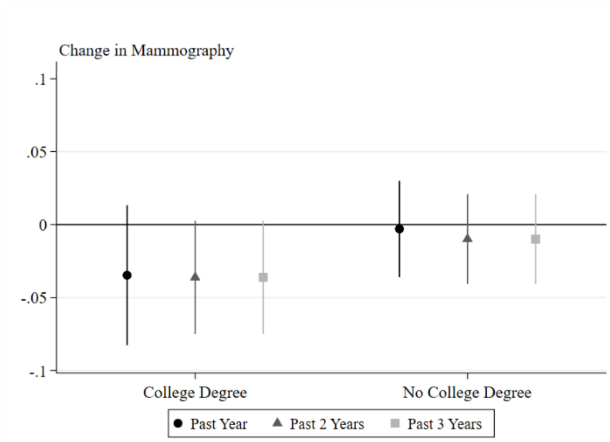
Figure 8: Heterogeneous Effects on Mammography Using NHIS Survey Data



(A) By Health Insurance Status



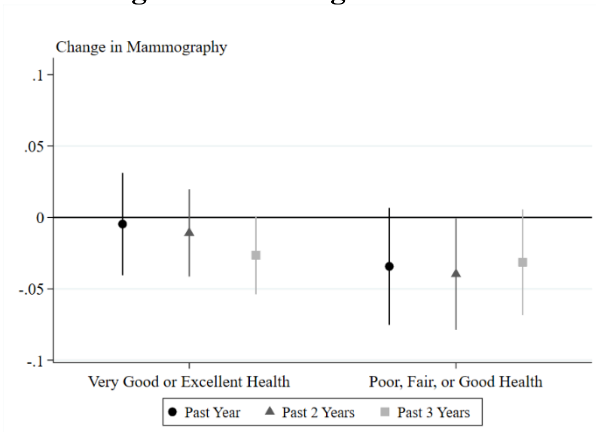
(B) By Race/Ethnicity



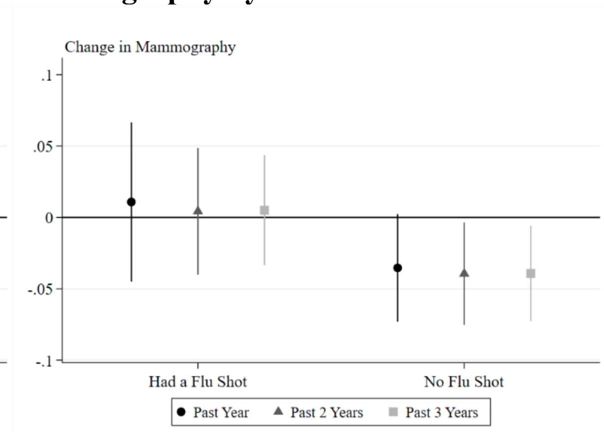
(C) By Educational Attainment

Source: National Health Interview Survey 2003-2018
Note: The markers plot the point estimates, and the lines represent the corresponding 95 percent confidence intervals using heteroskedastic robust standard errors. The black circles denote the results from a regression where the dependent variable is an indicator for having had a mammogram during the prior year, the grey triangles during the prior two years, and the light grey squares during the prior three years. The sample includes women aged 30-54; women aged 50-54 are the omitted (control) group. Each panel presents results from regressions where the sample is stratified by the characteristic shown on the horizontal axis. Panel A considers women who reported having health insurance compared to those who reported being uninsured. Panel B considers white women compared to non-Hispanic Black, Hispanic, and all other race/ethnicity women. Panel C considers women with a college degree compared to those without a college degree. The estimates use the sample weights.

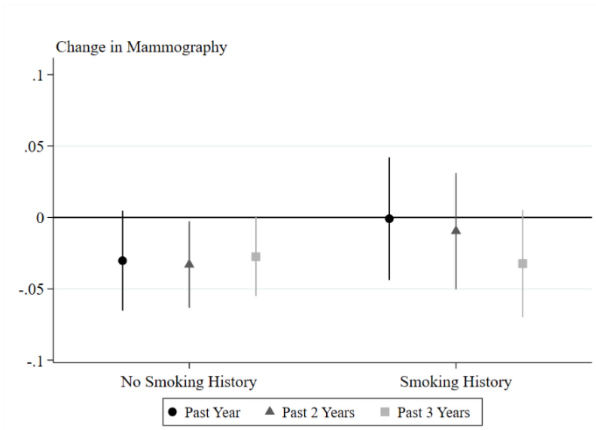
Figure 9: Heterogeneous Effects on Mammography by Health Behaviors



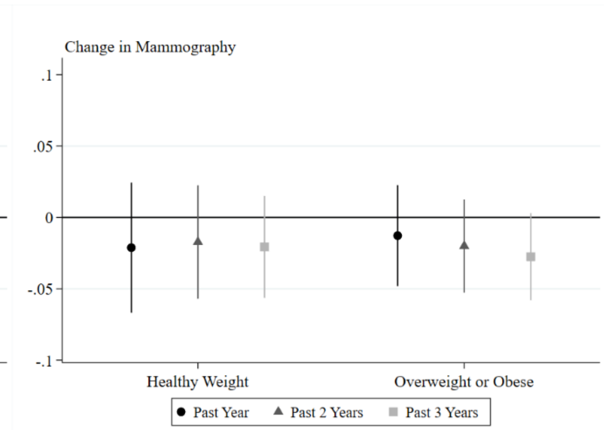
(A)



(B)



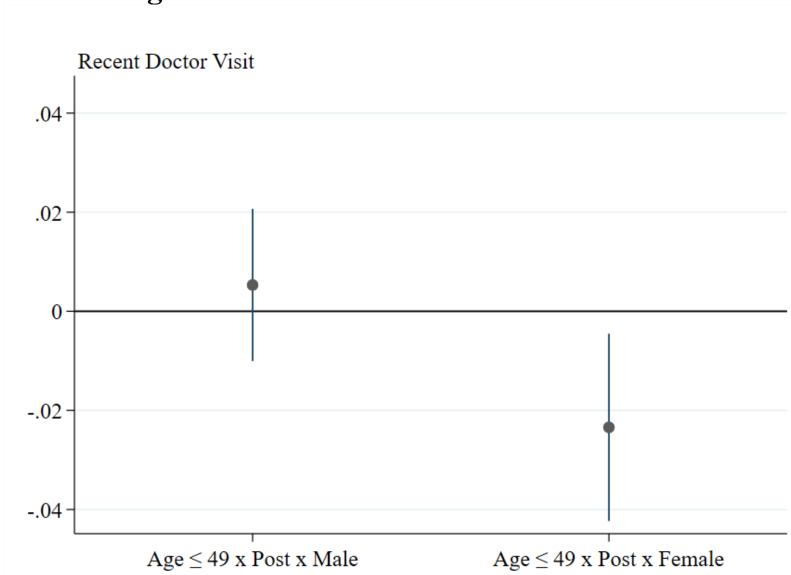
(C)



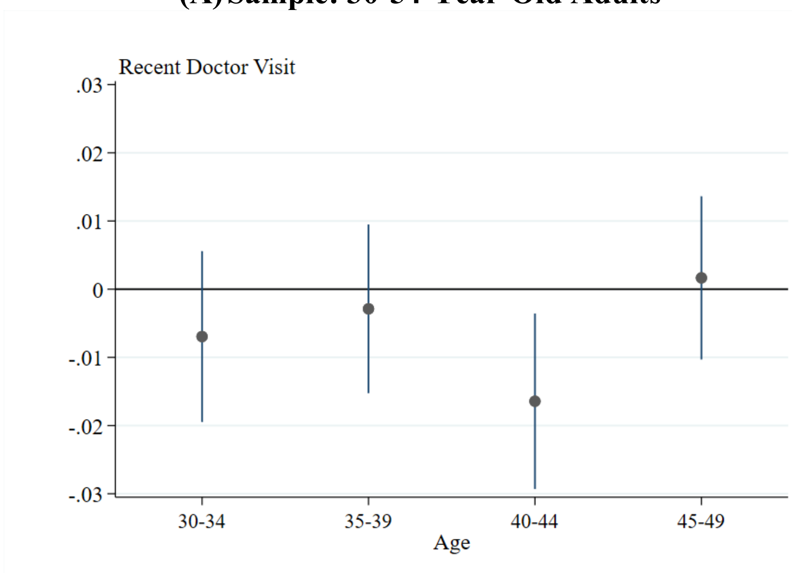
(D)

Source: National Health Interview Survey 2003-2018
Note: The markers plot the point estimates, and the lines represent the corresponding 95 percent confidence intervals using heteroskedastic robust standard errors. The black circles denote the results from a regression where the dependent variable is an indicator for having had a mammogram during the prior year, the grey triangles during the prior two years, and the light grey squares during the prior three years. The sample includes women aged 30-54. The independent variables of interest are indicators for the five-year age groups interacted with an indicator for the post-recommendation period, with ages 50-54 as the omitted (control) group. Each panel presents results from regressions where the sample is stratified by the characteristic shown on the horizontal axis. Panel A considers women who reported being in Excellent or Very Good Health compared to those who reported being in Good, Fair, or Poor Health. Panel B considers women who reported receiving a flu shot during the past 12 months compared to those who reported not receiving a flu shot. Panel C considers women who reported smoking 100 cigarettes during their lives to women who reported not having smoked 100 cigarettes during their lives. Finally, Panel D considers women who are classified as overweight or obese compared to those who are classified as healthy weight. The estimates use the sample weights.

Figure 10: Effects on Recent Doctor Visits



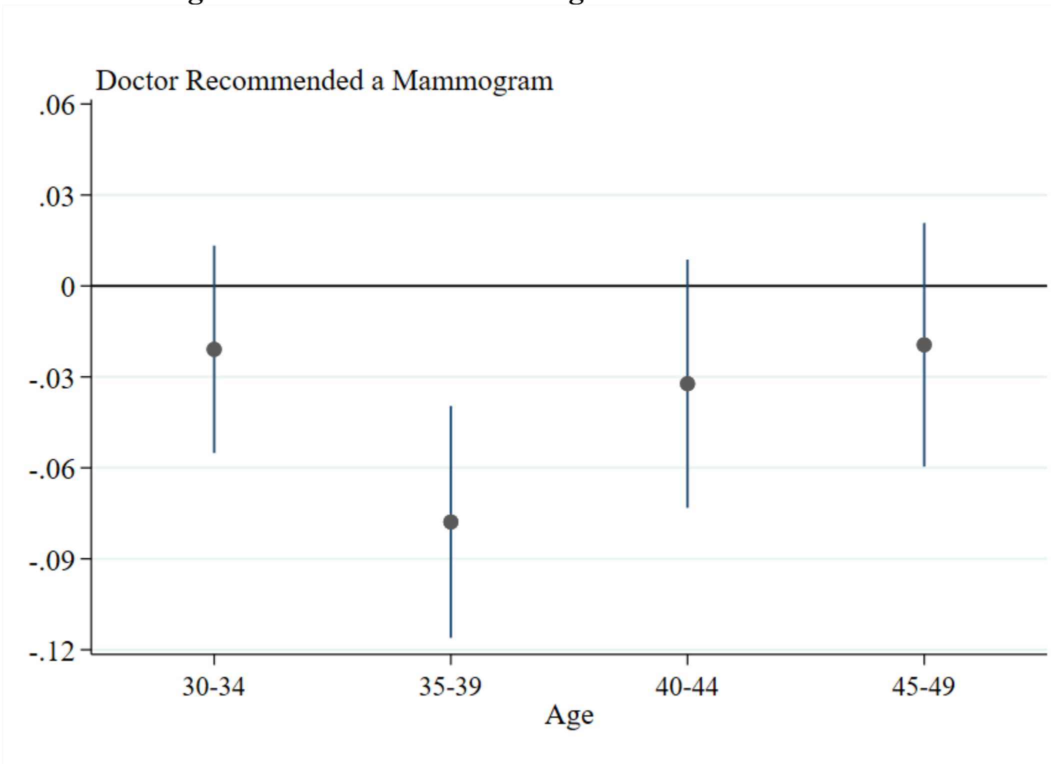
(A) Sample: 30-54-Year-Old Adults



(B) Sample: 30-54-Year-Old Women

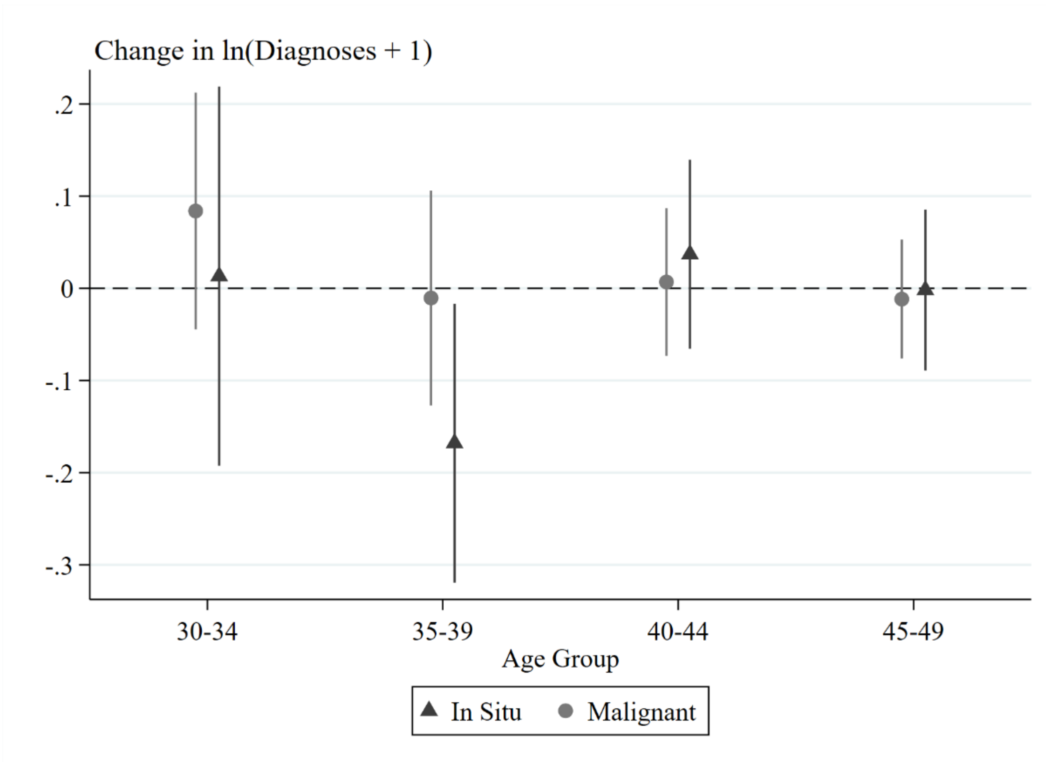
Source: National Health Interview Survey 2003-2018
Note: The grey circles plot the point estimates and the lines the corresponding 95 percent confidence intervals obtained from a modified version of equation (2). In Panel A the sample is 30-54-year-old adults, including both men and women. All the right-hand side covariates are then interacted with an indicator for being female to separately estimate the effect of the 2009 USPSTF recommendation on recent care visits for 30-49-year-old men and 30-49-year-old women. In Panel B the sample is 30-54-year-old women. In this specification, the independent variables of interest are indicators for the five-year age groups interacted with an indicator for the post-recommendation period, with ages 50-54 as the omitted (control) group. The estimates utilize the sample weights.

Figure 11: Effects on Mammogram Recommendations



Source: National Health Interview Survey 2003-2018
Note: The grey circles plot the point estimates and the lines the corresponding 95 percent confidence intervals obtained from estimating equation (2). The independent variables of interest are indicators for the five-year age groups interacted with an indicator for the post-recommendation period, with ages 50-54 as the omitted (control) group. More granular age-specific estimates are presented in Appendix Figure 25. The estimates utilize the sample weights.

Figure 12: Effects on Breast Cancer Diagnoses



Source: National Cancer Institute's Surveillance, Epidemiology, and End Results Program 2002-2019
Note: The triangles and circles plot the point estimates and the lines the corresponding 95 percent confidence intervals obtained from a modified version of equation (1), for the outcome variables ln(in situ cases +1) and ln(malignant cases +1), respectively. The independent variables of interest are indicators for the five-year age groups interacted with an indicator for the post-recommendation period, with ages 50-54 as the omitted (control) group. Each regression includes state-by-diagnosis year, five-year age group, and race fixed effects, as well as time-varying controls (see text for details). Regressions are weighted by population, and heteroskedastic robust standard errors are reported.

Table 1: USPSTF Recommendations Over Time

Age →	40-49	50-69	70-74	75 +
1996				
Rating	C	A	C	
Frequency		Every 1-2 Years		
2002				
Rating	B	B	B	B
Frequency	Every 1-2 Years	Every 1-2 Years	Every 1-2 Years	Every 1-2 Years
2009				
Rating	C	B	B	I
Frequency		Biennial Screening	Biennial Screening	
2016				
Rating	C	B	B	I
Frequency		Biennial Screening	Biennial Screening	
2024				
Rating	B	B	B	I
Frequency	Biennial Screening	Biennial Screening	Biennial Screening	

Source: USPSTF Recommendations in 1996, 2002, 2009, 2016, and 2024
Note: Grade A indicates 'strongly recommend,' grade B indicates 'recommend,' grade C indicates 'no recommendation,' grade D indicates 'not recommended,' and grade I indicates 'insufficient evidence to make a recommendation.' The 1996 USPSTF guidelines did not explicitly mention a recommendation for women aged 75 or older. The 2009 guidelines gave a C rating to routine screening for all women under the age of 50. The 2009 and 2016 recommendations did not explicitly mention women under the age of 40.

Table 2: Facility and Patient Characteristics in the NMD Data

	(1)	(2)
	Exam Count	Share of Total
Facility Type		
Academic	83,182	0.136
Community Hospital	258,529	0.423
Freestanding Center	247,928	0.405
Multi-Specialty Clinic	21,780	0.036
Location		
Metropolitan (> 100K)	83,182	0.136
Suburban/Small (50K-100K)	431,214	0.705
Rural (<50K)	97,023	0.159
Region		
Midwest	256,590	0.420
South	182,558	0.299
West	172,271	0.282
Trauma Center Levels		
Level I	106,347	0.174
Level II	183,286	0.300
N/A	321,786	0.526
Volume		
< 5K	123,980	0.203
5K-10K	201,759	0.330
10K-30K	285,680	0.467
Patient Race		
Asian	3,588	0.006
Black	34,077	0.056
Other	890	0.001
White	324,653	0.531
Missing/Not Reported	248,211	0.406
Patient Ethnicity		
Hispanic	11,385	0.019
Non-Hispanic	421,432	0.689
Missing/Not Reported	178,602	0.292

Source: National Mammography Database 2008-2015
Note: The table reports facility and patient characteristics in the NMD data for the set of 10 facilities continuously reporting between Q1 2008 and Q4 2015.

Table 3: Heterogeneity by Age at Time of the Recommendation

	(1)	(2)	(3)
Outcome →	Mammogram in the Past Year	Mammogram in the Past 2 Years	Mammogram in the Past 3 Years
Panel A: Women Aged 40-49 Who Turned 40 After the Rec. Change			
$\mathbf{1}\{40 \leq \text{Age} \leq 49\} \times \mathbf{1}\{\text{2009 USPSTF}\}$	-0.022	-0.020	-0.029*
	(0.018)	(0.017)	(0.016)
	[0.232]	[0.222]	[0.084]
R^2	0.104	0.137	0.149
Treated Mean in 2008	0.491	0.630	0.691
Observations	21,288	21,288	21,288
Panel B: Women Aged 40-49 Who Turned 40 Before the Rec. Change			
$\mathbf{1}\{40 \leq \text{Age} \leq 49\} \times \mathbf{1}\{\text{2009 USPSTF}\}$	-0.012	-0.007	-0.003
	(0.017)	(0.015)	(0.014)
	[0.462]	[0.689]	[0.830]
R^2	0.100	0.128	0.133
Treated Mean in 2008	0.491	0.630	0.691
Observations	21,607	21,607	21,607

Source: National Health Interview Survey 2003-2018

Note: The dependent variable in column 1 is an indicator for whether the women reported receiving a mammogram during the past year, in column 2 for whether she reported receiving a mammogram during the past two years, and in column 3 for whether she reported receiving a mammogram during the past three years. The sample is women aged 40-54. Panel A limits the sample to women aged 40-49 who turned 40 after the recommendation and to the 50-54-year-old comparison women. Panel B limits the sample to women aged 40-49 who turned 40 prior to the 2009 recommendation change and to the 50-54-year-old comparison women. Because all women in Panel A turned 40 after the recommendation change, we report the sample mean for those who were aged 40-49 during the 2008 survey wave. Heteroskedastic robust standard errors are shown in parentheses. Wild bootstrapped p-values from clustering standard errors at the five-year age group-calendar year level are shown in brackets. The estimates utilize the sample weights.

