Is low-value care really low-value?
Evidence from prostate cancer screening

Liam Rose[a,b,*]

[a] *Department of Veterans Affairs, Health Economics Resource Center,*

[b] *Stanford University, School of Medicine,*

Abstract

In order to address the high costs of health care in the United States, there has been substantial focus on wasteful spending. Yet there is little evidence behind determining which services are "low-value" – that is, services for which the harms or costs outweigh the benefits. We examine this in prostate-specific antigen (PSA) testing for prostate cancer, one of the the most common services deemed low-value care. Using regression discontinuity and kink designs among patients in the Veterans Affairs Health Care System, we find that providers follow guidelines, with a sharp 4 percent decrease in PSA testing at the recommended cutoff age as well as a steep decline soon after, resulting in a commiserate increase in the rate of prostate cancer diagnoses. We further find that the proportion of patients with stage 3 and 4 and likelihood of death following a diagnosis both increase. Back of the envelope calculations of costs of PSA testing and downstream care suggest the total cost of these services are extremely unlikely to outweigh the loss in life-years, opening questions about how low-value care can be identified and whether it should continue to be a key target for lowering health care costs.

Keywords: Low-value care, Cancer screening, National Government Expenditures and Health

1. Introduction

Spending on health care in the United States far exceeds that of other countries, yet outcomes often lag behind other developed nations. A common interpretation is that this is a result of resource misallocation (Papanicolas et al., 2018; Chandra et al., 2016). It has been estimated that up to 20% of all U.S. health care spending consists of low-value care, making it a prime target for tackling these high health care costs without harming patients (Berwick and Hackbarth, 2012). "Low-value" care is defined as services that offer

*Corresponding author
Email address: liamrose@stanford.edu (Liam Rose)

no net clinical benefit in specific scenarios. Under this definition, identifying and reducing or eliminating these services would be key for improving efficiency and controlling costs in the health care sector.

It has been well documented that this type of care is prevalent, persistent, and associated with substantial costs across many health care systems.[1] There has been a tremendous amount of effort poured into curbing low-value care. The "Choosing Wisely" campaign – launched in 2012 to reduce utilization of unnecessary tests and procedures – has garnered widespread publicity and participation, with over 80 medical specialist professional organizations contributing more than 600 recommendations (Cassel and Guest, 2012; CLIFF et al., 2021). Many strategies have been attempted to implement these recommendations, including clinical decision support tools (Levick et al., 2013; Vartanians et al., 2010; Sharma et al., 2019), provider educations and feedback (McMillan and Ziegelstein, 2014; Kullgren et al., 2018), patient information (Hibbard et al., 2012; Aouad et al., 2019), and patient cost sharing (Siddiqui et al., 2015; Reid et al., 2017).

The definition of low-value care is typically outlined by professional organizations. Often these are groups in the clinical field of the service, such as the American Academy of Family Physicians, the American College of Surgeons, and the American Geriatrics Society. But other groups synthesize and aggregate these recommendations, notably including the American Board of Internal Medicine Foundation under the Choosing Wisely campaign and the U.S. Preventative Services Task Force (USPSTF). USPSTF "makes evidence-based recommendations about preventive services such as screenings, behavioral counseling, and preventive medications." The USPSTF grades services from A to D – as well as "I" for insufficient evidence. An "A" grade signifies that there is high certainty that the service is beneficial, while a "D" grade indicates there is high certainty that the service has no net benefit or that harms outweigh the benefits.

In this paper, we question the ability to define low-value care and whether it is really the "low-hanging fruit" that saves costs without harming patients. We do this by examining prostate cancer screening. Behind imaging for low-back pain, this is the second-most common form of low-value care (Schwartz et al., 2014). The screening consists of a blood test that measures the level of prostate-specific antigen (PSA) in the blood, with prostate cancer nearly always associated with elevated levels. While PSA testing is useful, false positives are possible, and a finding of elevated PSA levels represents only the beginning of a path to a possible prostate cancer diagnosis. Patients often undergo repeat tests, followup visits with a urologist, biopsies, and imaging tests. Should the patient eventually receive a prostate cancer diagnosis, treatment

[1]There is a long literature on low-value care. Schwartz et al. (2014) and Colla et al. (2015a) documents that low-value care is widespread in Medicare, affecting upwards of 40% of beneficiaries. Reviews by Colla et al. (2017) and Maratt et al. (2019) examine demand- and supply-side interventions to reduce low-value care. Moriates (2023) and Ganguli et al. (2023) highlight the difficulty in reducing low-value care. There has also been much work on trying to reduce low-value care in specific domains, such as low-back pain (Buchbinder et al., 2020) and imaging (Kjelle et al., 2021).

options include radiation, hormonal therapy, and surgery. However, many cases are treated with active surveillance – also known as "watchful waiting" – when it is likely treating the cancer would cause more damage than the cancer itself. This approach is used when the tumor is in early stage and slow growing, and/or if the patient has a limited life expectancy due to other health issues. A positive PSA test can often lead to a multitude of downstream services and intensive treatment for tumors that would not cause any symptoms. As a result, USPSTF gives a "D" grade to prostate cancer screening for men 70 years and older.

We focus on prostate cancer screening in the Veterans Affairs Health Care System (VA). The VA provides an optimal setting for examining low-value PSA testing for several reasons. First, over 80 percent of VA enrollees are male, making prostate cancer screening a priority for VA providers. Second, the integrated nature of the VA system allows for the tracking of downstream costs and outcomes without changes to insurance status. Finally, while USPSTF has changed guidelines several times in recent years, guidelines within VA have remained steady in recommending against screening for those aged 70 and older.[2] Using data from 2007-2019 with over 40 million PSA tests, we leverage the threshold at age 70 to examine the effect of the low-value care recommendations on downstream outcomes and costs.

Specifically, we employ regression discontinuity and regression kink designs due to the change in levels associated with following low-value care testing guidelines and the change in slope associated with downstream outcomes. We find that the low-value care recommendations on PSA testing cause a small but significant 4 percent drop in PSA testing at age 70. We then show that predictably, prostate cancer diagnoses drop by a nearly equal amount. However, we next show that there are significant kinks in the probability of a cancer diagnosis being stage III/IV when diagnosed and the probability of mortality within two years of diagnosis. Finally, we show that the change in costs associated with PSA tests and all downstream services are very unlikely to outweigh the loss in life years from the cessation of PSA testing.