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$

Table 4: Potential Mechanisms

	(1)	(2)
Outcome →	Healthcare Visit in Past Year	Doctor Recommended Mammogram in Past Year
Panel A: Sample Includes 30-54-Year-Old Women		
1{Age ≤ 49}×	-0.018***	-0.037**
1{2009 USPSTF Rec.}	(0.006)	(0.016)
	[0.002]	[0.021]
R^2	0.100	0.238
Treated Mean in 2008	0.869	0.454
Observations	118,130	33,089
Panel B: Sample Includes 40-54-Year-Old Women		
1{40 ≤ Age ≤ 49}×	-0.020***	-0.024
1{2009 USPSTF Rec.}	(0.006)	(0.018)
	[0.002]	[0.150]
R^2	0.103	0.089
Treated Mean in 2008	0.880	0.652
Observations	69,323	19,495

Source: National Health Interview Survey 2003-2018

Note: The dependent variable in column 1 is an indicator for whether the respondent had a recent care visit and in column 2 for whether a physician recommended a mammogram during the prior year. The sample in Panel A is women aged 30-54, while the sample in Panel B is women aged 40-54. Women aged 50-54 serve as the omitted (control) group. The estimates include the full set of controls from equation (2). Heteroskedastic robust standard errors are shown in parentheses. Wild bootstrapped p-values from clustering standard errors at the five-year age group-calendar year level are shown in brackets. The estimates utilize the sample weights.

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$

Table 5: Trust, Complexity, and Involvement with the Healthcare Process

	(1)	(2)	(3)	(4)	(5)
Outcome →	Ever Had Mammogram	Doctor always involved you in care decisions as much as you wanted	Hard to know which recommendations to follow for preventing cancer	Highly trust health information from a doctor	Highly trust health information from government health agency
Panel A: Sample Includes 35-54-Year-Old Women					
1{Age ≤ 49}× **1**{2009 USPSTF Rec.}	-0.051**	-0.031	0.089**	0.019	-0.066
	(0.022)	(0.042)	(0.036)	(0.041)	(0.056)
	[0.360]	[0.446]	[0.351]	[0.907]	[0.004]
R^2	0.303	0.040	0.043	0.031	0.059
Mean	0.759	0.555	0.281	0.687	0.311
Observations	7,233	5,777	7,587	5,495	4,170
Panel B: Sample Includes 40-54-Year-Old Women					
1{40 ≤ Age ≤ 49}× **1**{2009 USPSTF Rec.}	-0.050**	-0.037	0.078**	0.037	-0.067
	(0.022)	(0.043)	(0.038)	(0.042)	(0.057)
	[0.421]	[0.529]	[0.386]	[0.811]	[0.088]
R^2	0.157	0.046	0.049	0.039	0.059
Mean	0.859	0.562	0.279	0.685	0.295
Observations	5,606	4,549	5,947	4,291	3,282

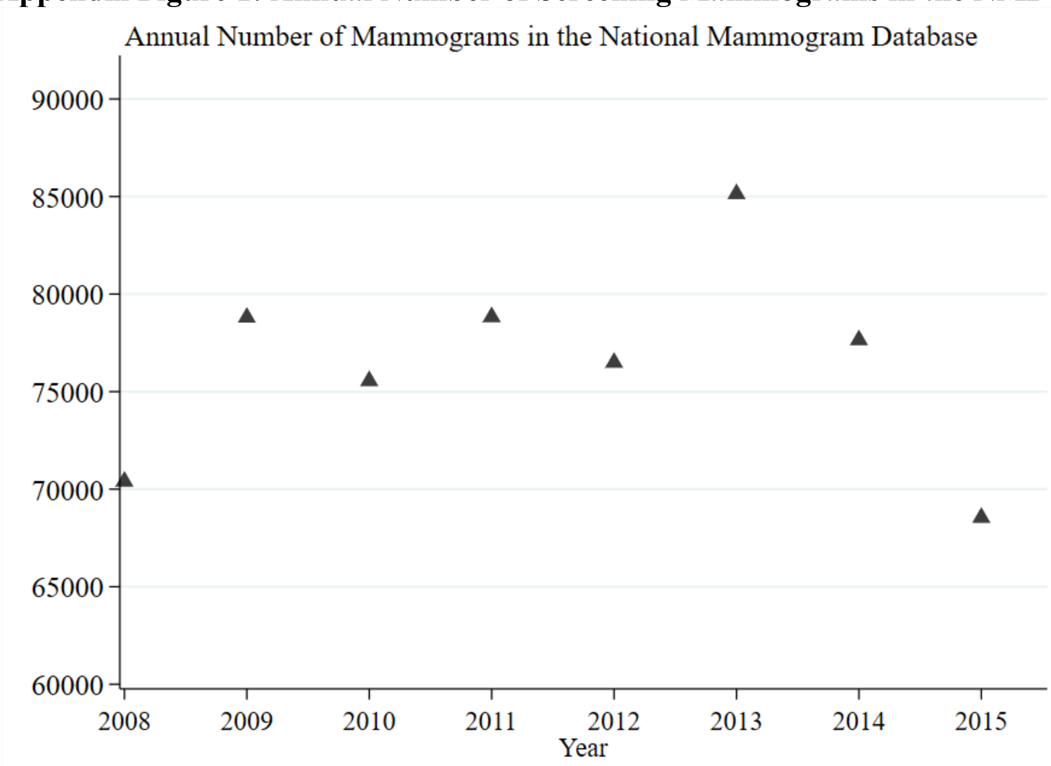
Source: Health Information National Trends Survey, 2003-2019.

Note: The sample in Panel A is women aged 35-54, and the sample in Panel B is women aged 40-54. Women aged 50-54 serve as the omitted (control) group. All columns include age and Census region-year fixed effects, as well as demographic controls (marital status, race/ethnicity, health insurance status, and educational attainment) and controls for changes to the ACS mammogram recommendation. The dependent variable in column 1 is an indicator for whether the woman reported ever receiving a mammogram. The dependent variable in column 2 is an indicator for whether the woman reported that during the past 12 months her healthcare professionals always involved her as much as she wanted in her healthcare decisions and in column 3 an indicator for whether the woman strongly agreed that there were so many recommendations for preventing cancer that it was difficult to know which ones to follow. The dependent variable in column 4 is an indicator for whether the woman reported high trust about health or medical topics from doctors and medical professionals and in column 5 an indicator for whether the woman reported high trust about these topics from government health agencies. Heteroskedastic robust standard errors are shown in parentheses, wild bootstrapped p-values clustered at the five-year age group-calendar year level are reported in brackets. The estimates utilize the survey weights.

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$

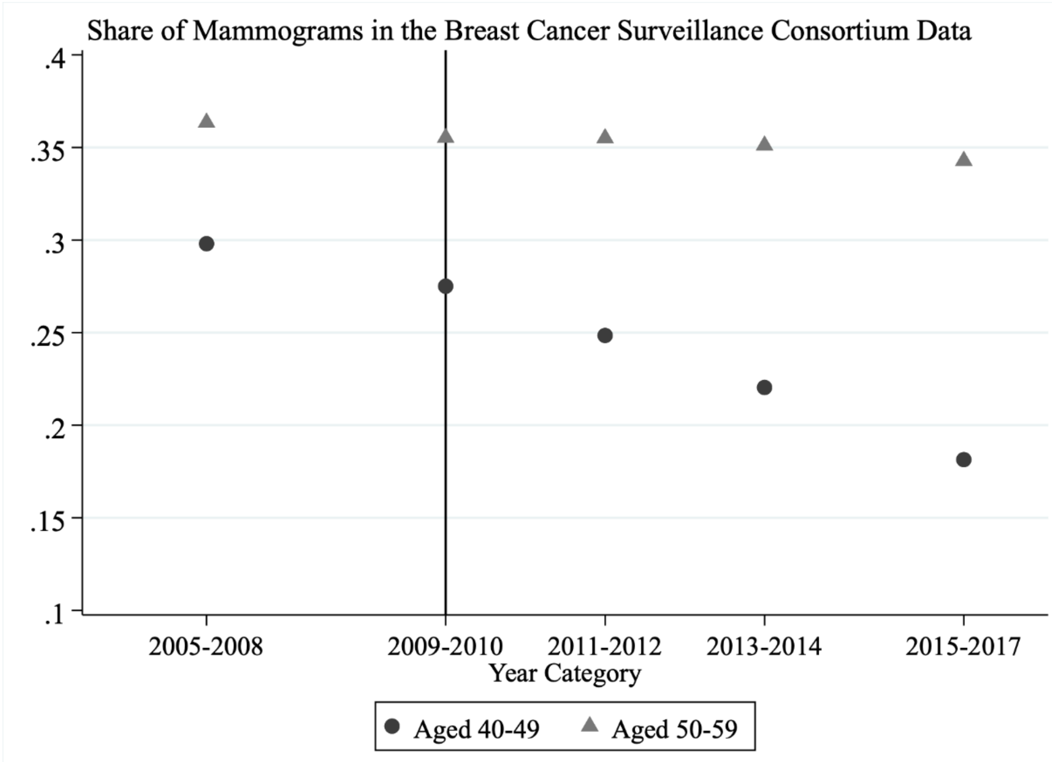
7. Appendix

Appendix Figure 1: Annual Number of Screening Mammograms in the NMD Sample



Source: National Mammography Database 2008-2015
Note: The figure plots the number of mammograms for women of all ages performed at the 10 facilities continuously reporting to the NMD between Q1 2008 and Q4 2015.

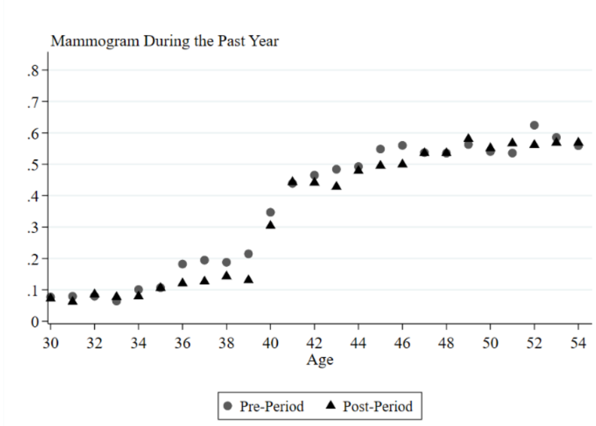
Appendix Figure 2: Mammography Trends in the BCSC Data



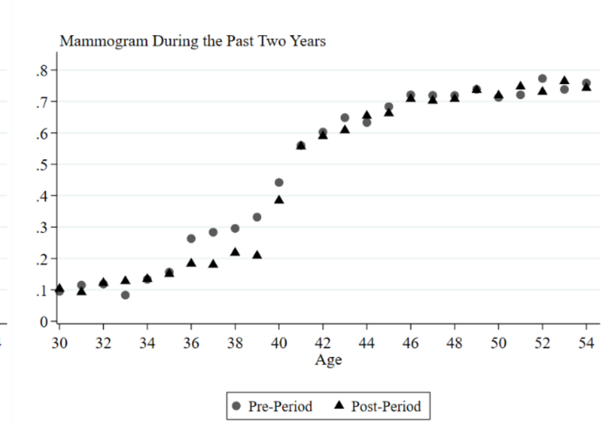
Source: Breast Cancer Surveillance Consortium Mammography Screening Performance Dataset, 2005-2017.

Note: The black circles plot the share of mammograms in each year of the BCSC data for women aged 40-49, the light grey triangles plot the share for women aged 50-59. The Breast Cancer Surveillance Consortium and its data collection and sharing activities are funded by the National Cancer Institute (P01CA154292). Downloaded 12/14/2023 from the Breast Cancer Surveillance Consortium Web site - http://www.bcsc-research.org/.

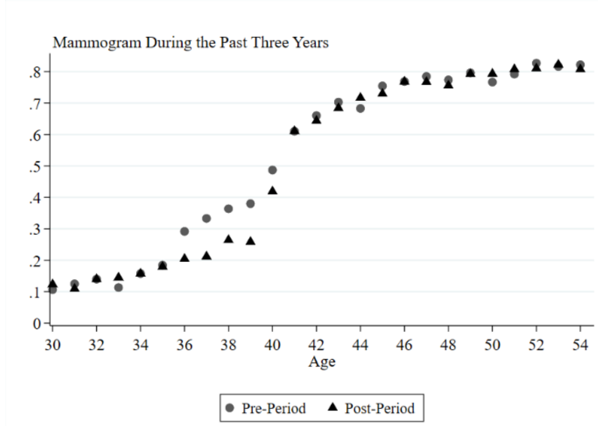
Appendix Figure 3: Age-Specific Screening Rates



(A)



(B)

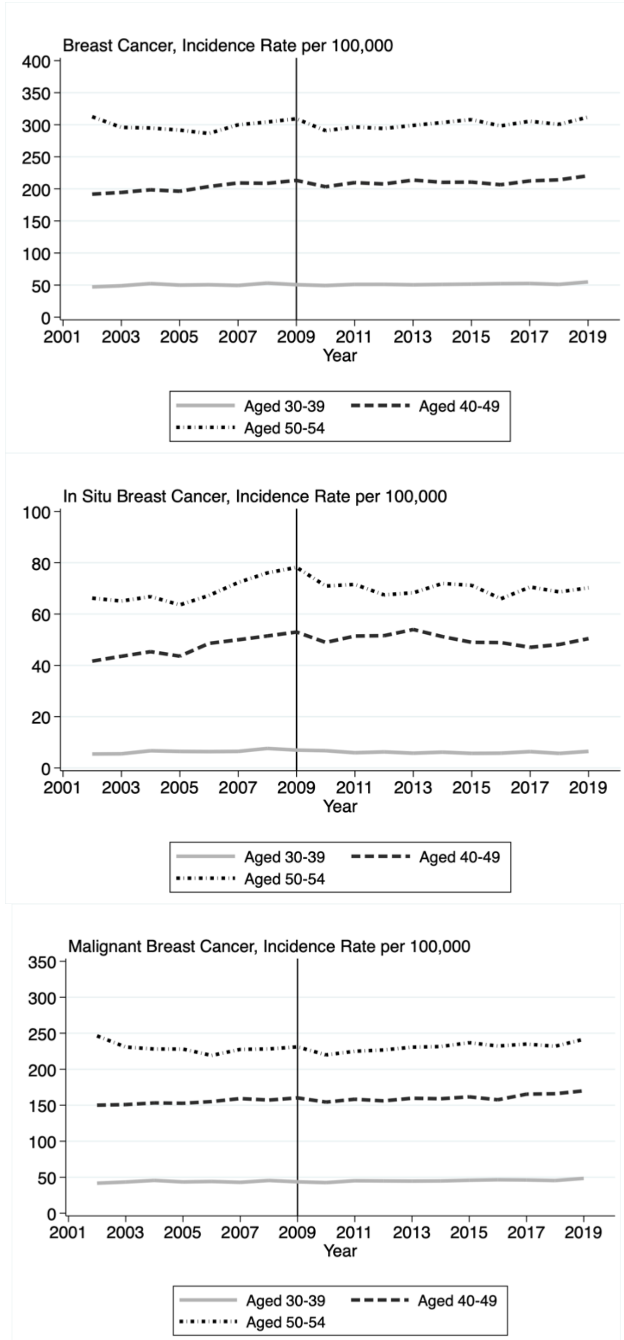


(C)

Source: National Health Interview Survey 2003-2018

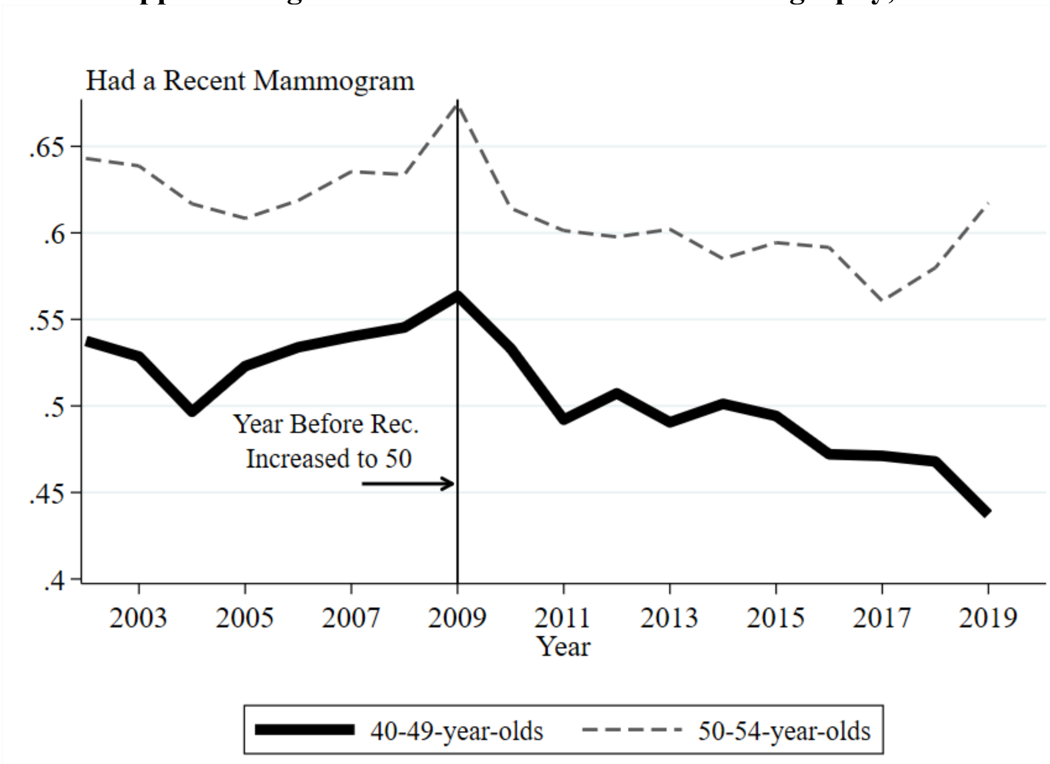
Note: The figures plot the share of each age that reported receiving a mammogram during the past year (Panel A), the past two years (Panel B), and the past three years (Panel C). The grey circles plot the shares during the pre-period, while the black triangles denote the corresponding share in the post-period. The descriptive statistics use the sample weights.

Appendix Figure 4: Breast Cancer Trends Over Time



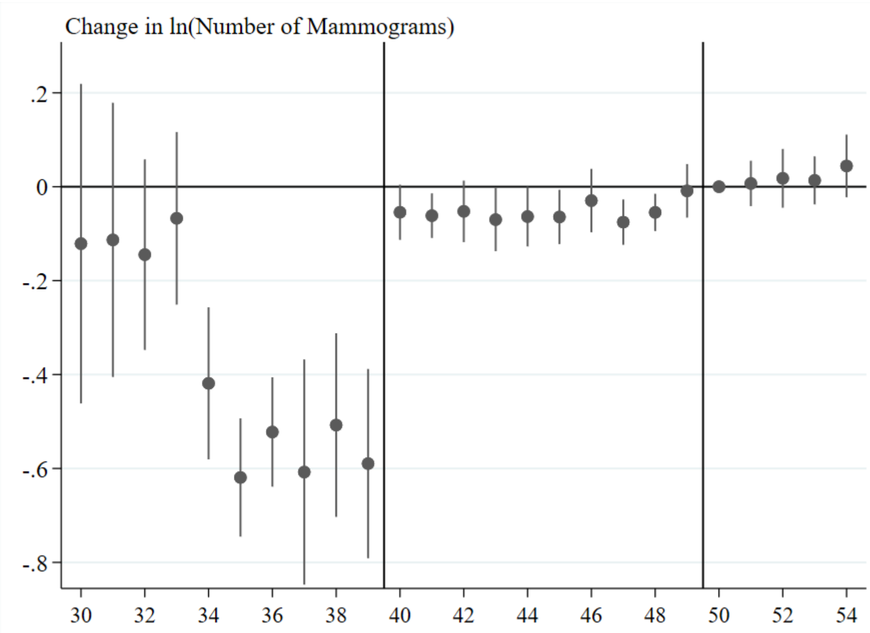
Source: National Cancer Institute's Surveillance, Epidemiology, and End Results Program 2002-2019
Note: Each panel plots trends in the number of diagnosed breast cancers per 100,000 women by age group. The solid black vertical line indicates the year of the USPSTF mammogram guidelines revision.

Appendix Figure 5: Trends in Past Year Mammography, BRFSS

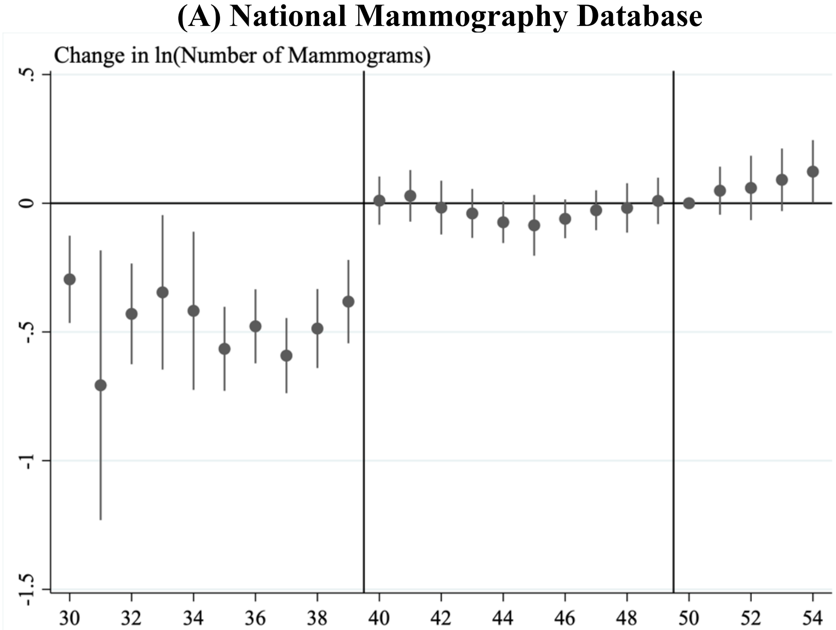


Source: Behavioral Risk Factor Surveillance System 2002-2019
Note: The figure plots the share of women reporting that they had received a mammogram during the prior year in the BRFSS data. The solid black line plots the share for women aged 40-49 and the light dashed line the share for women aged 50-54. The descriptive statistics utilize the sample weights.

Appendix Figure 6: Age-Specific Effects on Mammography Using Administrative Data



(A) National Mammography Database

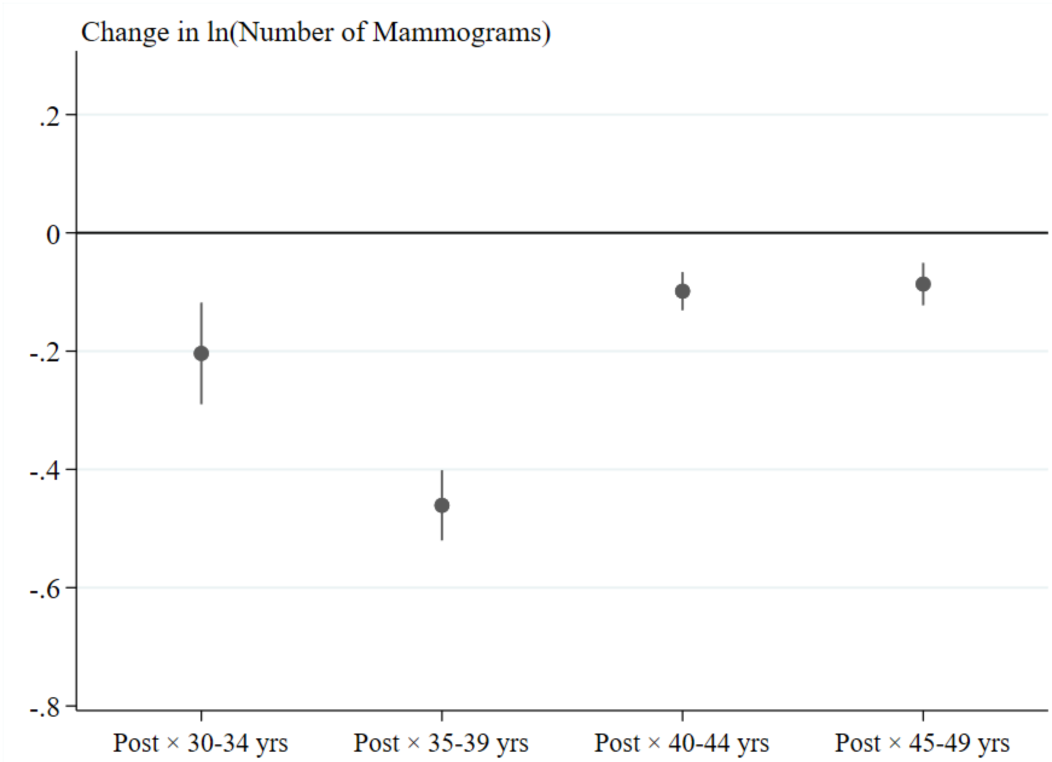


(B) Maryland HCUP Data

Source: National Mammography Database 2008-2015, Maryland HCUP State Ambulatory Surgery and Services Databases 2008-2014

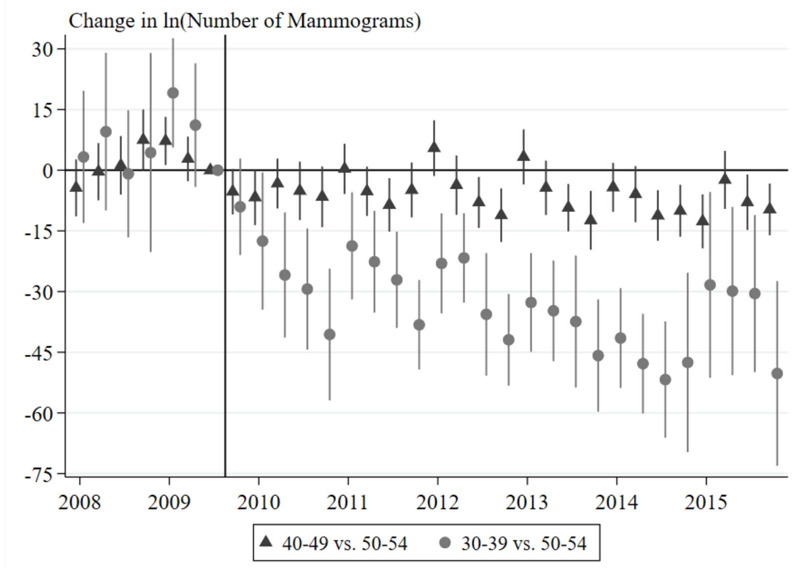
Note: The dependent variable is the natural log of the number of mammograms performed each year. The independent variables of interest are indicators for each age interacted with an indicator for the post-recommendation period, with age 50 as the omitted (control) group. The regression controls for age and year fixed effects. The vertical bars denote 95 percent confidence intervals using heteroskedastic robust standard errors.

Appendix Figure 7: Age-Specific Effects on Mammography Using an Alternative NMD Sample with a Shorter Pre-Period but More Facilities

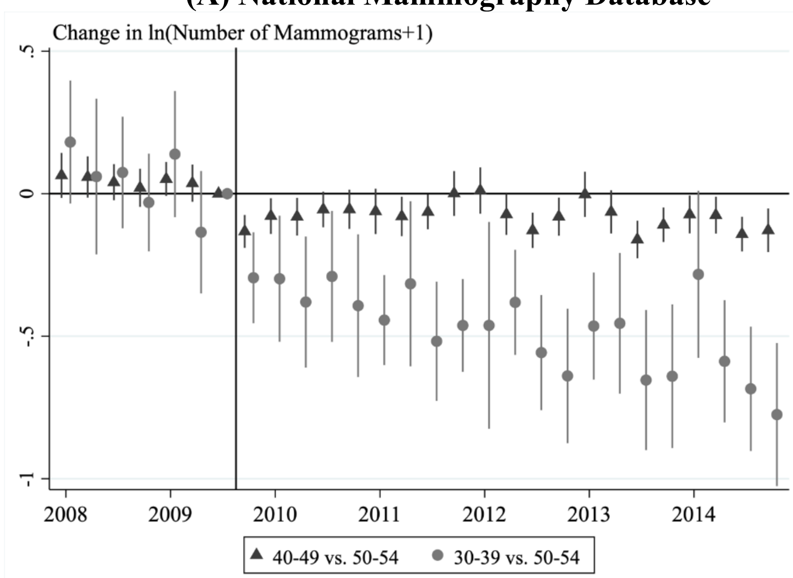


Source: National Mammography Database 2009-2015
Note: The sample includes 19 facilities that consistently reported mammography data from 2009-2015. The dependent variable is the natural log of the number of mammograms performed each year. The independent variables of interest are indicators for the five-year age groups interacted with an indicator for the post-recommendation period, with ages 50-54 as the omitted (control) group. The regression controls for age fixed effects and year fixed effects. The vertical bars denote 95 percent confidence intervals using heteroskedastic robust standard errors.

Appendix Figure 8: Quarterly Event Study Estimates Using Administrative Data



(A) National Mammography Database

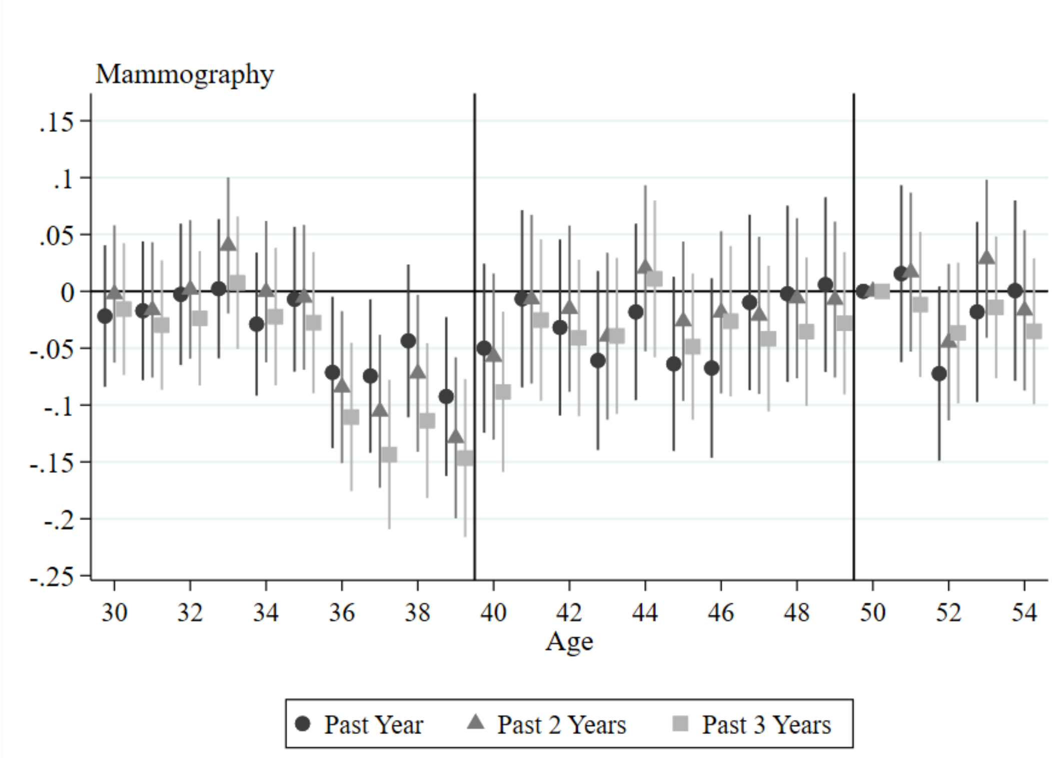


(B) Maryland HCUP Data

Sources: National Mammography Database 2008-2015, Maryland HCUP State Ambulatory Surgery and Services Databases 2008-2014

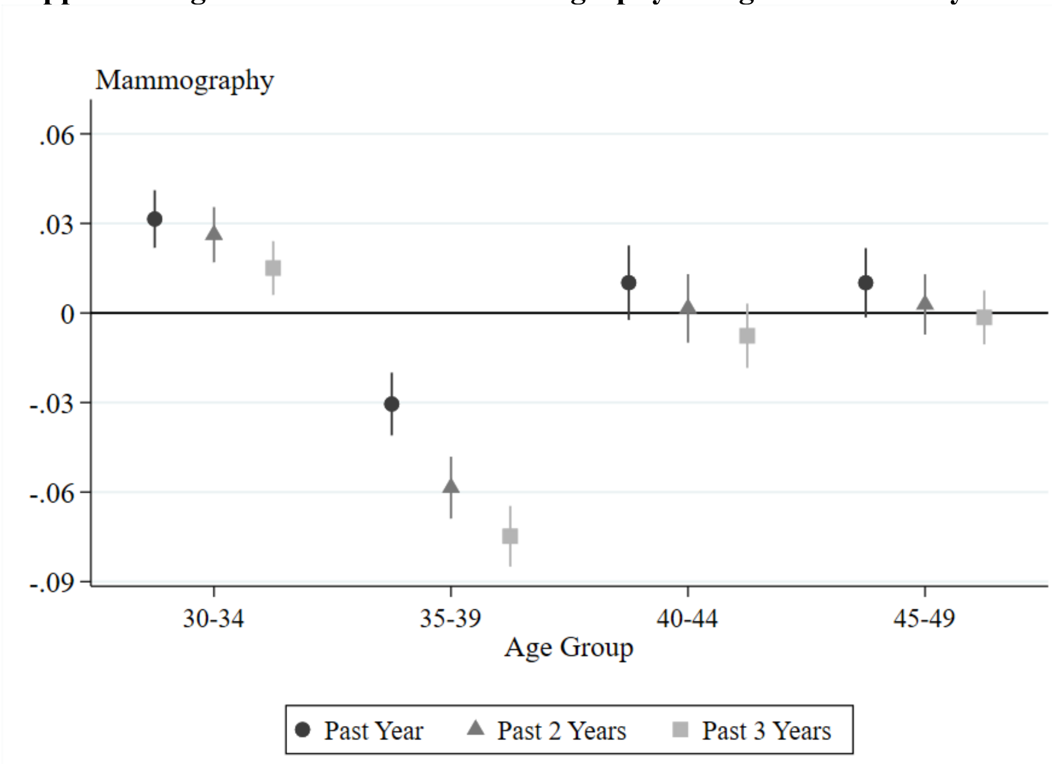
Note: The dependent variable in Panel A is the natural log of the number of mammograms, while the dependent variable in Panel B is the natural log of the number of mammograms +1 . The data are measured at the age-year-quarter level. The triangles denote the percent change in mammograms performed for women aged 40-49 compared to women aged 50-54 after controlling for age, year, and calendar quarter fixed effects. Meanwhile, the circles denote the percent change in mammograms performed for women aged 30-39 compared to women aged 50-54. The vertical bars denote 95 percent confidence intervals using heteroskedastic robust standard errors.

Appendix Figure 9: Age-Specific Effects on Mammography Using NHIS Survey Data



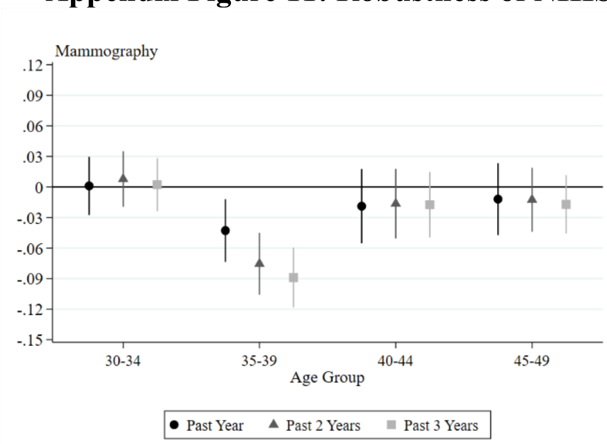
Source: National Health Interview Survey 2003-2018
Note: The markers plot the point estimates, and the lines represent the corresponding 95 percent confidence intervals using heteroskedastic robust standard errors. The black circles denote the results from a regression where the dependent variable is an indicator for having had a mammogram during the prior year, the grey triangles during the prior two years, and the light grey squares during the prior three years. The sample includes adults aged 30-54. The independent variables of interest are indicators for each age that have been interacted with the post-period indicator, with age 50 as the omitted (control) group. The regression includes the full set of controls from equation (2). The estimates use the sample weights.

Appendix Figure 10: Effects on Mammography Using BRFSS Survey Data

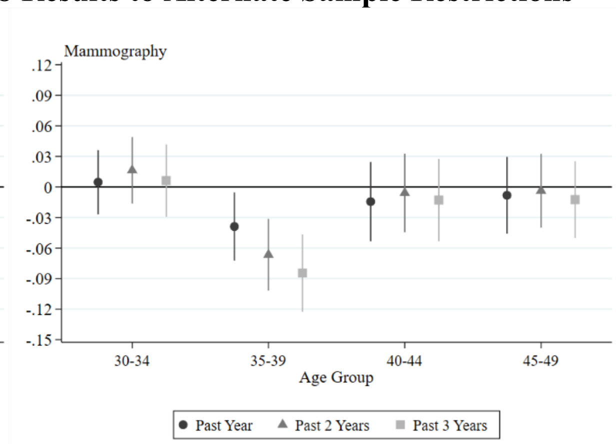


Source: Behavioral Risk Factor Surveillance System 2002-2019
Note: The markers plot the point estimates, and the lines represent the corresponding 95 percent confidence intervals using heteroskedastic robust standard errors. The black circles denote the results from a regression where the dependent variable is an indicator for having had a mammogram during the prior year, the grey triangles during the prior two years, and the light grey squares during the prior three years. The sample includes adults aged 30-54. The independent variables of interest are indicators for the five-year age groups interacted with an indicator for the post-recommendation period, with ages 50-54 as the omitted (control) group. The regression includes the full set of controls from equation (2), as well as state-year-month fixed effects. The estimates use the sample weights.

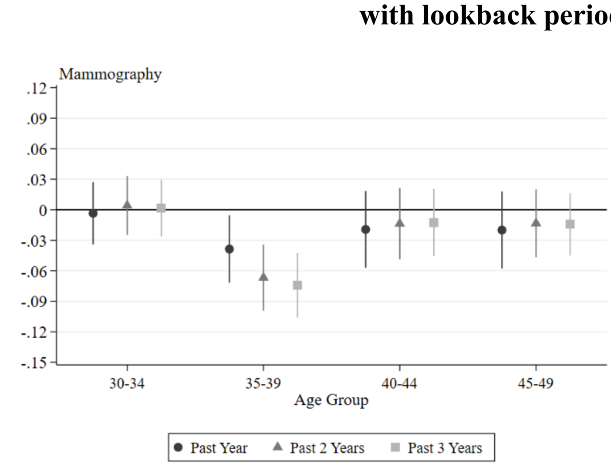
Appendix Figure 11: Robustness of NHIS Results to Alternate Sample Restrictions



(A) Baseline Estimates



(B) Dropping 50-54-year old women with lookback period overlapping ages <50



(C) Dropping post-Oct. 2015 observations

Source: National Health Interview Survey 2003-2018
Note: The markers plot the point estimates, and the lines represent the corresponding 95 percent confidence intervals using heteroskedastic robust standard errors. The black circles denote the results from a regression where the dependent variable is an indicator for having had a mammogram during the prior year, the grey triangles during the prior two years, and the light grey squares during the prior three years. The sample includes adults aged 30-54. The independent variables of interest are indicators for the five-year age groups interacted with an indicator for the post-recommendation period, with ages 50-54 as the omitted (control) group. Panel A uses the full sample. Panel B excludes 50-year-old women when the outcome is an indicator for having had a mammogram during the prior year, 50- and 51-year-old women when the outcome is an indicator for having had a mammogram during the prior two years, and 50-52-year-old women when the outcome is an indicator for having had a mammogram during the prior three years. Panel C excludes individuals interviewed following October 2015. The estimates use the sample weights.