This paper contributes to the literature on productivity in health care. Categorizing care into ineffective and effective bins is less than straightforward and has long been the matter of significant discussion (Hollingsworth, 2008; Wennberg, 2002; Morden et al., 2014). Some of the most costly services have limited or no associated clinical trials, such as commonly performed surgical procedures (McCulloch et al., 2002). Chandra and Skinner (2012) approach this by categorizing medical technology productivity into highly cost-

[2]From 2008-2012, the USPSTF recommendation was against screening for prostate cancer for men age 75 years old and older. From 2012-2018, USPSTF recommended against PSA-based screening for prostate cancer. Since 2018, USPSTF has recommended against PSA screening for men age 70 years old and older. Full details of these recommendations, including archived recommendations, are listed on the USPSTF website: https://www.uspreventiveservicestaskforce.org/uspstf/recommendation/prostate-cancer-screening. VA guidelines are kept in internal documentation at vaww.prevention.va.gov and are current as of April 2023, but also referenced publicly in an VA OIG report on prostate cancer screening (of Veterans Affairs and of Inspector General, 2015).

effective services, services that are only cost-effective for specific groups, and services that are low-value. They then show that countries that provide more of the latter two categories experience higher growth rates of health care spending relative to GDP. Chandra et al. (2016) use these categories as proxies for inputs to show wide variability in productivity across hospitals. To define low-value care, Chandra et al. (2016) expand the *Choosing Wisely* list to include post-acute care and ICU care for chronically-ill patients, all of which have limited evidence of effectiveness for the marginal patient. Colla et al. (2015b) show wide variation in the use of these inputs, and Cutler et al. (2019) demonstrate that most of this variation is driven by physicians.

More generally, this paper opens the question of how health care services should be defined as "low-value." For our setting, PSA testing has been subject to five randomized controlled trials including over 700,000 men. A 2018 meta-analysis of these trials showed that PSA testing did not improve overall mortality, but control groups did show higher rates of disease-specific mortality and late-stage diagnosis (Ilic et al., 2018). The two most recent of these concluded that "the findings do not support single PSA testing for population-based screening" and "this intervention should not be considered for public screening", respectively (Martin et al., 2018; Lundgren et al., 2018). Yet both of these studies did not enroll men older than 70 years old, there is evidence that CAP trial based in the UK was subject to significant contamination (Clift et al., 2021), and an earlier trial did find PSA testing lowered disease specific mortality (Schröder et al., 2014). While it is difficult to compare estimates directly, our estimates of the LATE from this analytic strategy suggest PSA testing is effective for a cohort of patients that were not represented in previous clinical trials. More importantly, most recommendations for curbing low-value care do not have any associated randomized control trial (Kim et al., 2021). Our results show that substantial ambiguity can exist even with these trials present, indicating that categorization into "low-value" remains a significant obstacle.

In the next section we provide brief background about our setting. This is followed by a presentation of our empirical strategy, results, and conclusion.

2. Methods

2.1. Data

The Department of Veterans Affairs Health Care System is the largest integrated health care system in the United States. VA provides care to over 6 million individuals annually in inpatient and outpatient settings across the country and in US territories at over 1100 locations. While VA also refers some services to non-VA providers, this study focuses on encounters provided directly by VA providers in VA facilities. Most enrollees face no cost sharing for visits. Individuals that receive disability benefits from the Veterans Benefits Administration do not face any cost sharing for health care visits. Individuals that do not face a

copay for primary and specialty care visits if the visit is not related to condition related to the patient's time in service. In 2020, that amount was $15 and $50, respectively. No enrollee faces any cost for lab tests, including PSA tests. Most VA enrollees have at least one encounter per year, with the VA providing about 15 million primary care visits every year (Hynes et al., 2021).

Using VA medical records, we capture the universe of PSA tests conducted by VA from 2007-2019.[3] PSA tests are simple blood tests and often ordered with other blood tests during regular checkups and visits. Our dataset includes tests ordered by any provider, including primary care teams, urology clinics, and general internists. Our dataset includes 40,550,559 PSA tests on 6,515,600 unique individuals, including 15,136,118 tests conducted on individuals between 65 and 75.

We then use the VA Central Cancer Registry (VACCR) to identify prostate cancer diagnoses and stage at diagnosis. Like other cancer registries, the VACCR uses information abstracted from medical records by local site staff. The VACCR contains data going back to 1995, and includes cases that are diagnosed outside of the VA if subsequent cancer care is received within VA. These data also indicate if the individual died from the cancer. All-cause mortality is obtained through VA vital status files, which in addition to VA medical records includes data feeds from the Veterans Benefits Administration (VBA), Social Security Administration (SSA), and Centers for Medicare & Medicaid Services (CMS). For our analysis, however, we focus on prostate-cancer mortality.

We follow previous work of Pickering et al. (2022) to capture downstream services of PSA testing. This approach is broad and includes services related to the PSA test – including follow-up PSA tests – as well as treatments for prostate cancer. Specifically, this includes costs of visits with a urologist, additional PSA testing, prostate imaging and biopsy, and surgeries and treatments for prostate cancer (see appendix Table A1 for a full list of CPT and ICD codes for downstream services). Importantly, this can include costs for both downstream services that lead to a cancer diagnosis and those that are ultimately shown to be a false positive. To be conservative, we include all costs associated with these services rather than only those directly linked to an initial PSA test. This includes any visit in these categories within six months of the initial PSA test. For individuals with multiple tests, a PSA test was only counted as an index test if there was no other test within this six-month period. Costs are derived from VA's Managerial Cost Accounting (MCA) data, which serve as the official accounting source of VA health care expenditures. Because costs include expenditure for the entire visit, we winsorize costs at the 99th percentile to account for extreme outliers.

[3]We do this with ICD-9 codes (790.93), ICD-10 codes (G0102, G0103), and CPT codes (84152, 84153, 84154).

2.2. Approach

We utilize both a regression discontinuity design and a regression kink designs. These approaches are useful in this application because of the nature of age-based testing recommendations: testing can be stopped discretely at a specified age, but mortality changes slowly over time as symptoms begin to appear. As such, we further follow Dong (2018) in implementing the Regression Probability Jump and Kink (RPJK) design, which allows for identification whether there is a jump, kink, or both is present. This gives the two-stage least squares estimator where either a jump or kink is present, imitating the standard approach with a fuzzy RD.

In the RD design we estimate:

$$Y_c = \beta_0 + \beta_1 Post_c + \beta_2 Age_c + \beta_3 Age_c \times Post_c + \varepsilon_c \tag{1}$$

where Y is the outcome for age cell c, $Post_c$ is a binary variable for if the age cell is greater than or equal to 70, and Age_c is the age cell centered around age 70. We show that results are robust to more flexible functions of age in the appendix. We use Equation 1 to estimate PSA testing and number of prostate cancer diagnoses. Bandwidth is calculated using optimal bandwidth procedures of Calonico et al. (2015), but bandwidth robustness is also reported in the appendix.

Because VA demographics vary greatly over time – primarily due to the Vietnam War veterans in our cohort – PSA testing and prostate cancer diagnoses outcomes need to be expressed in rates to avoid bias in age profiles. Large changes in the volume of a sppecific service due to increased population can be misattributed to provider or patient behavior. To construct denominators, we use birth dates, death dates, and VA enrollment dates to calculate the number of person-months lived during our sample period. For each month age cell, we calculate the total number of individuals that were that age during the sample period. We then multiply this number by 10,000 for ease of interpretation. To show that our sample does not change discretely at age 70, Table 1 shows the balance across the threshold for select characteristics, as well as a McCrary test (McCrary, 2008) of the change in person-months at the threshold. We include whether or not the patient's race/ethnicity is white, whether or not the patient is married, whether or not the patient is in priority group 1-4, distance from the patient's home address to a VA facility, and 1-year predicted hospitalization risk according to a VA clinical model.[4] The clinical model is the Care Assessment of Needs (CAN) that is regularly updated and available for all VA users. All characteristics are taken from

[4]VA priority groups go from 1 through 8, but all groups are eligible for health care at VA facilities. Priority groups 1-4 have higher service-connected disability ratings through VBA or receive VA aid and attendance benefits.

the closest day on or before the index PSA test.[5] None of these characteristics show statistically significant changes, and the McCrary test likewise is not statistically significant.

Similarly, in the RK design, we estimate:

$$Y_c = \alpha_0 + \alpha_2 Age_c + \alpha_3 Age_c \times Post_c + \epsilon_c \tag{2}$$

We use Equation 2 to estimate stage at diagnosis and mortality. Advanced stage at diagnosis and death within 2 years of diagnosis are estimated in proportions for diagnoses in each age cell. Rather than use optimal bandwidth calculations for RD designs, we use larger bandwidths of 120 months (i.e. age 60-80) due to the longer time frame for these outcomes. Bandwidth robustness is again shown in the appendix.

We then use the RPJK estimator developed by Dong (2018) to find the effect of PSA testing on stage at diagnosis and mortality. This method is well suited to situations where there is a kink but it is unclear if there is a significant jump, particularly with longer-term outcomes. The estimator takes the form:

$$\tau = \frac{\omega_1(\beta_1) + \omega_2(\alpha_1)}{\omega_1(\beta_1^{'}) + \omega_2(\alpha_1^{'})} \tag{3}$$

where $\omega_1 = cov(T^*, Z_1^*)$ and $\omega_2 = cov(T^*, Z_2^*)$. T^*, Z_1^* , and Z_2^* are the residuals from local linear regressions of the testing rate, $Post$, $Age \times Post$, respectively, on the running variable Age and a constant. The two sets estimates – β, β', α, α' – represent the RD and RK estimates of the reduced form and first stage, respectively. Intuitively, the weights ω represent the relative strength of the jump or kink, such that if $\beta_1 = 0$ (i.e. no jump) then Equation 3 collapses to the RK estimand. If there is a jump (i.e. $\beta_1 \neq 1$) then this asymptotically collapses to the classic 2SLS RD approach. This allows us to recover the 2SLS estimator in the case there is a jump or kink in either the first stage (PSA testing) or reduced form (prostate cancer diagnoses, proportion of diagnoses stage III/IV, mortality). For these calculations, the first stage is estimated in log terms such that both the first stage and reduced form can be interpreted as a percent change. Standard errors are estimated via the delta method.

3. Results

We first show the effects of the age 70 testing guideline on the rate of PSA testing and subsequent prostate cancer diagnoses. Figure 1 shows the age profile of PSA testing per 10,000 person-months from 2007-2019.

[5]The CAN score is updated weekly for most patients. Distances to VA facilities are updated yearly with administrative data from the US Post Office.

While the rate of PSA testing is declining somewhat before age 70, there is no notable bump just before age 70, suggesting that individuals do not receive a final test before the age recommendation. There is then a sharp, 4 percent drop in the PSA testing rate at age 70, as shown in Table 2. The rate of PSA testing declines even more quickly after this point. Correspondingly, Figure 2 shows a similar drop in prostate cancer diagnoses per 10,000 person-months at the threshold. This corresponds to a 6.3 percent drop in diagnoses. With the assumption that PSA testing is the only cause of this reduction, the implied IV estimate gives a 150 percent drop in prostate cancer diagnoses caused by the reduction in PSA testing. However, the standard errors (generated via the delta method) indicate that a one-for-one drop is well within the confidence interval. This indicates that at least some proportion of providers listen to the guidelines, and that there is an expected drop in diagnoses to go along with the drop in testing.[6]

Next, we examine how the change in PSA testing rates affected late-stage prostate cancer diagnoses and prostate-cancer mortality. Figure 3 gives the age profile of the proportion of new prostate cancer cases that are diagnosed at stage III or stage IV. For diagnoses age 60 to 70, this proportion is relatively steady at about 5 percent of cases. At age 70, this proportion begins to rise, reaching over 10 percent by age 75. Regression kink estimates shown in Table 3 indicate that a one year increase in the age at diagnosis after age 70 increases the likelihood of a late-stage diagnosis by 0.6 percentage points.[7] Likewise, Figure 4 gives the age profile of the proportion of new prostate cancer cases that result in death from prostate cancer within 2 years.[8] As with Figure 3, this mortality rate is steady from ages 60 to 70, at around 2.5 percent of cases. At age 70, this rate begins to rise, going to 6 percent at age 75. The regression kink estimate indicates that a one year increase in the age at diagnosis after age 70 increases the 2-year mortality rate by 1.2 percentage points, or 40 percent. When combined with the first-stage estimates listed above using the RPJK estimator, there is a 32 percent increase in proportion of cases diagnosed at stage III or stage IV and a 37 percent increase in the prostate cancer mortality rate.

Changes in costs associated with PSA testing are shown in Figure 5. This is expressed as the costs of all related services per 10,000 person-months for the entire study sample. Costs are relatively steady until age 70, then begin to slowly fall soon after. Table 4 shows that costs decrease by about $11 per 10,000 person-months for each month after age 70, with an estimate of $9,698 per 10,000 person-months just before the age cutoff. Extrapolating this out for one year, this indicates that PSA testing-related costs are about 1.4 percent lower for individuals age 71 compared to those age 70, and that savings over this year would be

[6] We further show that irrespective of the change in the testing rate, the mean and median test results do not change at the age threshold in Appendix Figure A7. This simply indicates that there are no obvious changes to information that can be gleaned from the test at age 70.

[7] Corresponding regression discontinuity estimates are not statistically significant, show visually in Appendix Figure A8.

[8] Appendix Figure A10 gives the same age profile with the proportion of cases that result in death from any cause within two years.

about $164 per 10,000 person-months. We can then compare this to the increase in deaths from prostate cancer. From age 70 to 71, our estimates show that the 2-year prostate cancer mortality rate increases from 3.059 percent to 3.732 percent (+22%). Over that same age band, costs associated with PSA testing go from just under $8,900 per 10,000 person months to $8,732 per 10,000 person months (-11.4%). Thus, the elasticity of PSA testing costs with respect to prostate cancer mortality is -15.71. Alternatively, one could calculate this with the RD estimates also in Table 4. Here, there is a 7 percent drop in costs at age 70 (773.14/10096.83). Ignoring the issue of comparing the RD and RK based estimates, this would result in an elasticity of -3.14.

For context, the elasticity of NHS expenditure in the UK on all-cancer mortality is estimated to be -0.27 on the low end and -1.18 on the high end, with all-cause mortality expenditure elasticities estimated to be between -1.089 and −1.372 (Claxton et al., 2018; Gallet and Doucouliagos, 2017; Martin et al., 2023). Our estimate is far greater than that of gaining health insurance coverage through Medicare for the chronically ill and gaining Medicaid coverage from the Oregon Health insurance Experiment (-0.19 and -0.09, respectively) (Andersen, 2018; Finkelstein et al., 2012).