Appendix Figure 12: Estimates for Women Aged 40-54
Using Administrative Data and Alternate Sample Windows

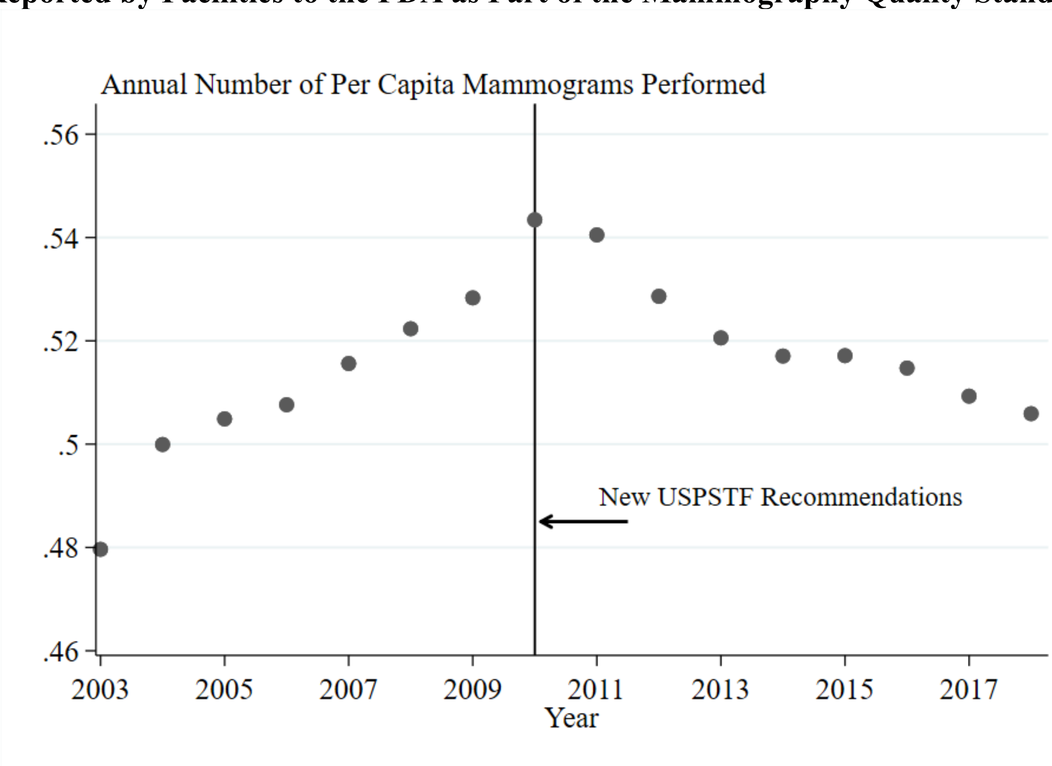
(A) National Mammography Database

(B) Maryland HCUP Data

Sources: National Mammography Database 2008-2015, Maryland HCUP State Ambulatory Surgery and Services Databases 2008-2014

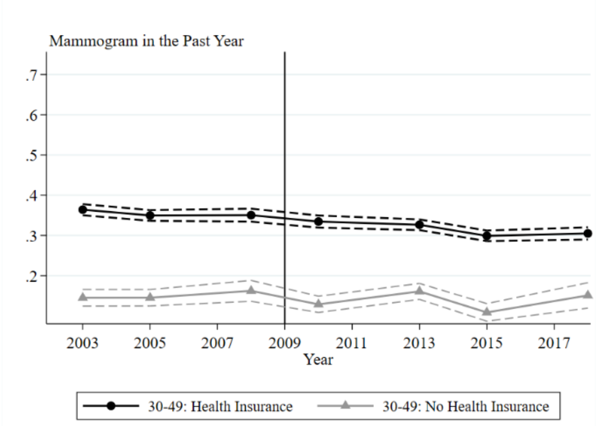
Note: Each marker plots the point estimate from a separate regression, in which the dependent variable is the natural log of the number of mammograms performed each year and the sample years are as indicated on the horizontal axis. The vertical bars denote 95 percent confidence intervals using heteroskedastic robust standard errors.

Appendix Figure 13: Trends in the Number of Mammogram Procedures Performed Reported by Facilities to the FDA as Part of the Mammography Quality Standards Act

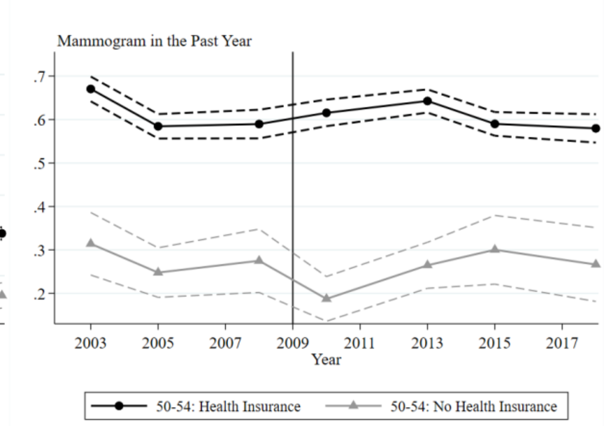


Source: FDA Mammography Quality Standards Act (MQSA) National Statistics 2002-2018
Note: The grey circles plot the annual number of mammogram procedures performed per female aged 40-84 each year. The FDA aggregates these data, which are based on the numbers that facilities reported to their accreditation bodies at the time of their re-accreditation, which occurs every three years. These numbers include MQSA-certified, non-Veterans Hospital Administration facilities.

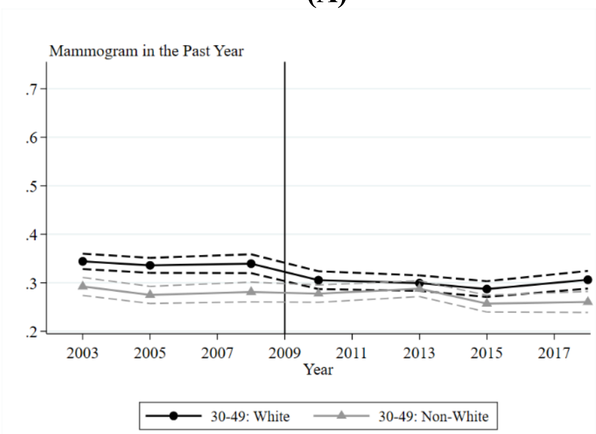
Appendix Figure 14: Trends in Past Year Mammography, by Demographic Group



(A)



(B)



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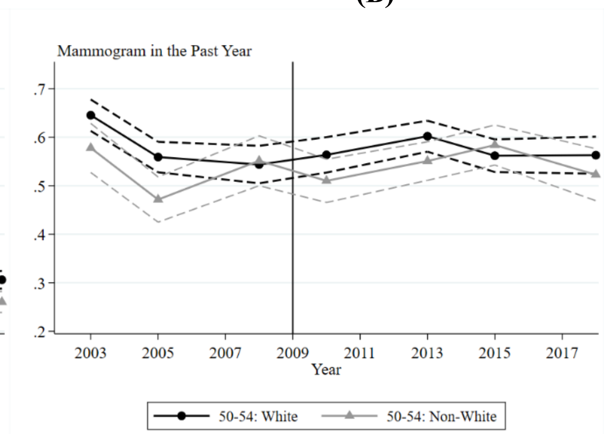
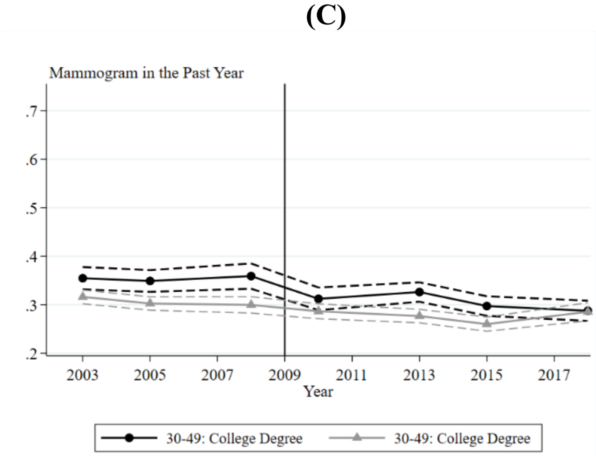
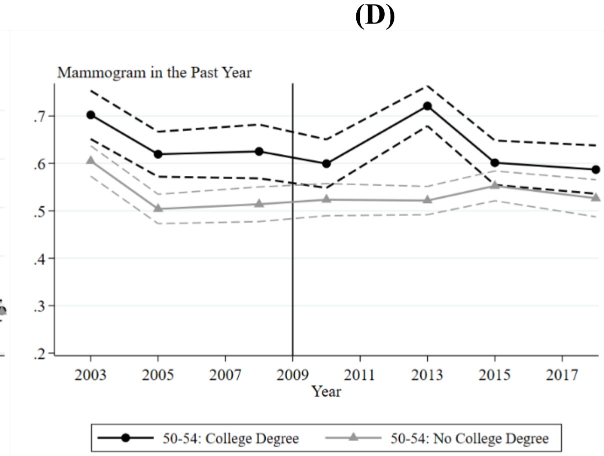


(D)



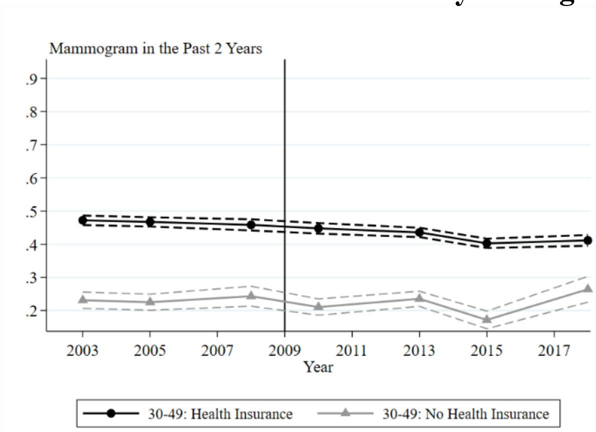
(E)



(F)

Source: National Health Interview Survey 2003-2018
Note: The figures plot the share of women who reported receiving a mammogram during the past year at the time of the survey by age group and demographic characteristic. Panels A and B plot the shares for women who reported having health insurance compared to those who reported being uninsured. Panels C and D plot the shares for white women compared to non-Hispanic Black, Hispanic, and all other race/ethnicity women. Panels E and F plot the shares for women with a college degree compared to those without a college degree. The descriptive statistics utilize the sample weights.

Appendix Figure 15: Trends in Mammography During the Past Two Years, by Demographic Group



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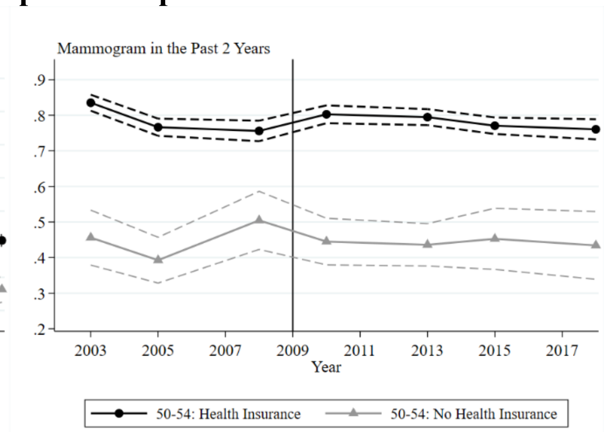

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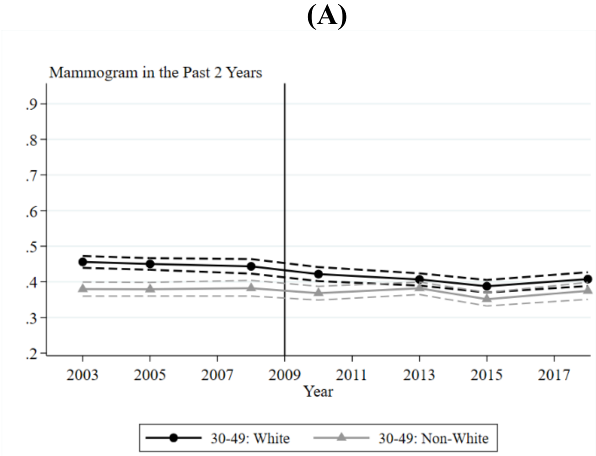
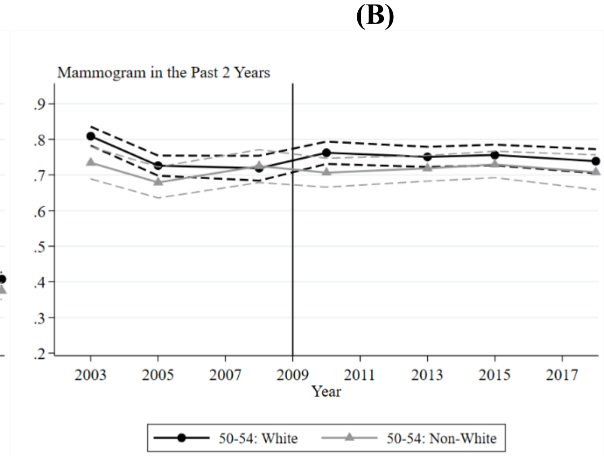
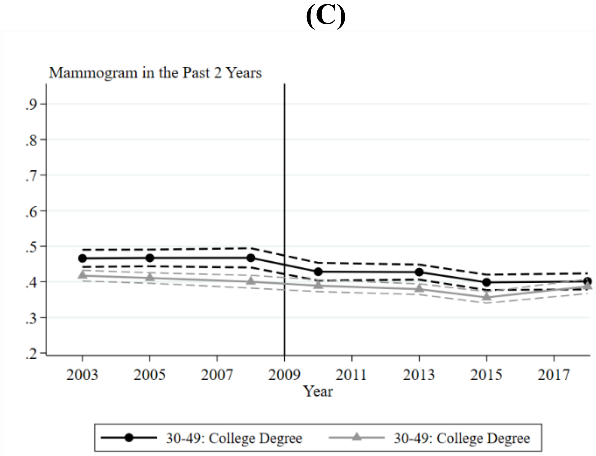


(C)



(D)



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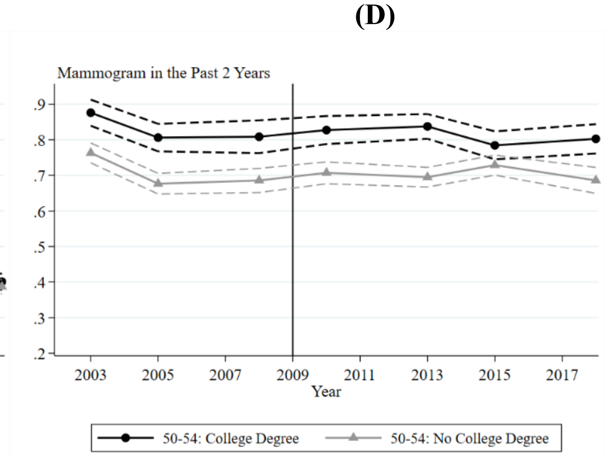
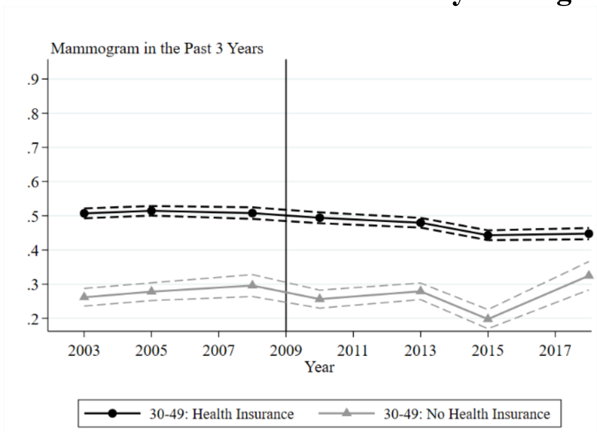


(F)

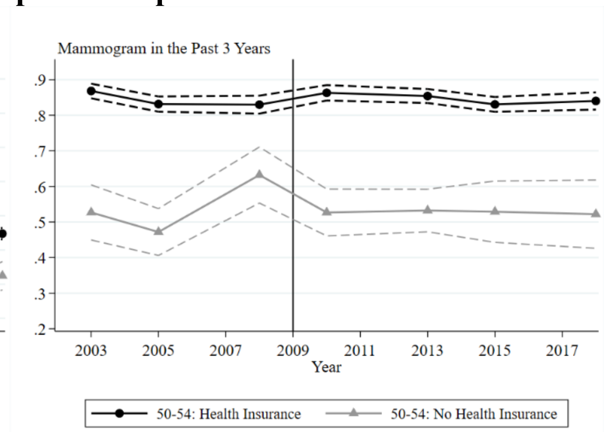
Source: National Health Interview Survey 2003-2018

Note: The figures plot the share of women who reported receiving a mammogram during the past two years at the time of the survey by age group and demographic characteristic. Panels A and B plot the shares for women who reported having health insurance compared to those who reported being uninsured. Panels C and D plot the shares for white women compared to non-Hispanic Black, Hispanic, and all other race/ethnicity women. Panels E and F plot the shares for women with a college degree compared to those without a college degree. The descriptive statistics utilize the sample weights.