While our criteria for inclusion of visits into downstream costs is generous, a reader may not believe that these costs adequately capture the true costs of PSA testing. Certainly more can be added: patient copays, costs for patient travel and time, patient emotional distress, opportunity cost of provider time, and opportunity cost of laboratory staff to process the tests, among others. That being said, it would take extreme changes in our estimates in savings per PSA test to make the savings associated with labeling PSA testing low-value to be worthwhile. Because the cost per test in our data for individuals age 65 to 75 – including all downstream services – is just $28, the savings potential is relatively limited even if peripheral costs were added.

4. Discussion and Conclusion

In this paper, we find that the low-value care guidelines decrease the rate of PSA testing and prostate cancer diagnoses at age 70. This first set of results is expected; when guidelines dictate that testing should be reduced it is reduced, and subsequent detection of cancer cases falls. Perhaps the more surprising element is that there is not a larger drop, but this falls in line with previous literature on the difficulty of reducing low-value care.

PSA testing on older adults is not recommended because it is deemed that the costs outweigh the benefits. Prostate cancer treatment can be invasive and complex, and individuals may have a higher quality of life without undergoing treatment. However, if PSA testing indeed offers no net benefit, there should be little increase in late-stage diagnoses or mortality, or at least not at a magnitude that is large compared to

downstream costs of utilization. Yet we show that a one year increase in age at diagnosis after age 70 increases the probability of a stage III or IV diagnosis by 19 percent, and an increase in the probability of cancer-related death by 40 percent. It is possible that these changes would be acceptable if they were associated with significant cost savings. However, we find costs were only 7 percent lower. Moreover, these cost savings are qualitatively small: with 1,425,994 person-months lived between the age of 70 and 71 during the study period, costs for PSA testing and downstream services amounted to an average of XXXX per year, or approximately X % of the VA budget for healthcare. This aligns with previous literature showing that PSA testing alone cost Medicare $98 million in 2008, or 0.0002 percent of the Medicare budget (Schwartz et al., 2014), and PSA testing with downstream services cost VA $2 million in 2018 for those over age 75, or 0.0002 of the VA health budget for that year. We find that the increase in late-stage diagnoses and mortality have implied price elasticities that far exceed that of both cancer-specific and general health care expenditure. Put differently, if PSA testing for individuals at aged 70 was proposed as a new intervention, it would clearly be seen as worthwhile.

An obvious question from these results is how they can be true when there are multiple RCTs questioning the effectiveness of PSA testing. Figure 6 compares mortality estimates from this paper to several large-scale RCTs.[9] This shows that our estimates are comfortably within the confidence intervals of the estimates from the RCTs. Comparison to these RCTs is not straightforward for several reasons, even aside from quarrels about differences in estimands. First, these studies enroll younger populations on average. Lundgren et al. (2018) had a mean age of 62 at the start of the study (with a range of 54-70), the CAP trial (Martin et al., 2018) had a mean of 58 years old (range of 50-69), and the European Randomised Study of Screening for Prostate Cancer (Schröder et al., 2014) had 61 years old (range of 55-69). Second, there is significant non-compliance associated with these RCTs. A major reason that the guideline recommendations for PSA testing were changed frequently in the 2010s is because of this issue. The Prostate, Lung, Colorectal, and Ovarian (PLCO) trial randomly assigned men to annual PSA testing or care as usual, and found equivalent rates of prostate-cancer mortality (Andriole et al., 2009). Subsequently it was found that nearly 90% of the control group had undergone at least one PSA test before or during the trial, and surveys of participants suggested that the control group may have even had cumulatively more tests than the treatment group (E. et al., 2016). The CAP trial is also likely to have suffered from significant testing rates in the control group (Clift et al., 2021). Finally and perhaps most closely related to determining what care counts as "low-value", these RCTs do not directly test at what age PSA testing should be stopped. A recent extended followup of the CAP trial revealed small protective benefits of PSA testing against prostate-cancer mortality Martin

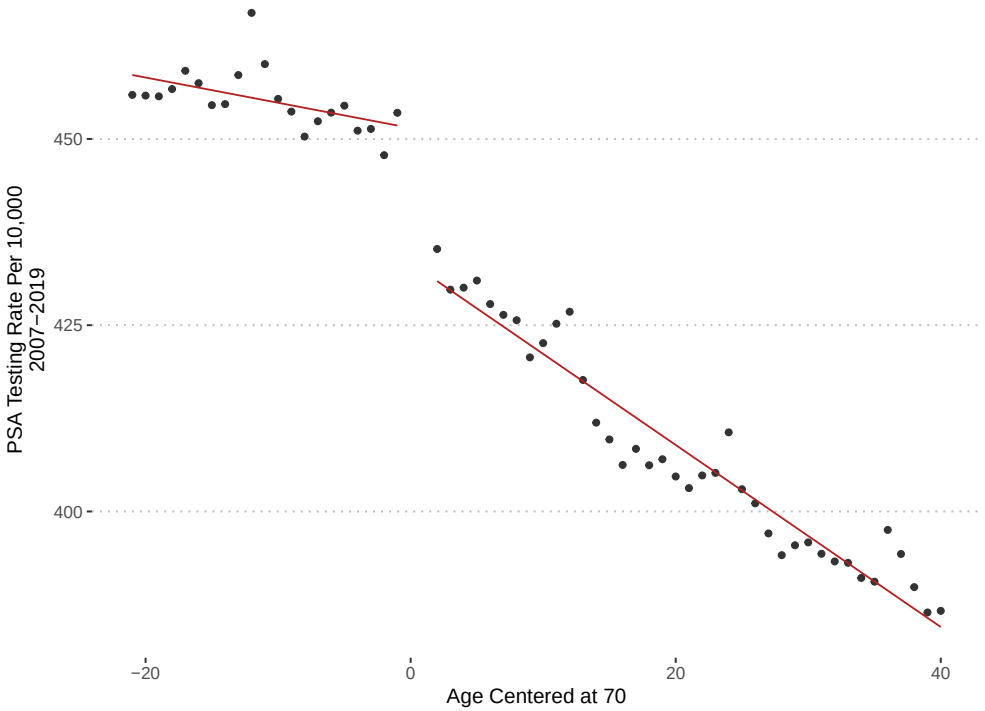
[9]For the RCTs, the estimates presented are rate ratios from IV analyses that adjust for PSA testing rates in intervention and control arms. For this paper, the 2SLS estimate in Table XXX is converted into an exponentiated coefficient as both stages come from logged outcome regressions.

et al. (2024). While the effect size is small, the fact that the 10-year followup (Martin et al., 2018) did not reveal protective effects while the 15-year follow-up did (Martin et al., 2024) highlights the difficulty of pinpointing when a service is valuable and when it is not, even when there are associated RCTs.

This study is not intended to take a stance on whether or not PSA testing is effective. It is abundantly clear that PSA testing is a cheap and unintrusive but imperfect technology for detecting prostate cancer. Rather, this study is meant to highlight that determining the value of care is not straightforward and that eliminating low-value care may not be the low hanging-fruit it seems to be. Policies created to reach for these potential savings may be well outside what guidelines clinical trials could reasonably provide. An analogous case has been shown before with sex differences in pharmaceuticals, with an FDA ban on many women in clinical trials until 1993 resulting a much greater rate of adverse drug events for women. Previous work has also shown that the influenza vaccine – which has substantial RCT evidence for its effectiveness – does not prevent hospitalizations and mortality when policy dictates that certain subgroups be prioritized (Anderson et al., 2020). While this example relates to public health decisions for contagious diseases, it highlights that services and treatments that have evidence of effectiveness with strong internal validity can have quite different results when put into practice outside the confines of a clinical trial. More importantly, the majority of services deemed "low-value" do not have associated clinical trials, making it even more difficult to determine which subpopulations may benefit and which may not. It can be the case the a superceding technology renders a service low-value; certainly none would argue that the rise of minimally invasive surgery has made open surgery a poor choice for many surgical cases. When uncertainty exists, however, labeling a service as "wasteful" needs to done with careful consideration.

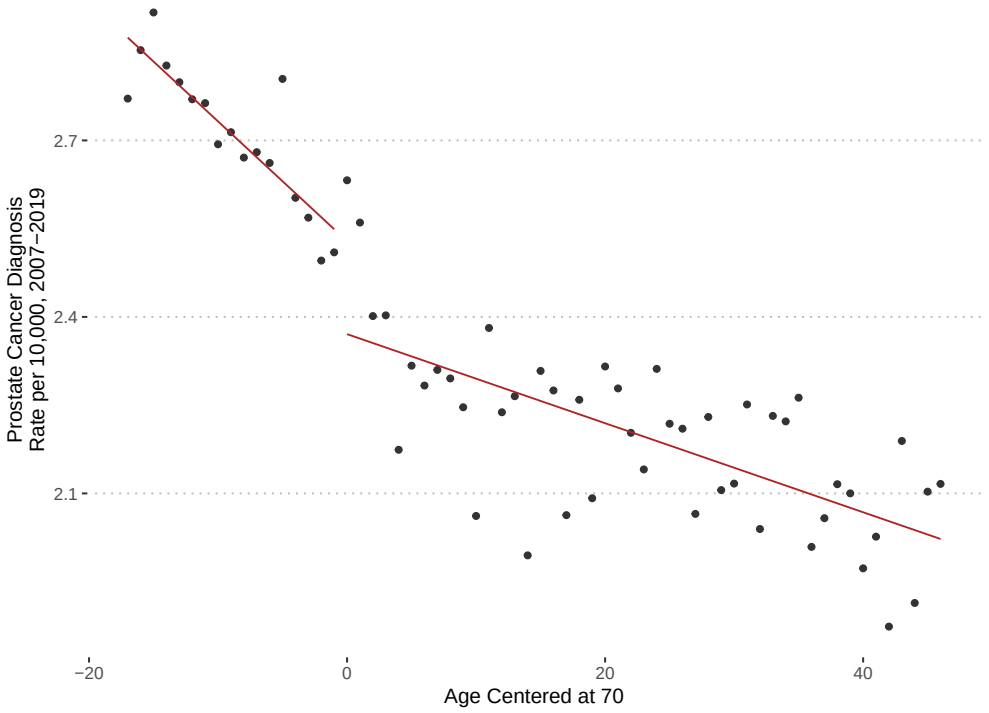
5. Figures and Tables

Figure 1: Age Profile of PSA Testing, 2007-2019



Notes: Age profile centered at age 70 of PSA testing per 10,000 person-months from 2007-2019 with fitted lines from an RD regression.

Figure 2: Age Profile of Prostate Cancer Diagnoses, 2007-2019



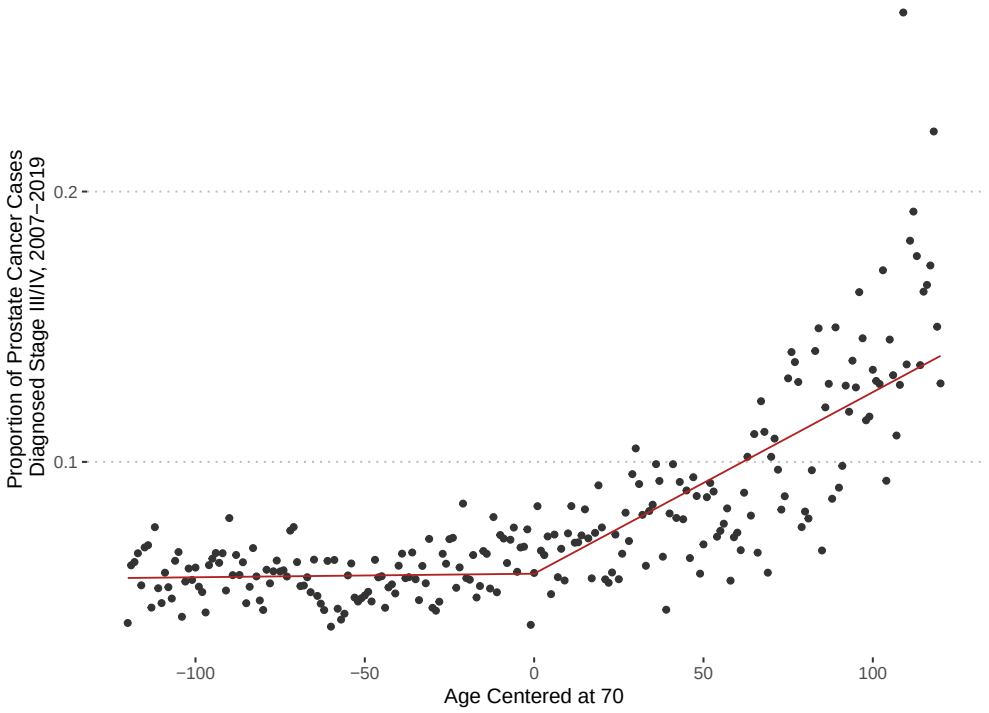
Notes: Age profile centered at age 70 of prostate cancer diagnoses per 10,000 person-months from 2007-2019 with fitted lines from an RD regression.

Table 1: Balance Across Age 70 and McCrary Test

Characteristic	Estimate	SE	p-value	Mean
White	0.0018	(0.001)	0.16	0.82
Married	0.0003	(0.002)	0.89	0.53
Priority Group	0.0027	(0.003)	0.32	0.42
Distance to VA	0.0058	(0.065)	0.93	16.92
1-year hosp. risk	0.0011	(0.001)	0.29	0.22
Person-months	-2929.8097	(7461.069)	0.70	