Appendix Figure 16: Trends in Mammography During the Past Three Years, by Demographic Group



(A)



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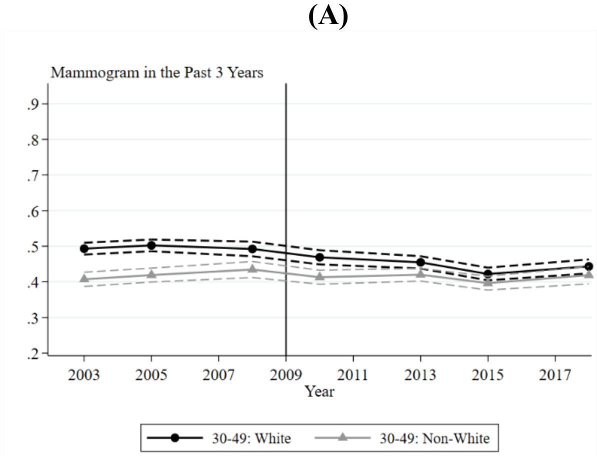

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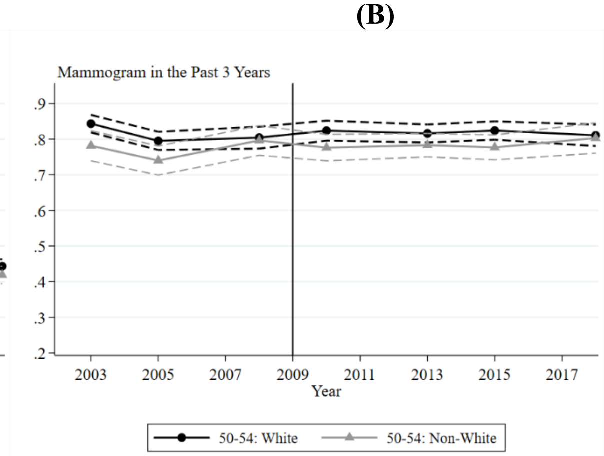

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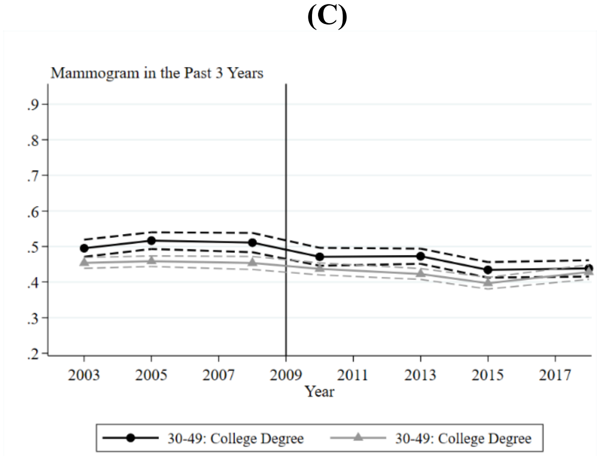

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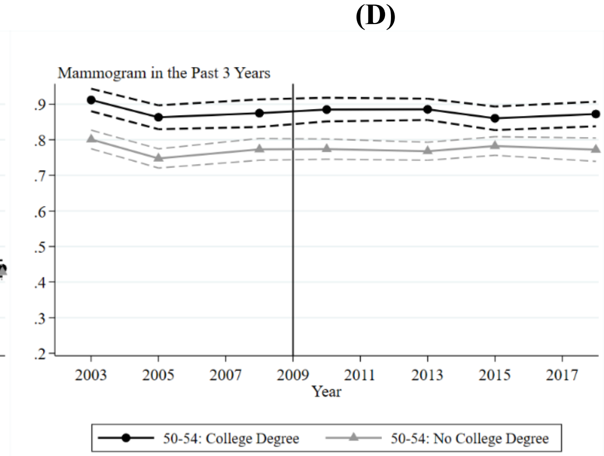
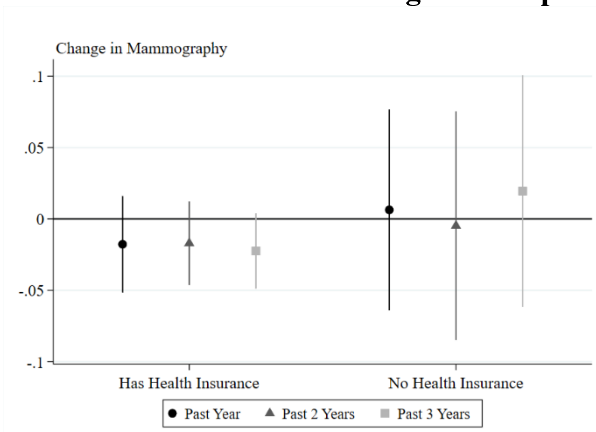


(F)

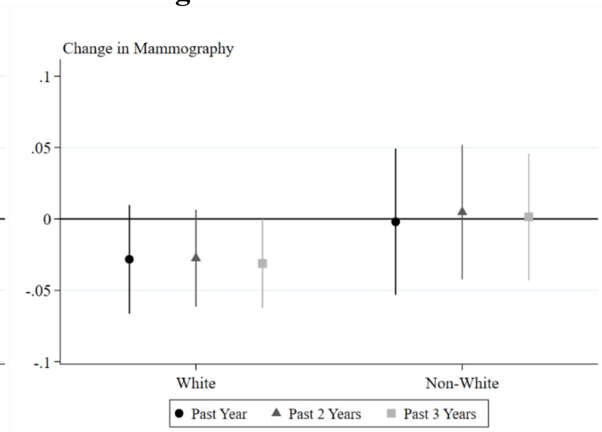
Source: National Health Interview Survey 2003-2018

Note: The figures plot the share of women who reported receiving a mammogram during the past three years at the time of the survey by age group and demographic characteristic. Panels A and B plot the shares for women who reported having health insurance compared to those who reported being uninsured. Panels C and D plot the shares for white women compared to non-Hispanic Black, Hispanic, and all other race/ethnicity women. Panels E and F plot the shares for women with a college degree compared to those without a college degree. The descriptive statistics utilize the sample weights.

Appendix Figure 17: Heterogeneous Effects When Limiting the Sample to Women Aged 40-54



(A)



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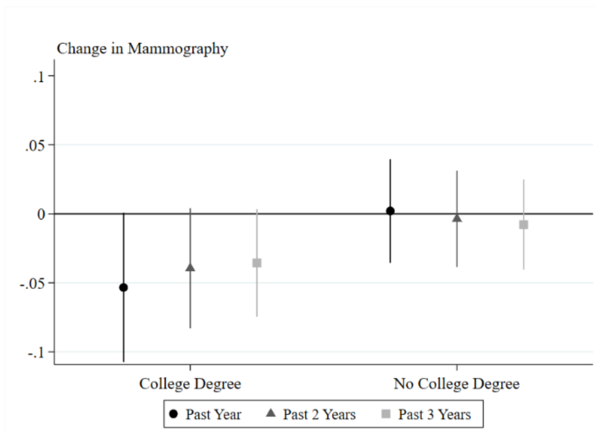
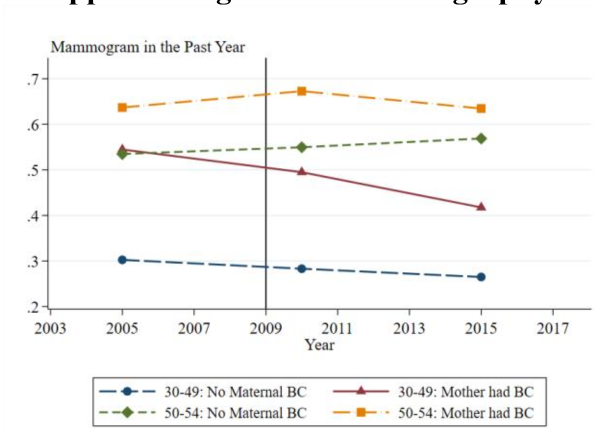


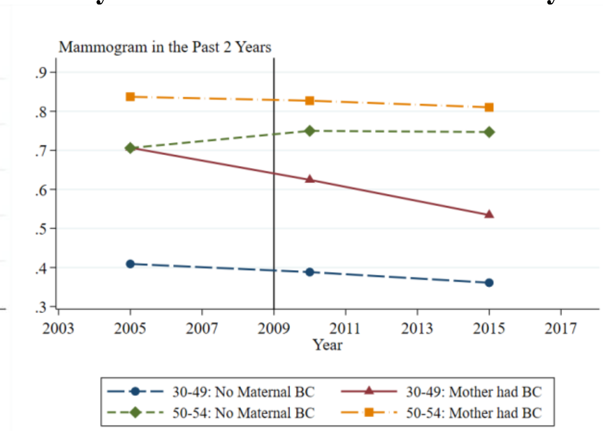
(C)

Source: National Health Interview Survey 2003-2018
Note: The markers plot the point estimates, and the lines represent the corresponding 95 percent confidence intervals using heteroskedastic robust standard errors. The black circles denote the results from a regression where the dependent variable is an indicator for having had a mammogram during the prior year, the grey triangles during the prior two years, and the light grey squares during the prior three years. The sample includes women aged 40-54; women aged 50-54 are the omitted (control) group. Each panel presents results from regressions where the sample is stratified by the characteristic shown on the horizontal axis. The estimates use the sample weights.

Appendix Figure 18: Mammography Trends by Maternal Breast Cancer History



(A)



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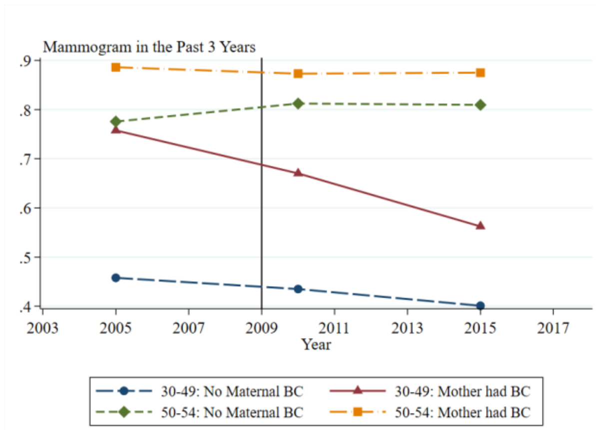
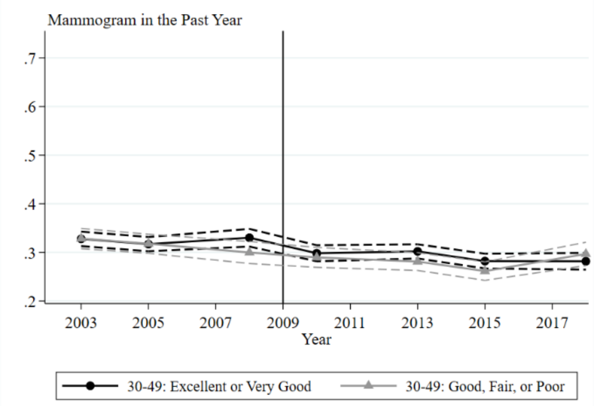


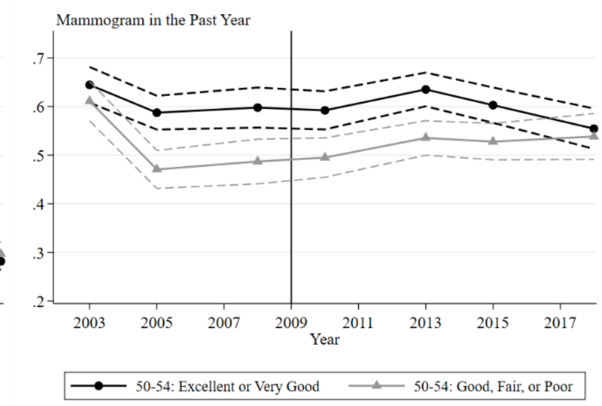
(C)

Source: National Health Interview Survey 2003-2018
Note: The figure plots the share of women of each individual age who reported receiving a mammogram during the past year (Panel A), during the past two years (Panel B), and during the past three years (Panel C) at the time of survey by age group and maternal breast cancer history. The descriptive statistics use the sample weights.

Appendix Figure 19: Trends in Past Year Mammography, by Health Behaviors



(A)



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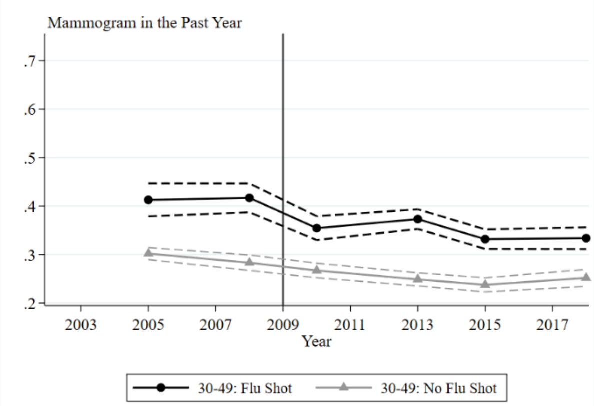
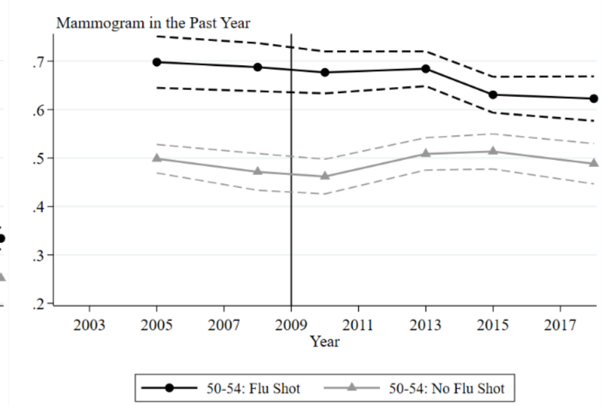


(C)



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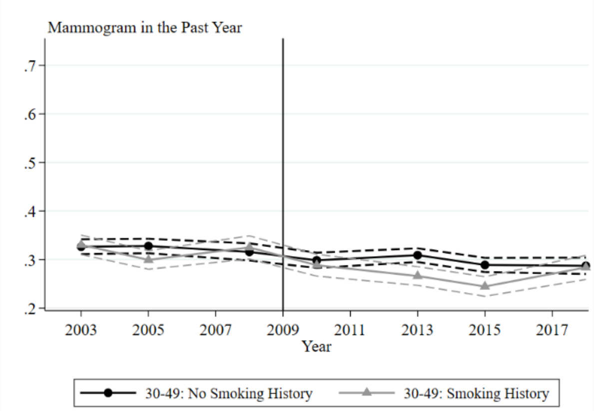

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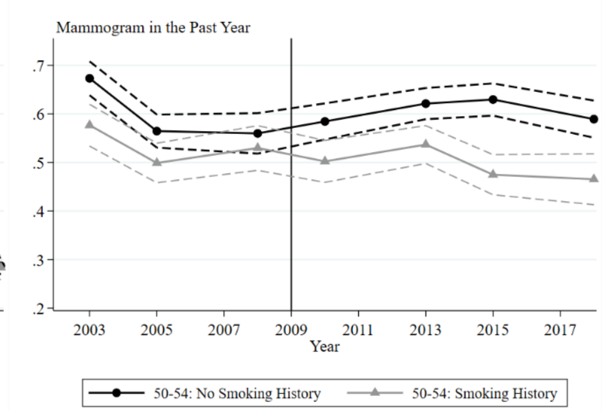

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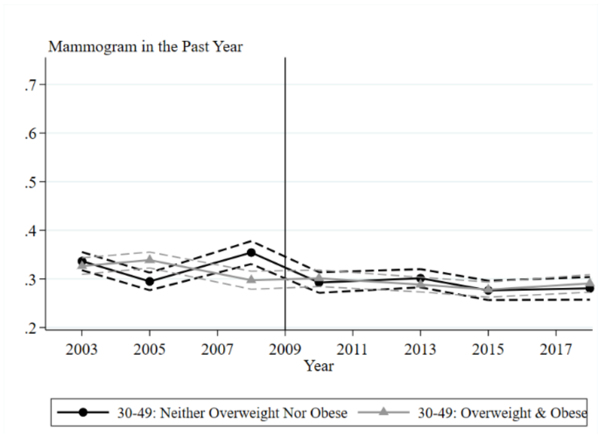
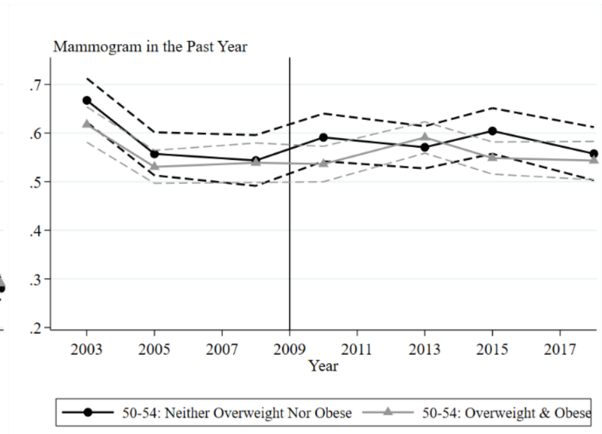


(G)

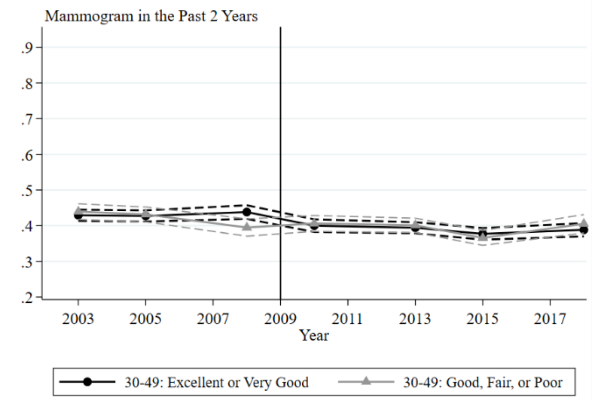


(H)

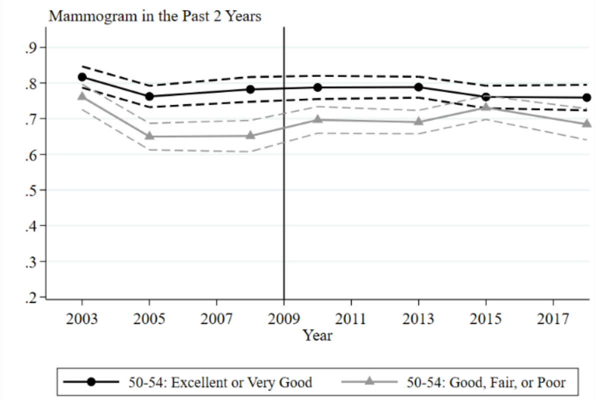
Source: National Health Interview Survey 2003-2018

Note: The figures plot the share of women who reported receiving a mammogram during the past year at the time of the survey by age group and health characteristic. Panels A and B plot the shares for women who reported being in Excellent or Very Good Health compared to those who reported being in Good, Fair, or Poor Health. Panels C and D plot the shares for women who reported receiving a flu shot during the past 12 months compared to those who reported not receiving a flu shot. Panels E and F plot the shares for women who reported smoking 100 cigarettes during their lives to women who reported not having smoked 100 cigarettes during their lives. Finally, Panel G and H plot the shares for women who are classified as overweight or obese compared to those who are classified as healthy weight. The descriptive statistics utilize the sample weights.

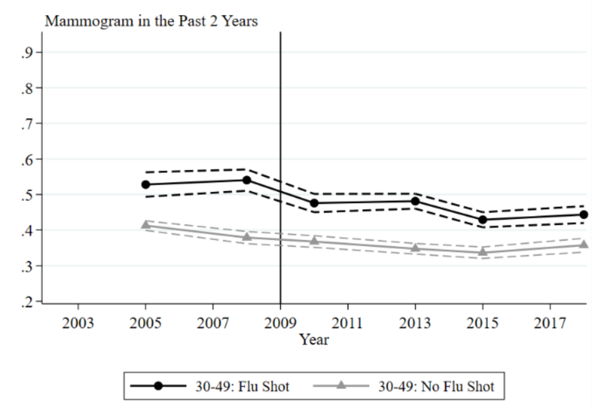
Appendix Figure 20: Trends in Mammography During the Past Two Years, by Health Behaviors



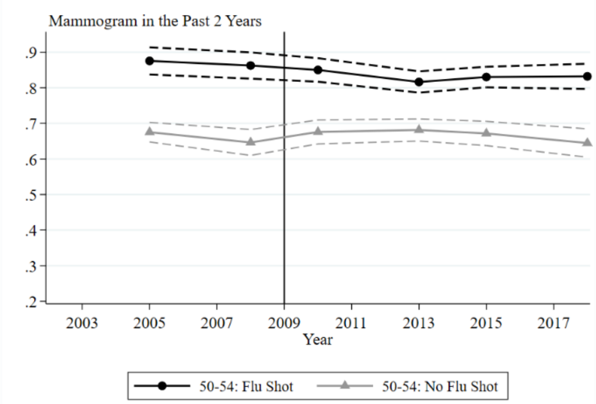
(A)



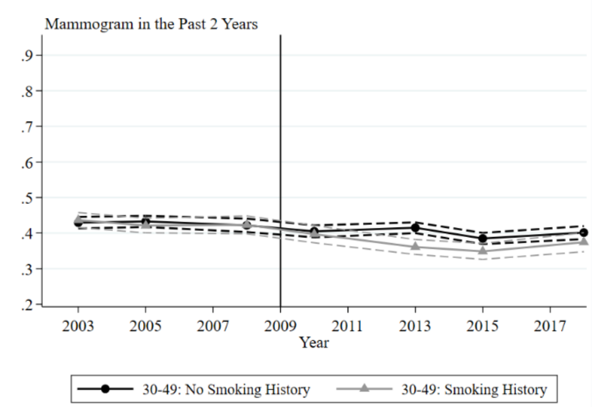
(B)



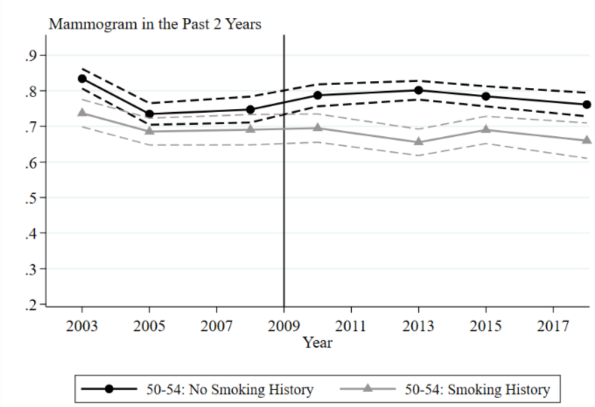
(C)