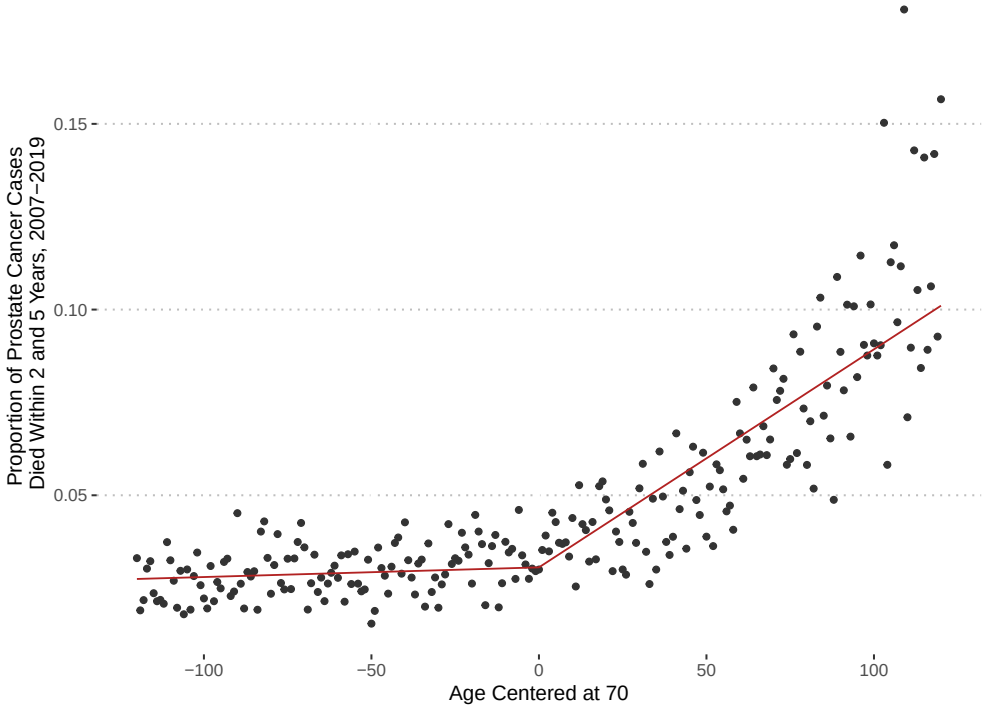
Note: RD estimates of the change at age 70 for the listed characteristics. *Distance to VA* signifies the driving distance to the nearest VA facility with a primary care provider, and *1-year hosp. risk* is the predicted risk of hospitalization within one year from the Care Assessment of Needs (CAN) score, an index of hospitalization and mortality risk used in VA. *Person-months* is the number of person-months lived in the sample.

Figure 3: Age Profile of the Proportion of Prostate Cancer Cases Diagnosed Stage III/IV, 2007-2019



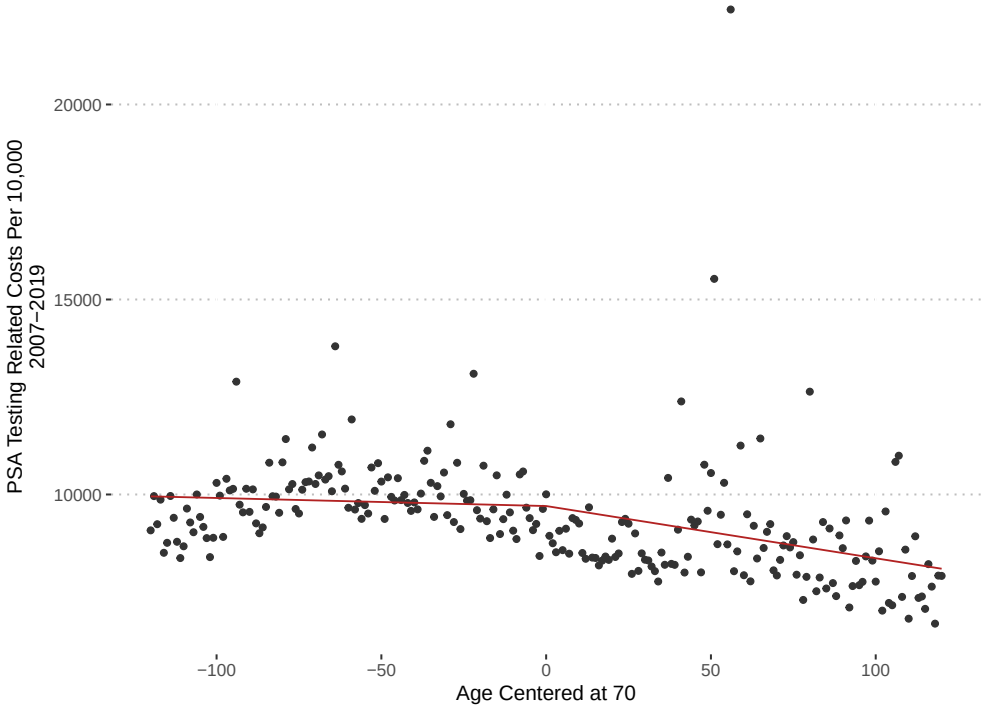
Notes: Age profile centered at age 70 of the proportion of prostate cancer diagnoses with a stage III/IV diagnosis from 2007-2019 with fitted lines from an RK regression.

Figure 4: Age Profile of Mortality from Prostate Cancer, 2007-2019



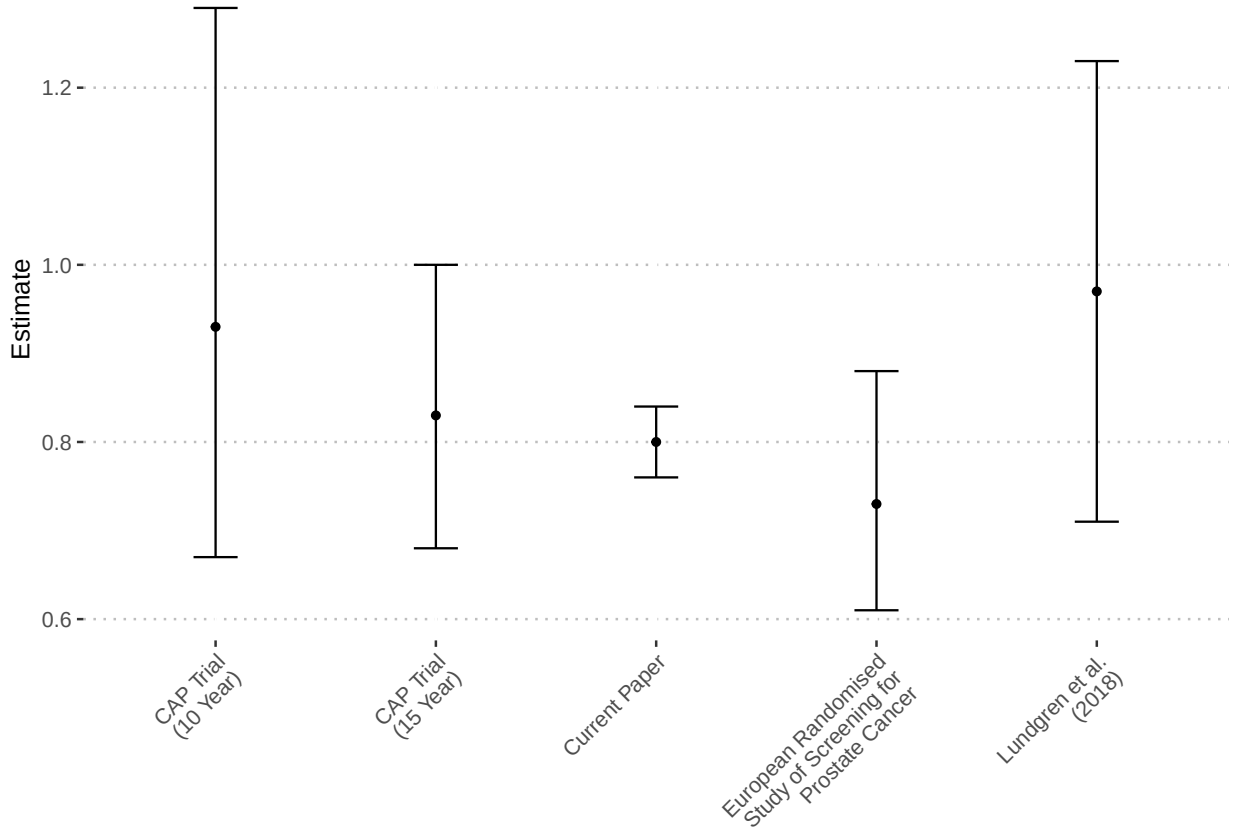
Notes: Age profile centered at age 70 of the proportion of prostate cancer cases that result in mortality within 2 years from 2007-2019 with fitted lines from an RK regression.