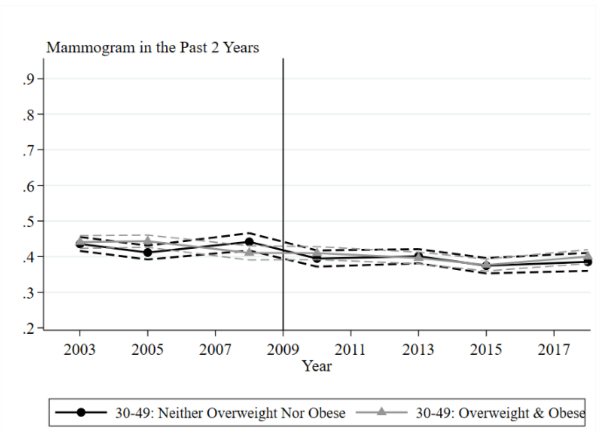
(D)

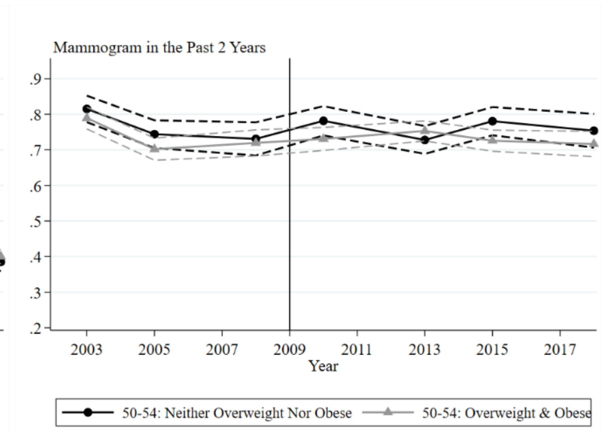


(E)



(F)



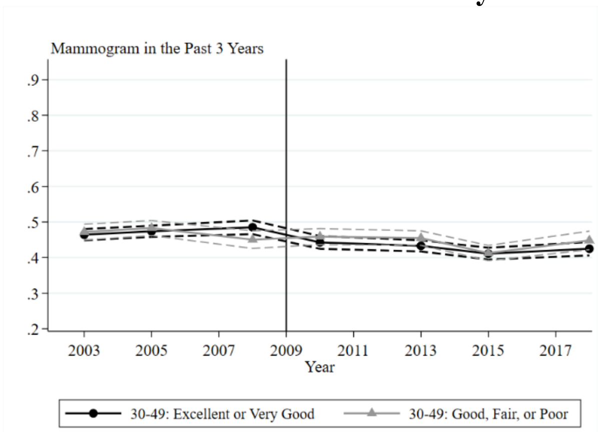


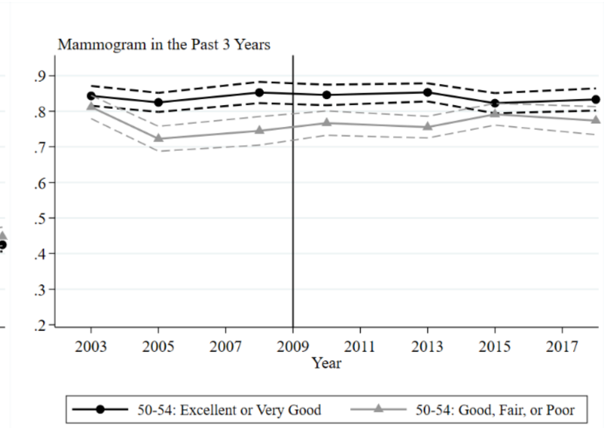
(G) **(H)**

Source: National Health Interview Survey 2003-2018

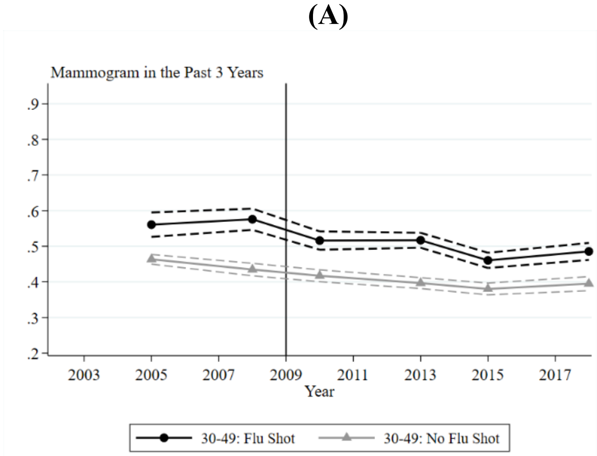
Note: The figures plot the share of women who reported receiving a mammogram during the past two year at the time of the survey by age group and health characteristic. Panels A and B plot the shares for women who reported being in Excellent or Very Good Health compared to those who reported being in Good, Fair, or Poor Health. Panels C and D plot the shares for women who reported receiving a flu shot during the past 12 months compared to those who reported not receiving a flu shot. Panels E and F plot the shares for women who reported smoking 100 cigarettes during their lives to women who reported not having smoked 100 cigarettes during their lives. Finally, Panel G and H plot the shares for women who are classified as overweight or obese compared to those who are classified as healthy weight. The descriptive statistics utilize the sample weights.

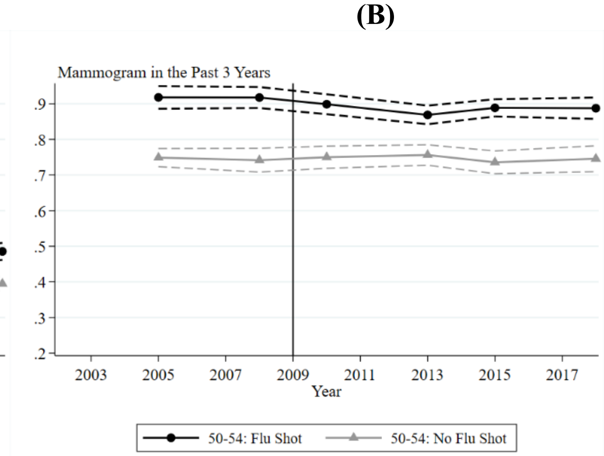
Appendix Figure 21: Trends in Mammography During the Past Three Years, by Health Behaviors



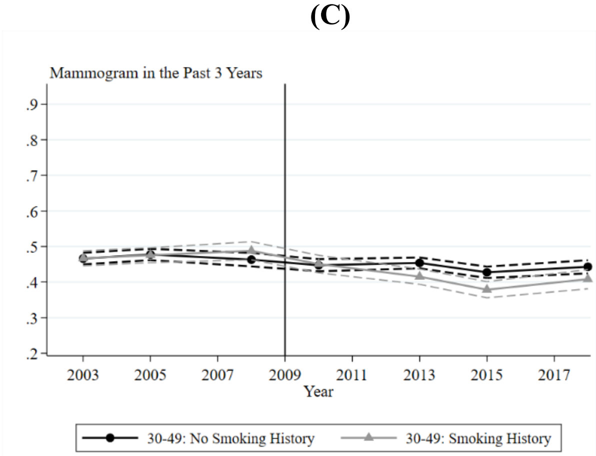


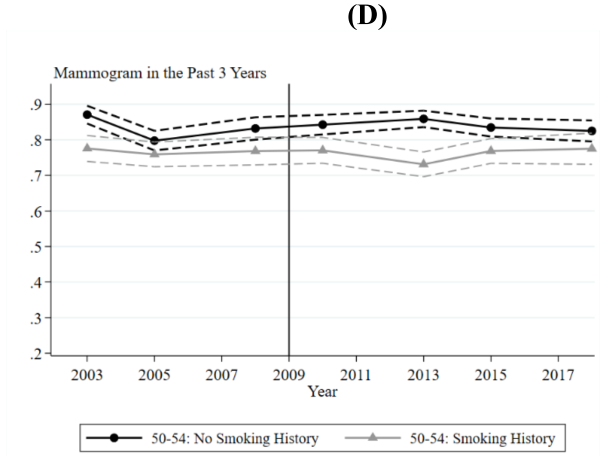
(A) **(B)**



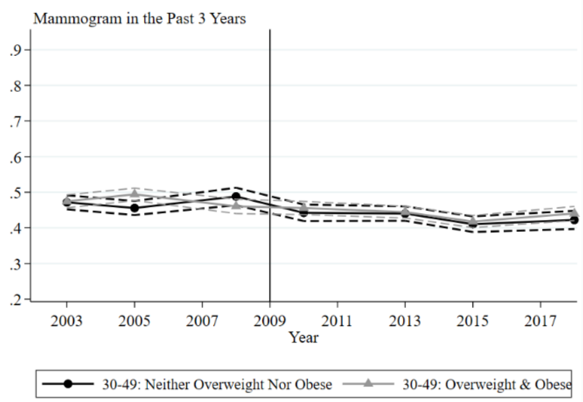


(C) **(D)**

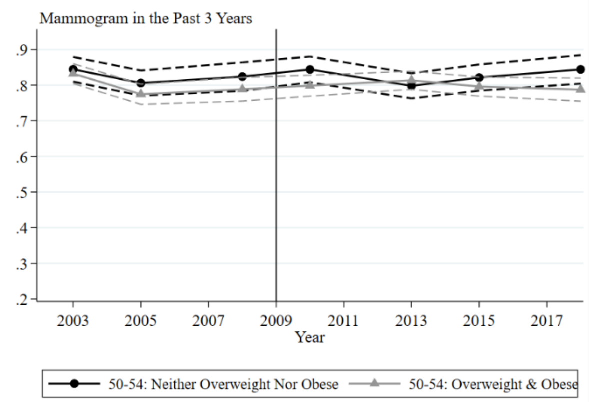




(E) **(F)**



(G)

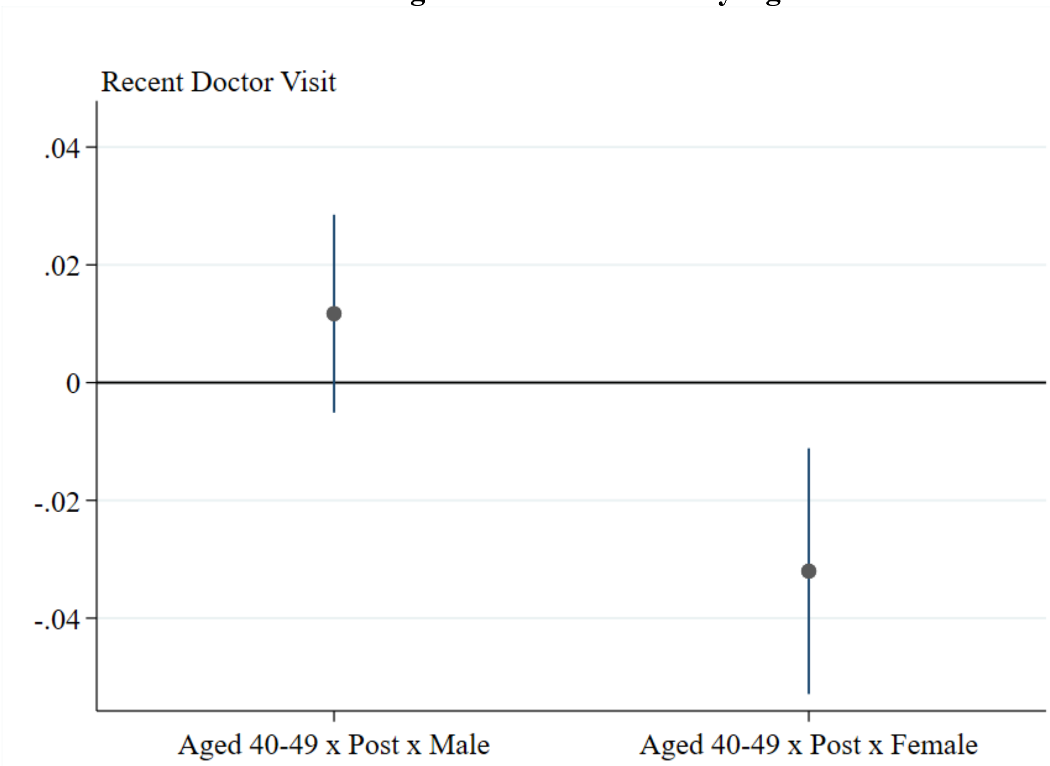


(H)

Source: National Health Interview Survey 2003-2018

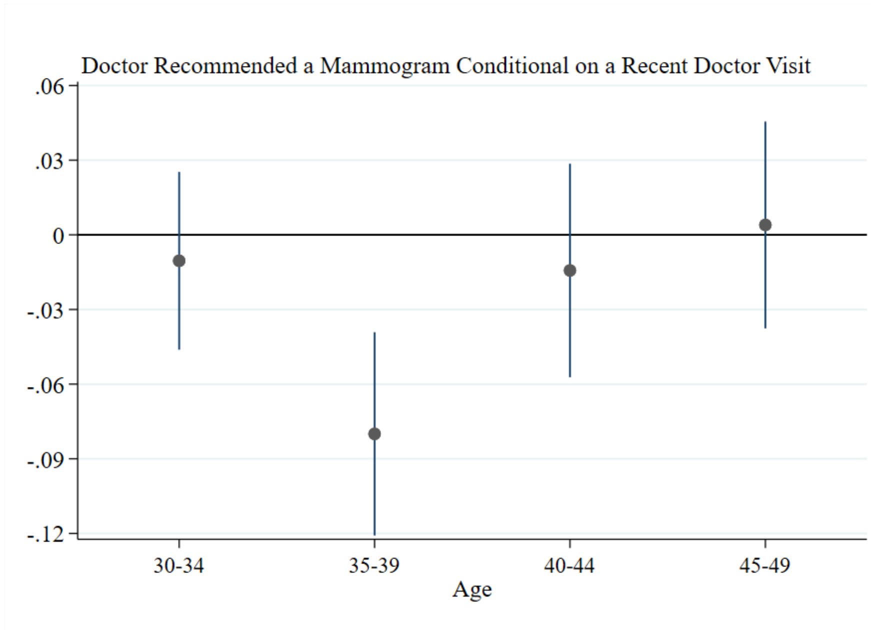
Note: The figures plot the share of women who reported receiving a mammogram during the past three year at the time of the survey by age group and health characteristic. Panels A and B plot the shares for women who reported being in Excellent or Very Good Health compared to those who reported being in Good, Fair, or Poor Health. Panels C and D plot the shares for women who reported receiving a flu shot during the past 12 months compared to those who reported not receiving a flu shot. Panels E and F plot the shares for women who reported smoking 100 cigarettes during their lives to women who reported not having smoked 100 cigarettes during their lives. Finally, Panel G and H plot the shares for women who are classified as overweight or obese compared to those who are classified as healthy weight. The descriptive statistics utilize the sample weights.

Appendix Figure 22: Effects on Healthcare Visits for Women Aged 40-49 and Similarly Aged Men



Source: National Health Interview Survey 2003-2018
Note: The grey circles plot the point estimates and the lines the corresponding 95 percent confidence intervals obtained from a modified version of equation (2). The sample is 40-54-year-old adults, including both men and women. All the right-hand side covariates are then interacted with an indicator for being female to separately estimate the effect of the 2009 USPSTF recommendation on recent care visits for 40-49-year-old men and 40-49-year-old women. The estimates use the sample weights.

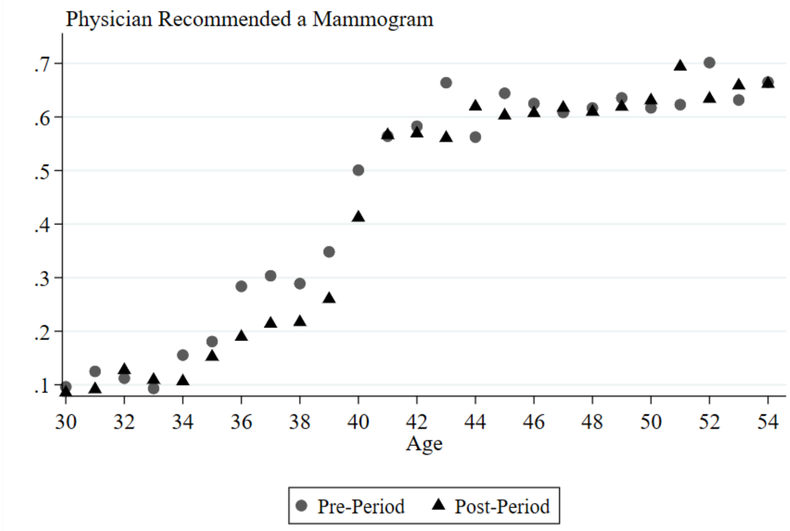
Appendix Figure 23: Effects on Mammogram Recommendations Conditional on Having a Recent Doctor Visit



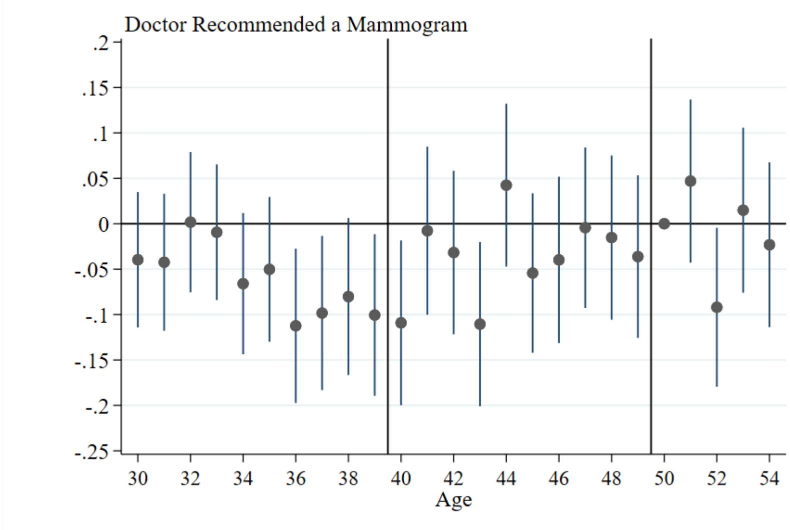
Source: National Health Interview Survey 2003-2018

Note: The grey circles plot the point estimates and the lines the corresponding 95 percent confidence intervals obtained from estimating equation (2). The independent variables of interest are indicators for the five-year age groups interacted with an indicator for the post-recommendation period, with ages 50-54 as the omitted (control) group. The estimates utilize the sample weights.

Appendix Figure 24: Individual Age Effects on Mammogram Recommendations



(A)

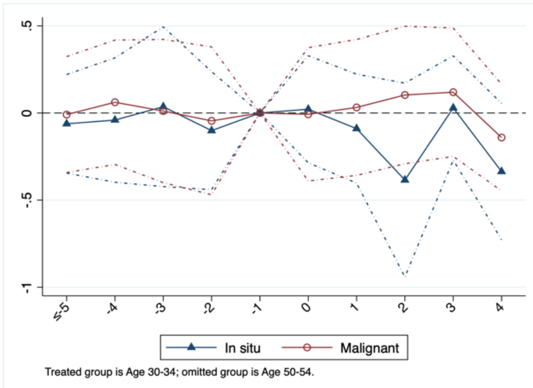


(B)

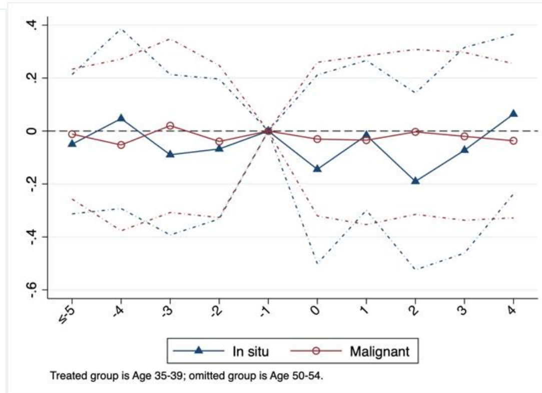
Source: National Health Interview Survey 2003-2018

Note: In Panel A, the grey circles plot the share of each age that reported a physician mammogram recommendation during the pre-period, while the black triangles denote the corresponding share in the post-period. In Panel B, the grey circles plot the point estimates, and the lines represent the corresponding 95 percent confidence intervals obtained from a modified version of equation (2). The independent variables of interest are indicators for each age interacted with an indicator for the post-recommendation period, with age 50 as the omitted (control) group. The estimates and descriptive statistics use the sample weights.

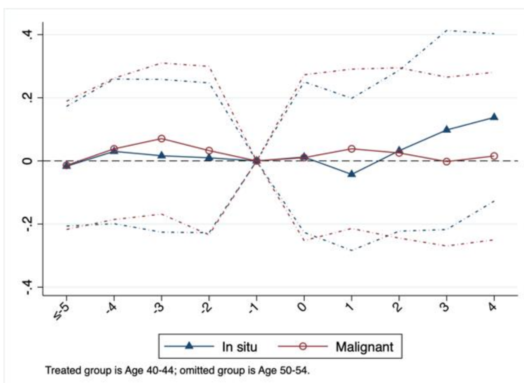
Appendix Figure 25: Event Study Estimates for Breast Cancer Effects



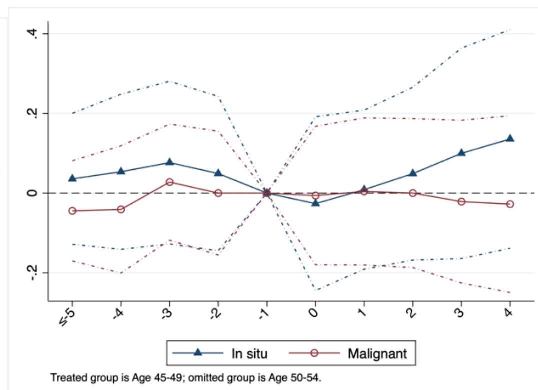
(A) 30-34



(B) 35-39



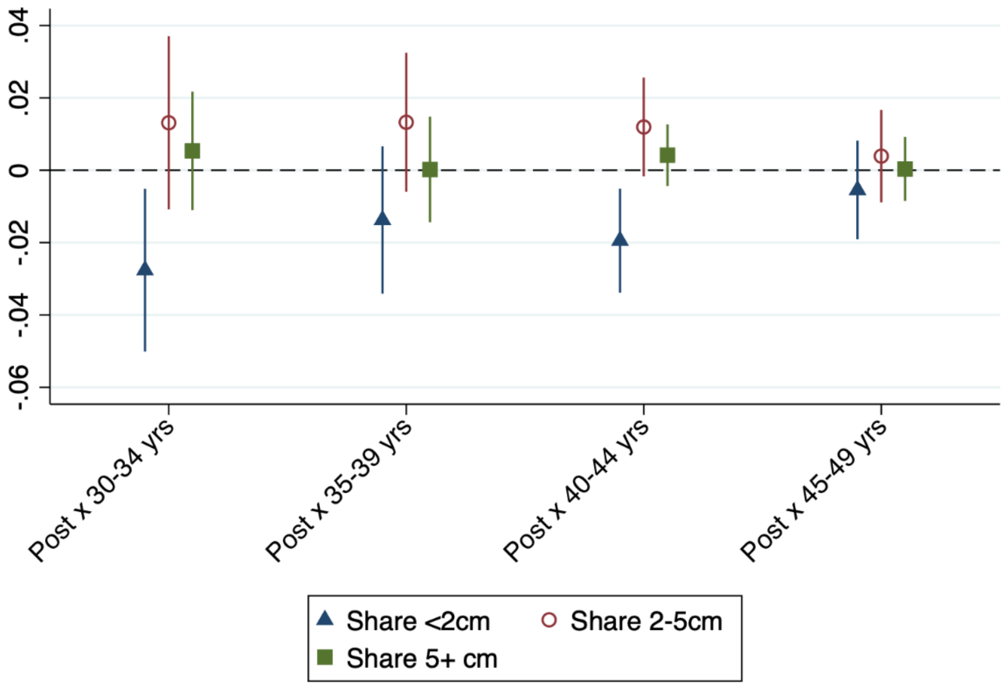
(C) 40-44



(D) 45-49

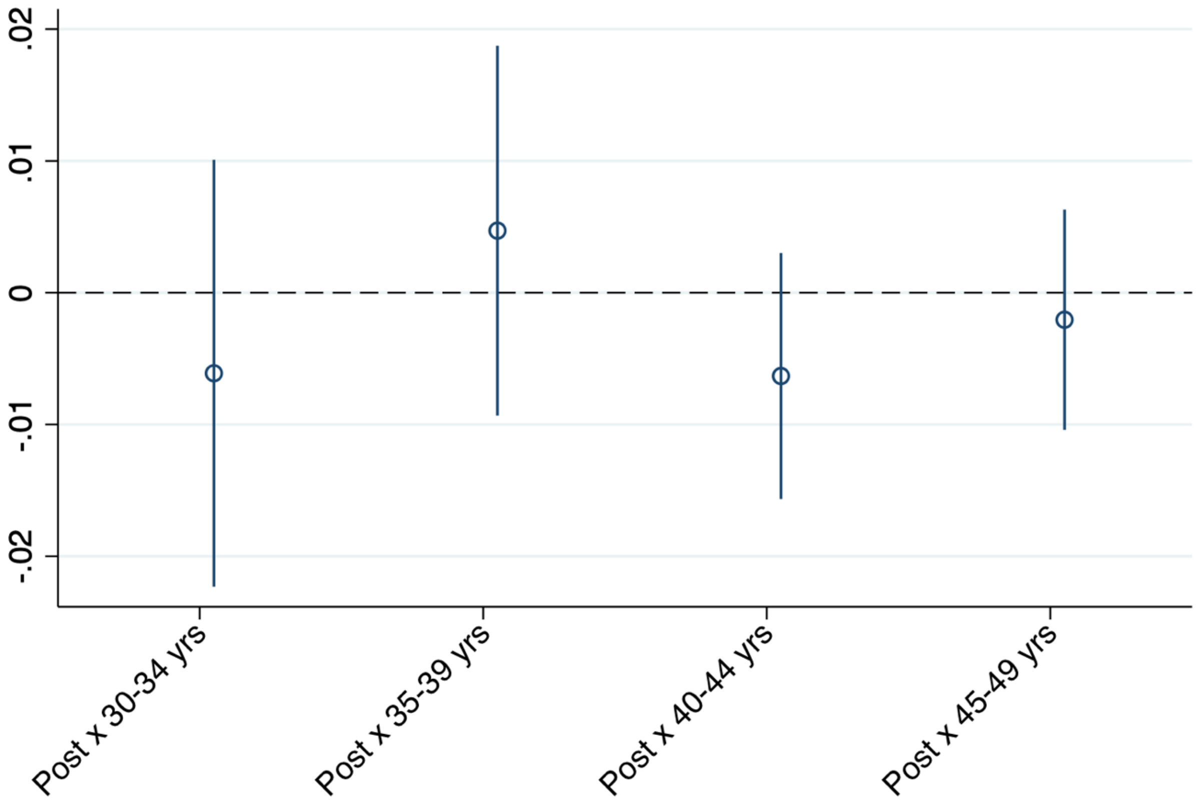
Source: National Cancer Institute's Surveillance, Epidemiology, and End Results Program 2002-2019
Note: The figures plot the event study estimates comparing changes in the natural log of in situ (blue triangles) and malignant (red circle) breast cancer diagnoses for each group relative to the changes for women aged 50-54. Regressions are weighted by population, and heteroskedastic robust standard errors are reported.

Appendix Figure 26: Effects on Tumor Size



Source: National Cancer Institute's Surveillance, Epidemiology, and End Results Program 2002-2019
Note: The figure plots the difference-in-differences estimates examining how the 2009 USPSTF's mammography recommendations affected the share of tumors less than 2 centimeters in size (blue triangles), the share between 2 and 5 centimeters (red circle), and the share greater than 5 centimeters (green square). The lines show the corresponding 95 percent confidence intervals obtained from a modified version of equation (1). The independent variables of interest are indicators for the five-year age groups interacted with an indicator for the post-recommendation period, with ages 50-54 as the omitted (control) group. Regressions are weighted by population, and heteroskedastic robust standard errors are reported.

Appendix Figure 27: Effects on 5-Year Breast Cancer Mortality



Source: National Cancer Institute's Surveillance, Epidemiology, and End Results Program 2002-2019
Note: Panel A plots the difference-in-differences estimates examining how the 2009 USPSTF's mammography recommendations affected the 5-year mortality rate for women diagnosed with breast cancer from 2002-2014 (the last year for which there is 5 years of post-diagnosis data). The circles plot the point estimates and the lines represent the corresponding 95 percent confidence intervals from a modified version of equation (1). The independent variables of interest are indicators for the five-year age groups interacted with an indicator for the post-recommendation period, with ages 50-54 as the omitted (control) group. Regressions are weighted by population, and heteroskedastic robust standard errors are reported.

Appendix Table 1: Facility and Patient Characteristics in the NMD Data Including More Facilities but a Shorter Pre-Period

	(1)	(2)
	Exam Count	Share of Total
Facility Type		
Academic	200,900	0.158
Community Hospital	468,796	0.369
Freestanding Center	580,947	0.458
Multi-Specialty Clinic	19,141	0.015
Location		
Metropolitan (> 100K)	422,238	0.333
Suburban/Small (50K-100K)	650,406	0.512
Rural (<50K)	197,140	0.155
Region		
Midwest	711,951	0.561
South	229,538	0.181
West	287,155	0.226
Northeast	41,140	0.032
Trauma Center Levels		
Level I	155,453	0.122
Level II	425,440	0.335
N/A	688,891	0.543
Volume		
< 5K	107,537	0.085
5K-10K	405,030	0.319
10K-30K	757,217	0.596
Patient Race		
Asian	11,548	0.009
Black	46,676	0.037
Other	49,241	0.039
White	516,417	0.407
Missing/Not Reported	657,450	0.518
Patient Ethnicity		
Hispanic	14,623	0.012
Non-Hispanic	945,233	0.744
Missing/Not Reported	309,928	0.244

Source: National Mammography Database 2009-2015
Note: The table reports facility and patient characteristics in the NMD data for the set of 19 facilities continuously reporting between Q1 2009 and Q4 2015.

Appendix Table 2: Facility and Patient Characteristics of the NMD Data in Lee et al. (2016)

	Share of Exams
Facility Type	
Academic	0.131
Community Hospital	0.401
Freestanding Center	0.442
Multi-Specialty Clinic	0.026
Location	
Metropolitan (> 100K)	0.620
Suburban/Small (50K-100K)	0.302
Rural (<50K)	0.078
Region	
Midwest	0.344
South	0.186
West	0.238
Volume	
< 5K	0.050
5K-10K	0.143
10K-30K	0.558
Patient Race	
Asian	0.007
Black	0.038
Other	0.036
White	0.353
Missing/Not Reported	0.551
Facility Count	90

Source: Lee et al. (2016)

Appendix Table 3: Characteristics of the BCSC Data

Key Data	
Facilities	304
Breast Imaging Exams	13,292,173
Patient Race and Ethnicity	
Asian	0.083
Black	0.102
Hispanic	0.048
Other	0.018
White	0.684
Missing/Not Reported	0.065

Source: BCSC (2025). The Breast Cancer Surveillance Consortium and its data collection and sharing activities are funded by the National Cancer Institute (P01CA154292). Downloaded 08/25/2025 from the Breast Cancer Surveillance Consortium Web site - http://www.bcsc-research.org.

Appendix Table 4: Maryland HCUP Summary Statistics

	(1)	(2)	(3)	(4)
Age Group →	Full Sample	Women Aged 30-39	Women Aged 40-49	Women Aged 50-54
Number of Screening Mammograms	168,782	6,685	98,126	63,971
Share of Mammograms:				
Non-Hispanic White	0.548	0.603	0.541	0.552
Non-Hispanic Black	0.333	0.288	0.328	0.344
Hispanic	0.040	0.032	0.045	0.033
Other race/ethnicity	0.080	0.077	0.086	0.071
Expected payer = Medicare	0.055	0.026	0.047	0.071
Expected payer = Medicaid	0.060	0.091	0.063	0.052
Expected payer = private insurance	0.756	0.796	0.753	0.758
Expected payer = other	0.129	0.087	0.138	0.120
Age-year Observations	175	70	70	35

Source: Maryland HCUP State Ambulatory Surgery and Services Databases 2008-2014
Note: Column 1 reports the summary measures for the entire sample. Column 2 reports the statistics for those aged 30-39, column 3 for those aged 40-49, and column 4 for those aged 50-54. The full sample is women aged 30-54. Observations are at the single year of age-year level.

Appendix Table 5: NHIS Summary Statistics of Share of Women That Report a Mammogram During Prior Year

	(1)	(2)	(3)	(4)
Age Group →	Full Sample	Women Aged 30-39	Women Aged 40-49	Women Aged 50-54
White	0.375	0.109	0.500	0.576
	(0.484)	(0.312)	(0.500)	(0.494)
Black	0.368	0.149	0.504	0.562
	(0.482)	(0.356)	(0.500)	(0.496)
Asian	0.299	0.093	0.444	0.498
	(0.458)	(0.290)	(0.497)	(0.501)
Hispanic	0.286	0.098	0.418	0.535
	(0.452)	(0.298)	(0.493)	(0.499)
Other	0.317	0.108	0.441	0.482
	(0.466)	(0.311)	(0.498)	(0.502)
Less than High School	0.272	0.095	0.359	0.457
	(0.445)	(0.293)	(0.480)	(0.498)
High School Diploma	0.345	0.117	0.436	0.516
	(0.475)	(0.321)	(0.496)	(0.500)
Some College	0.365	0.115	0.496	0.575
	(0.482)	(0.320)	(0.500)	(0.494)
College Degree	0.380	0.111	0.549	0.633
	(0.485)	(0.314)	(0.498)	(0.482)
Health Insurance Coverage	0.390	0.120	0.528	0.609
	(0.488)	(0.325)	(0.499)	(0.488)
No Health Insurance Coverage	0.163	0.071	0.229	0.258
	(0.370)	(0.256)	(0.420)	(0.438)
Married	0.375	0.113	0.511	0.594
	(0.484)	(0.316)	(0.500)	(0.491)
Widowed	0.422	0.148	0.419	0.500
	(0.494)	(0.356)	(0.494)	(0.501)
Divorced	0.378	0.122	0.445	0.511
	(0.485)	(0.328)	(0.497)	(0.500)
Separated	0.317	0.132	0.417	0.460
	(0.465)	(0.339)	(0.493)	(0.499)
Never Married	0.258	0.101	0.429	0.532
	(0.438)	(0.301)	(0.495)	(0.499)
ACS Recommended	0.518	-	0.492	0.565
	(0.500)		(0.500)	(0.496)
Not ACS Recommended	0.135	0.112	0.404	-
	(0.342)	(0.315)	(0.491)	

Source: National Health Interview Survey 2003-2018

Note: The table reports the share of women in each age and demographic group that reported that they had received a mammogram during the prior year. Column 1 reports the mean and standard deviation for the entire sample. Column 2 reports the statistics for those aged 30-39, column 3 for those aged 40-49, and column 4 for those aged 50-54. The summary statistics use the sample weights.

Appendix Table 6: HINTS Summary Statistics

	(1)	(2)	(2)	(3)
Age Group →	Full Sample	Women Aged 35-39	Women Aged 40-49	Women Aged 50-54
Ever Had Mammogram	0.759	0.385	0.811	0.940
	(0.428)	(0.487)	(0.391)	(0.237)
Involved in Care Decisions	0.555	0.530	0.556	0.573
	(0.497)	(0.499)	(0.497)	(0.495)
Too Many Recs.	0.281	0.287	0.283	0.273
	(0.449)	(0.452)	(0.451)	(0.445)
Trust Doctor	0.687	0.695	0.691	0.675
	(0.464)	(0.461)	(0.462)	(0.468)
Trust Gov. Health Agency	0.311	0.367	0.276	0.330
	(0.463)	(0.482)	(0.447)	(0.470)
Hispanic	0.156	0.165	0.169	0.124
	(0.363)	(0.372)	(0.375)	(0.329)
Non-Hispanic White	0.624	0.613	0.604	0.670
	(0.484)	(0.487)	(0.489)	(0.470)
Non-Hispanic Black	0.148	0.133	0.154	0.149
	(0.355)	(0.340)	(0.361)	(0.356)
Asian	0.042	0.052	0.042	0.034
	(0.201)	(0.222)	(0.202)	(0.182)
Other	0.030	0.036	0.031	0.024
	(0.170)	(0.187)	(0.172)	(0.152)
Less than High School	0.087	0.090	0.091	0.078
	(0.282)	(0.286)	(0.288)	(0.269)
High School Diploma	0.219	0.198	0.207	0.256
	(0.414)	(0.399)	(0.405)	(0.436)
Some College	0.331	0.291	0.347	0.334
	(0.471)	(0.455)	(0.476)	(0.472)
College Graduate	0.363	0.421	0.355	0.332
	(0.481)	(0.494)	(0.479)	(0.471)
Health Insurance	0.863	0.848	0.863	0.876
	(0.343)	(0.359)	(0.344)	(0.330)
Married	0.626	0.615	0.632	0.623
	(0.484)	(0.487)	(0.482)	(0.485)
ACS Recommended	0.710	0	0.851	1
	(0.454)	-	(0.356)	-
Observations	9,350	2,029	4,515	2,806

Source: Health Information National Trends Survey 2003-2019.
Note: Column 1 reports the mean and standard deviation for the entire sample (ages 35-54). Column 2 reports the statistics for those aged 35-39, column 3 for those aged 40-49, and column 4 for those aged 50-54. The summary statistics use the sample weights.

Appendix Table 7: HINTS Survey Question Availability Across Sample Waves

	2003	2005	2007	2011	2012	2013	2014	2015	2017	2018	2019
Ever Had Mammogram	●	●		●	●	●	●		●	●	●
Involved in Care Decisions	●		●	●	●	●	●		●	●	●
Too Many Recs.	●		●	●	●	●	●	●	●	●	●
Trust Doctor		●	●	●		●		●	●		●
Trust Gov. Health Agency			●	●		●		●	●		●

Source: Health Information National Trends Survey 2003-2019.
Note: A black dot indicates that the survey question was asked in a given sample wave. A year is omitted from the table if nationally representative surveys were not conducted in that year.

Appendix Table 8: SEER Summary Statistics

	(1)	(2)	(3)	(4)
Age Group →	Full Sample	Women Aged 30-39	Women Aged 40-49	Women Aged 50-54
Breast Cancer Cases	203.0	62.7	260.4	368.6
	(345.4)	(94.0)	(361.7)	(494.6)
In Situ Cases	44.7	7.7	61.4	85.6
	(80.3)	(12.0)	(84.0)	(113.6)
Malignant Cases	158.2	55.0	199.1	283.0
	(267.0)	(82.9)	(279.5)	(383.0)
Population (000s)	124.2	123.1	126.0	122.8
	(196.4)	(196.7)	(198.6)	(191.7)
5-Year Mortality Rate	0.145	0.168	0.127	0.134
	(0.093)	(0.118)	(0.070)	(0.061)
Share of Tumors ≤ 2 cm	0.426	0.344	0.462	0.513
	(0.142)	(0.156)	(0.103)	(0.085)
Share of Tumors 2 cm – 5 cm	0.388	0.443	0.364	0.329
	(0.129)	(0.157)	(0.095)	(0.069)
Share of Tumors 5+ cm	0.117	0.143	0.103	0.090
	(0.086)	(0.116)	(0.056)	(0.041)
Observations	2,070	828	828	414

Source: National Cancer Institute's Surveillance, Epidemiology, and End Results Program 2002-2019
Note: Column 1 reports the mean and standard deviation for the entire sample. Column 2 reports the statistics for those aged 30-39, column 3 for those aged 40-49, and column 4 for those aged 50-54. The full sample is women aged 30-54. Observations are at the registry-5-year age group-race-year level. Registries included are from AK, CA, CT, GA, HI, IA, KY, LA, NJ, NM, UT, and WA.