Figure 5: Age Profile of PSA-related Costs, 2007-2019



Notes: Age profile centered at age 70 of the costs related to PSA testing from 2007-2019 with fitted lines from an RK regression.

Figure 6: Comparison of Estimates to PSA testing RCTs



Notes: Estimates from RCTs of PSA testing on mortality from prostate cancer compared to estimates from this paper. For the RCTs, the estimates presented are rate ratios of the the IV analysis estimates that are adjusted for PSA testing rates. For the estimates from this paper, the 2SLS estimate from Table XXX is converted to an odds ratio.

Table 2: Regression Discontinuity and Regression Kink Estimates of Changes in Prostate Cancer Testing and Diagnoses at Age 70

	RD	RK
PSA Testing		
Pre-Cutoff Estimate	344.825	335.882
	(0.930)	(1.442)
Change in Level at Age 70	-14.711	
	(1.458)	
Change in Slope at Age 70	-0.609	-0.243
	(0.081)	(0.177)
Num.Obs.	58	58
R2	0.974	0.945
Prostate Cancer Diagnoses		
Pre-Cutoff Estimate	2.529	2.409
	(0.037)	(0.031)
Change in Level at Age 70	-0.158	
	(0.054)	
Change in Slope at Age 70	0.013	0.022
	(0.004)	(0.004)
Num.Obs.	64	64
R2	0.865	0.849

Note: Regression discontinuity (RD) and regression kink (RK) estimates of the changes in the level and slope of rates of PSA testing and prostate cancer diangoses at age 70. Outcomes are in terms of 10,000 person-months and include data from 2007-2019.

Table 3: Regression Discontinuity and Regression Kink Estimates of Changes in Prostate Cancer Stage at Diagnosis and 2-Year Mortality at Age 70

	RD	RK	RJPK
Prostate Cancer Diagnoses Stage III/IV			
Pre-Cutoff Estimate	0.066	0.059	
	(0.003)	(0.001)	
Change in Level at Age 70	0.005		
	(0.004)		
Change in Slope at Age 70	-0.001	0.001	
	(0.000)	(0.000)	
2SLS Estimate	0.221	0.119	0.156
	(0.053)	(0.003)	(0.016)
Num.Obs.	125900	125900	
R2	0.006	0.006	
2-Year Mortality			
Pre-Cutoff Estimate	0.033	0.031	
	(0.002)	(0.001)	
Change in Level at Age 70	0.008		
	(0.005)		
Change in Slope at Age 70	0.000	0.001	
	(0.000)	(0.000)	
2SLS Estimate	0.357	0.102	0.221
	(0.086)	(0.002)	(0.027)
Num.Obs.	142913	142913	
R2	0.008	0.008	

Note: Regression discontinuity (RD) and regression kink (RK) estimates of the changes at age 70 in the level and slope of proportion of prostate cancer cases diagnosed at stage III or IV and the proportion of prostate cancer cases that result in mortality within 2 years. 2SLS estimates come from rescaling by first stage testing estimates for RD and RK and from the RJPK estimator described in the text, with standard errors calculated via the delta method.

Table 4: Regression Discontinuity and Regression Kink Estimates of Changes in PSA Testing-Related Costs at Age 70

	RD	RK
Pre-Cutoff Estimate	10 096.836	9698.778
	(161.852)	(142.759)
Change in Level at Age 70	−773.141	
	(270.158)	
Change in Slope at Age 70	−11.488	−11.202
	(3.379)	(3.543)
Num.Obs.	241	240
R2	0.166	0.148

Note:

Regression discontinuity (RD) and regression kink (RK) estimates of the changes in the level and slope of PSA testing-related costs at age 70. Outcomes are in terms of 10,000 person-months and include data from 2007-2019.

Appendix A. Appendix

Appendix A.1. Bandwidth Robustness Figures

Figure A1: Robustness to Bandwidth of the Change in PSA Testing Rates at Age 70

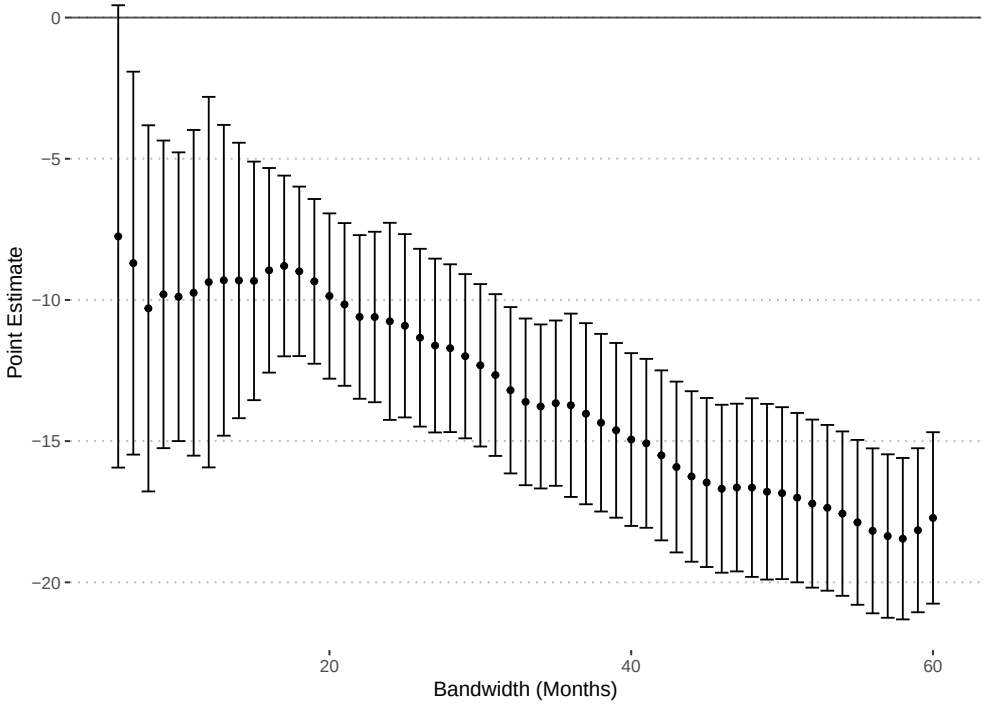


Figure A2: Robustness to Bandwidth of the Change in Prostate Cancer Diagnosis Rates at Age 70