Appendix Table 9: Robustness of Reduction in the Number of Mammograms in the National Mammography Database

	(1)	(2)	(3)	(4)
Specification →	Baseline	(1) but Include All Women Aged 30-85+	(1) but Outcome is IHS(Mammograms)	(1) but Poisson Specification
Outcome: ln(Mammograms)				
1{30 ≤ Age ≤ 34}× **1**{2009 USPSTF Rec.}	-0.190***	-0.325***	-0.189***	-0.227***
	(0.062)	(0.061)	(0.062)	(0.057)
	[0.010]	[0.000]	[0.006]	
1{35 ≤ Age ≤ 39}× **1**{2009 USPSTF Rec.}	-0.586***	-0.722***	-0.586***	-0.564***
	(0.041)	(0.047)	(0.041)	(0.040)
	[0.000]	[0.000]	[0.000]	
1{40 ≤ Age ≤ 44}× **1**{2009 USPSTF Rec.}	-0.077***	-0.213***	-0.077***	-0.077***
	(0.014)	(0.017)	(0.014)	(0.011)
	[0.000]	[0.000]	[0.000]	
1{45 ≤ Age ≤ 49}× **1**{2009 USPSTF Rec.}	-0.063***	-0.199***	-0.063***	-0.061***
	(0.014)	(0.020)	(0.014)	(0.011)
	[0.000]	[0.000]	[0.000]	
R^2	0.996	0.995	0.996	-
Observations	200	360	200	200

Source: National Mammography Database 2008-2015

Note: The dependent variable in columns 1 and 2 is ln(number of mammograms). The baseline sample is women aged 30-54. Column 1 reprints the baseline estimate where the post-period indicator is interacted with four age group indicators (women aged 50-54 serve as the omitted group). The regression includes age and year fixed effects. Column 2 estimates the baseline specification but expands the sample to include adults aged 30-85+. Column 3 replaces the dependent variable with the inverse hyperbolic sine of the number of mammograms. Column 4 replaces the dependent variable with the number of mammograms and is estimated using a Poisson specification. Heteroskedastic robust standard errors are shown in parentheses and wild bootstrapped p-values clustered at the five-year age group-calendar year level are reported in brackets.

Appendix Table 10: Robustness of Reduction in the Number of Mammograms in the Maryland HCUP Data

	(1)	(2)	(3)	(4)
Specification →	Baseline	(1) but Include All Women Aged 30-85+	(1) but Outcome is IHS(Mammograms)	(1) but Poisson Specification
Outcome: ln(Mammograms)				
1{30 ≤ Age ≤ 34}× **1**{2009 USPSTF Rec.}	-0.504***	-0.543***	-0.503***	-0.469***
	(0.0789)	(0.0797)	(0.0787)	(0.0681)
	[0.000]	[0.000]	[0.000]	
1{35 ≤ Age ≤ 39}× **1**{2009 USPSTF Rec.}	-0.565***	-0.605***	-0.565***	-0.535***
	(0.0407)	(0.0397)	(0.0407)	(0.0395)
	[0.000]	[0.000]	[0.000]	
1{40 ≤ Age ≤ 44}× **1**{2009 USPSTF Rec.}	-0.0827***	-0.122***	-0.0827***	-0.0852***
	(0.0271)	(0.0174)	(0.0271)	(0.0182)
	[0.004]	[0.000]	[0.003]	
1{45 ≤ Age ≤ 49}× **1**{2009 USPSTF Rec.}	-0.101***	-0.140***	-0.101***	-0.0976***
	(0.0265)	(0.0170)	(0.0265)	(0.0170)
	[0.001]	[0.000]	[0.001]	
R^2	0.996	0.995	0.996	-
Observations	175	392	175	175

Source: Maryland HCUP State Ambulatory Surgery and Services Databases 2008-2014

Note: The dependent variable in columns 1 and 2 is ln(number of mammograms). The baseline sample is women aged 30-54. Column 1 reprints the baseline estimate where the post-period indicator is interacted with four age group indicators (women aged 50-54 serve as the omitted group). The regression includes age and year fixed effects. Column 2 estimates the baseline specification but expands the sample to include adults aged 30-85+. Column 3 replaces the dependent variable with the inverse hyperbolic sine of the number of mammograms. Column 4 replaces the dependent variable with the number of mammograms and is estimated using a Poisson specification. Heteroskedastic robust standard errors are shown in parentheses and subcluster bootstrapped p-values at the 5-year age group and calendar year level are reported in brackets.

Appendix Table 11: Changes in Mammography in NHIS Data

	(1)	(2)	(3)
Mammogram in the →	Past Year	Past 2 Years	Past 3 Years
1{30 ≤ Age ≤ 34}×	0.001	0.008	0.002
1{2009 USPSTF Rec.}	(0.015)	(0.014)	(0.013)
	[0.946]	[0.589]	[0.871]
	{0.083}	{0.113}	{0.136}
1{35 ≤ Age ≤ 39}×	-0.043***	-0.076***	-0.089***
1{2009 USPSTF Rec.}	(0.016)	(0.015)	(0.015)
	[0.006]	[0.000]	[0.000]
	{0.164}	{0.439}	{0.463}
1{40 ≤ Age ≤ 44}×	-0.019	-0.016	-0.017
1{2009 USPSTF Rec.}	(0.019)	(0.017)	(0.016)
	[0.312]	[0.351]	[0.306]
	{0.443}	{0.562}	{0.613}
1{45 ≤ Age ≤ 49}×	-0.012	-0.013	-0.017
1{2009 USPSTF Rec.}	(0.018)	(0.016)	(0.015)
	[0.495]	[0.477]	[0.243]
	{0.538}	{0.696}	{0.767}

Source: National Health Interview Survey 2003-2018
Note: The dependent variable in column 1 is an indicator for whether the women reported receiving a mammogram during the past year, in column 2 for whether she reported receiving a mammogram during the past two years, and in column 3 for whether she reported receiving a mammogram during the past three years. The sample is women aged 30-54. Heteroskedastic robust standard errors are shown in parentheses. Wild bootstrapped p-values from clustering standard errors at the five-year age group-calendar year level are shown in brackets. The sample mean from the year 2008, immediately prior to the recommendation change, is shown in curled brackets. The estimates use the sample weights.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$

Appendix Table 12: NHIS Estimates for Women Aged 40-54 Using Alternate Sample Windows

	(1)	(2)	(3)
Outcome →	Mammogram in the Past Year	Mammogram in the Past 2 Years	Mammogram in the Past 3 Years
Panel A: Survey Years 2003-2010			
1{40 ≤ Age ≤ 49}× **1**{2009 USPSTF}	0.002	-0.008	-0.009
	(0.023)	(0.021)	(0.019)
	[0.940]	[0.706]	[0.603]
Treated Mean in 2008	0.488	0.623	0.690
Observations	15,046	15,046	15,046
Panel B: Survey Years 2003-2013			
1{40 ≤ Age ≤ 49}× **1**{2009 USPSTF}	-0.021	-0.018	-0.014
	(0.018)	(0.016)	(0.015)
	[0.239]	[0.273]	[0.355]
Treated Mean in 2008	0.488	0.623	0.690
Observations	19,423	19,423	19,423
Panel C: Survey Years 2003-2015			
1{40 ≤ Age ≤ 49}× **1**{2009 USPSTF}	-0.022	-0.019	-0.018
	(0.016)	(0.015)	(0.014)
	[0.179]	[0.225]	[0.159]
Treated Mean in 2008	0.488	0.623	0.690
Observations	23,401	23,401	23,401
Panel D: Survey Years 2003-2018			
1{40 ≤ Age ≤ 49}× **1**{2009 USPSTF}	-0.015	-0.014	-0.018
	(0.016)	(0.014)	(0.013)
	[0.350]	[0.297]	[0.181]
Treated Mean in 2008	0.488	0.623	0.690
Observations	26,352	26,352	26,352

Source: National Health Interview Survey 2003-2018

Note: The dependent variable in column 1 is an indicator for whether the women reported receiving a mammogram during the past year, in column 2 for whether she reported receiving a mammogram during the past two years, and in column 3 for whether she reported receiving a mammogram during the past three years. The sample is women aged 40-54. Heteroskedastic robust standard errors are shown in parentheses. Wild bootstrapped p-values from clustering standard errors at the five-year age group-calendar year level are shown in brackets. The estimates utilize the sample weights.
*** p < 0.01, ** p < 0.05, * p < 0.10

Appendix Table 13: Comparing Difference-in-Differences Estimates for Women Aged 40-54 to Single-Difference Estimates

	(1)	(2)	(3)	(4)	(5)
	DD	Single Difference			
Specification →	Comparing Changes for Ages 40-49 vs. 50-54	Ages 40-49, Smooth Trend	Ages 50-54, Smooth Trend	Ages 40-49	Ages 50-54
Panel A: NHIS – Outcome is 1{Mammogram in the Past Year}					
1{40 ≤ Age ≤ 49} × **1**{2009 USPSTF}	-0.013				
	(0.016)				
	[0.392]				
1{2009 USPSTF}		-0.001	0.048*	-0.022**	-0.013
		(0.019)	(0.026)	(0.009)	(0.013)
		[0.964]	[0.063]	[0.022]	[0.313]
Mean for Ages 40-49 in 2008	0.488	0.488		0.488	
Mean for Ages 50-54 in 2008	0.558		0.558		0.558
Observations	26,358	17,672	8,686	17,672	8,686
Panel B: NMD – Outcome is ln(Mammograms)					
1{40 ≤ Age ≤ 49} × **1**{2009 USPSTF}	-0.070***				
	(0.010)				
	[0.000]				
1{2009 USPSTF}		0.039	0.083**	-0.095***	-0.025
		(0.026)	(0.032)	(0.018)	(0.023)
		[0.159]	[0.011]	[0.000]	[0.280]
Mean for Ages 40-49 in 2008	1,999.80	1,999.80		1,999.80	
Mean for Ages 50-54 in 2008	2,474.40		2,474.40		2,474.40
Observations	120	80	40	80	40
Panel C: MD HCUP – Outcome is ln(Mammograms)					
1{40 ≤ Age ≤ 49} × **1**{2009 USPSTF}	-0.092***				
	(0.018)				
	[0.000]				
1{2009 USPSTF}		-0.081	-0.034	-0.216***	-0.124***
		(0.069)	(0.021)	(0.042)	(0.014)
		[0.261]	[0.133]	[0.000]	[0.000]
Mean for Ages 40-49 in 2008	1562.88	1562.88		1562.88	
Mean for Ages 50-54 in 2008	1969.20		1969.20		1969.20
Observations	105	70	35	70	35

Sources: National Health Interview Surveys 2003-2018, National Mammography Database 2008-2015, Maryland HCUP State Ambulatory Surgery and Services Databases 2008-2014

Note: The data source and dependent variable are shown in the panel headers. Column 1 reports estimates obtained using a difference-in-differences model including age and year fixed effects comparing changes for women aged 40-49 to changes for those aged 50-54. Columns 2-5 report estimates obtained from a single-difference specification that includes a post-period indicator. Columns 2 and 4 limit the sample to 40-49-year-olds and columns 3 and 5 limit the sample to 50-54-year-olds. Columns 2-3 include a smooth linear trend. Heteroskedastic robust standard errors are in parentheses. Wild bootstrapped p-values clustered at the five-year age group-calendar year level are shown in brackets.

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$

Appendix Table 14: Sample Demographics

	(1)	(2)	(3)
Outcome →	Health Insurance Coverage	White	College Degree
Panel A: Sample Includes Women Aged 30-54			
1{Age ≤ 49}× **1**{2009 USPSTF}	-0.001	0.002	0.010
	(0.009)	(0.012)	(0.014)
	[0.899]	[0.832]	[0.497]
R^2	0.128	0.150	0.107
Observations	45,096	45,096	45,096
Panel B: Sample Includes Women Aged 40-54			
1{40 ≤ Age ≤ 49}× **1**{2009 USPSTF}	-0.000	-0.003	0.007
	(0.010)	(0.013)	(0.015)
	[0.976]	[0.988]	[0.674]
R^2	0.117	0.156	0.093
Observations	26,358	26,358	26,358

Source: National Health Interview Survey 2003-2018

Note: The dependent variable is the indicator variable listed in the column header. The sample in Panel A is women aged 30-54. The sample in Panel B is women aged 40-54. Women aged 50-54 are the omitted (control) group. Heteroskedastic robust standard errors are shown in parentheses. Wild bootstrapped p-values from clustering standard errors at the five-year age group-calendar year level are shown in brackets. The estimates use the sample weights.

*** p < 0.01, ** p < 0.05, * p < 0.10

Appendix Table 15: Effects by Maternal Breast Cancer History

	(1)	(2)	(3)
Sample →	Women Aged 30-54	Women Aged 30-54 Without a Maternal History of Breast Cancer	Women Aged 30-54 With a Maternal History of Breast Cancer
Panel A: Mammogram in the Past Year			
1{Age ≤ 49}× **1**{2009 USPSTF Rec.}	-0.041*	-0.037*	-0.106
	(0.021)	(0.022)	(0.076)
	[0.044]	[0.081]	[0.166]
Mean	0.349	0.337	0.536
R^2	0.229	0.230	0.331
Observations	19,676	18,491	1,185
Panel B: Mammogram in the Past 2 Years			
1{Age ≤ 49}× **1**{2009 USPSTF Rec.}	-0.055***	-0.054***	-0.070
	(0.019)	(0.020)	(0.062)
	[0.001]	[0.006]	[0.262]
Mean	0.470	0.456	0.684
R^2	0.333	0.334	0.399
Observations	19,676	18,491	1,185
Panel C: Mammogram in the Past 3 Years			
1{Age ≤ 49}× **1**{2009 USPSTF Rec.}	-0.055***	-0.052***	-0.113**
	(0.017)	(0.018)	(0.056)
	[0.001]	[0.005]	[0.046]
Mean	0.519	0.505	0.730
R^2	0.361	0.364	0.396
Observations	19,676	18,491	1,185

Source: National Health Interview Survey 2003-2018

Note: The dependent variables are indicators for whether the woman reported receiving a mammogram during the past year (Panel A), during the past two years (Panel B), and during the past three years (Panel C). The sample is women aged 30-54 with data on maternal breast cancer history. Women aged 50-54 are the omitted (control) group. The estimates include the full set of controls from equation (2). Column 1 uses the full sample, column 2 restricts the sample to those without a maternal history of breast cancer, and column 3 restricts the sample to those with a maternal history of breast cancer. Heteroskedastic robust standard errors are shown in parentheses. Wild bootstrapped p-values from clustering standard errors at the five-year age group-calendar year level are shown in brackets. The estimates use the sample weights. *** p < 0.01, ** p < 0.05, * p < 0.10

Appendix Table 16: SEER Estimates

	(1)	(2)	(3)	(4)	(5)	(6)
Specification →	ln(In situ cases+1)	ln(Malignant cases+1)	5-year Mortality Rate	Share 5+cm	Share 2-5cm	Share <2cm
1{30 ≤ Age ≤ 34}×	0.0126	0.0844	-0.00582	0.00591	0.0128	-0.0274**
1{2009 USPSTF Rec.}	(0.102)	(0.0633)	(0.00900)	(0.00834)	(0.0128)	(0.0120)
	[0.899]	[0.0170]	[0.356]	[0.370]	[0.308]	[0.0300]
1{35 ≤ Age ≤ 39}×	-0.169**	-0.00981	0.00505	0.000727	0.013	-0.0136
1{2009 USPSTF Rec.}	(0.0747)	(0.0573)	(0.00696)	(0.00735)	(0.00998)	(0.0103)
	[0.001]	[0.588]	[0.061]	[0.879]	[0.244]	[0.223]
1{40 ≤ Age ≤ 44}×	0.0352	0.00737	-0.006	0.00454	0.0117*	-0.0195***
1{2009 USPSTF Rec.}	(0.0497)	(0.0393)	(0.00542)	(0.00391)	(0.00604)	(0.00684)
	[0.199]	[0.447]	[0.127]	[0.110]	[0.116]	[0.0971]
1{45 ≤ Age ≤ 49}×	-0.00331	-0.0113	-0.00185	0.000554	0.00385	-0.00559
1{2009 USPSTF Rec.}	(0.0420)	(0.0320)	(0.00491)	(0.00400)	(0.00613)	(0.00676)
	[0.771]	[0.000]	[0.346]	[0.670]	[0.269]	[0.183]
R^2	0.956	0.967	0.596	0.440	0.510	0.730
Mean	3.949	5.468	0.135	0.113	0.379	0.443
Observations	2,070	2,070	1,487	1,374	1,374	1,374

Source: SEER data, 2002-2019.

Note: The sample is women aged 30-54, with women aged 50-54 as the omitted (control) group. The dependent variable in column 1 is the natural log + 1 of in situ precancer diagnoses, in column 2 the natural log + 1 of malignant diagnoses, in column 3 the 5-year mortality rate (measured 2002-2014), in column 4 the share of tumors larger than 5 cm, in column 5 the share 2-5 cm, and in column 6 the share less than 2 cm. The estimates use population weights. Heteroskedastic robust standard errors are shown in parentheses and wild bootstrap p-values from clustering standard errors at the five-year age group-calendar year level are reported in brackets.

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$

Appendix Table 17: Robustness of Reduction in In Situ Cases

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Specification →	Baseline	(1) but No Sample Weights	(1) but No Time-Varying Controls	(1) but before 2015 ACS Rec. Change	(1) but include registry-by-year fixed effects	(1) but Include All Women Aged 30-85+	(1) but Outcome is IHS(In situ cases)	(1) but Poisson Specification
Outcome: Ln(In situ cases +1)								
1{30 ≤ Age ≤ 34}× **1**{2009 Rec.}	0.0126	-0.0397	0.0774	-0.0581	0.0133	0.0221	0.0167	0.0956
	(0.102)	(0.0870)	(0.0761)	(0.113)	(0.105)	(0.109)	(0.103)	(0.129)
1{35 ≤ Age ≤ 39}× **1**{2009 Rec.}	-0.169**	-0.145**	-0.178***	-0.0838	-0.168**	-0.150**	-0.175**	-0.172
	(0.0747)	(0.0730)	(0.0550)	(0.0738)	(0.0771)	(0.0763)	(0.0763)	(0.109)
1{40 ≤ Age ≤ 44}× **1**{2009 Rec.}	0.0352	0.101*	-0.0893*	0.0381	0.0371	0.0457	0.0494	-0.0806
	(0.0497)	(0.0598)	(0.0500)	(0.0509)	(0.0523)	(0.0471)	(0.0508)	(0.104)
1{45 ≤ Age ≤ 49}× **1**{2009 Rec.}	-0.00331	-0.0451	-0.0886*	0.0119	-0.00184	0.00732	0.00505	-0.0732
	(0.0420)	(0.0535)	(0.0529)	(0.0457)	(0.0445)	(0.0343)	(0.0408)	(0.0941)
R^2	0.956	0.921	0.938	0.960	0.958	0.959	0.954	-
Mean	3.949	2.667	3.949	3.978	3.949	4.295	4.579	44.74
Observations	2,070	2,070	2,070	1,495	2,070	4,968	2,070	2,070

Source: SEER data, 2002-2019.

Note: The dependent variable is ln(in situ cases +1), except in column 7, in which the outcome variable is the inverse hyperbolic sine of the count of in situ cases, and column 8, in which the dependent variable is the number of in situ cases. The baseline sample is women aged 30-54 and observations are at the 5-year age group-race-registry-year level in all columns. Column 1 reprints the baseline estimate from Figure 7. Column 2 estimates the baseline specification but does not use the population weights. Column 3 omits the time-varying controls; column 4 restricts the sample to the periods prior to the American Cancer Society's decision to raise its recommended mammography age from 40 to 45-years-old, and column 5 includes registry-by-year fixed effects. Column 6 estimates the baseline specification but expands the sample to include adults aged 30-85+. Column 7 estimates the baseline specification but the outcome variable is the inverse hyperbolic sine of the count of in situ cases. Column 8 replaces the dependent variable with the number of in situ cases and is estimated using a Poisson specification with the baseline year (2002) population as the exposure measure. Women aged 50+ serve as the omitted (control) group. Except for column 2, the estimates use population weights. Heteroskedastic robust standard errors are shown in parentheses.