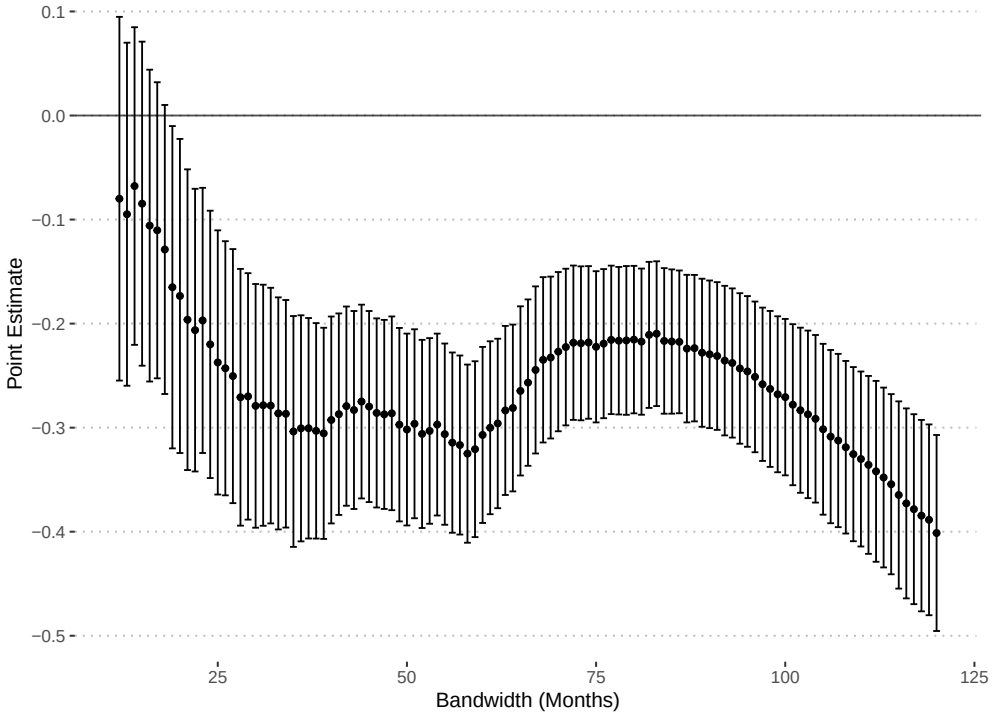


Figure A3: Robustness to Bandwidth of the Change in the Proportion of Prostate Cancer Cases Diagnosed State III/IV

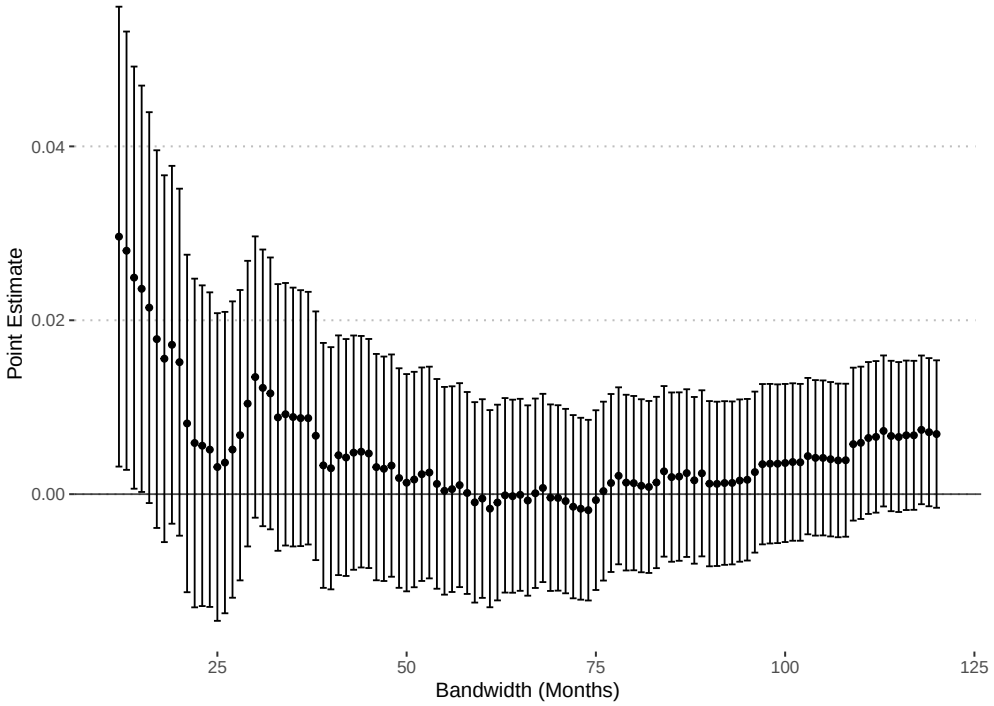


Figure A4: Robustness to Bandwidth of the Regression Kink Estimates of Prostate Cancer Diagnoses State III/IV at Age 70

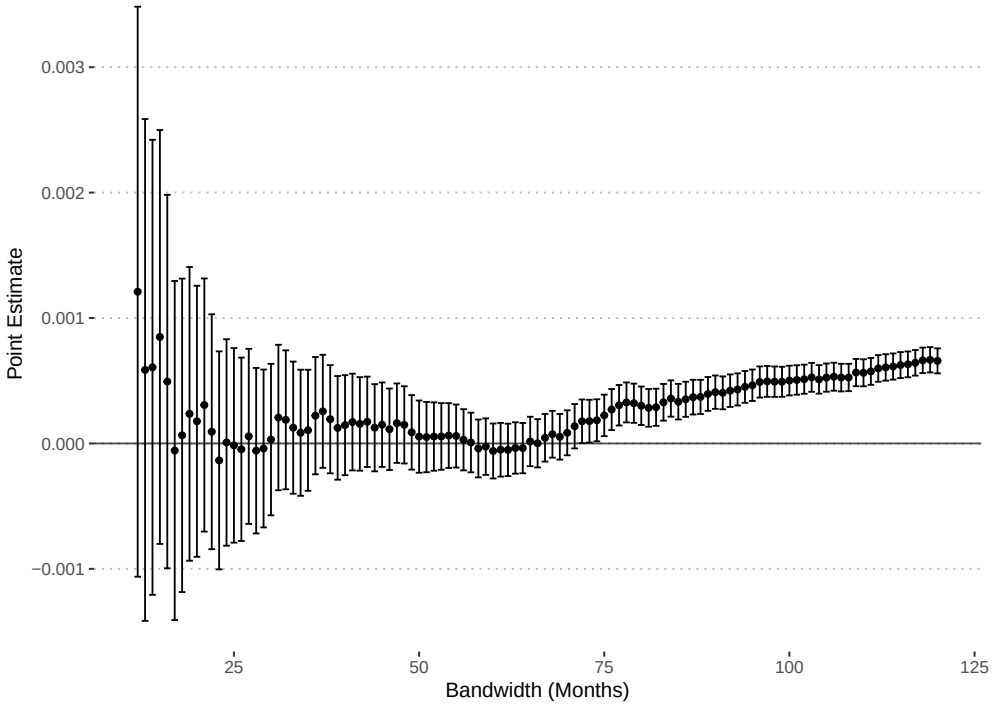


Figure A5: Robustness to Bandwidth of the Change in Mortality from Prostate Cancer at Age 70

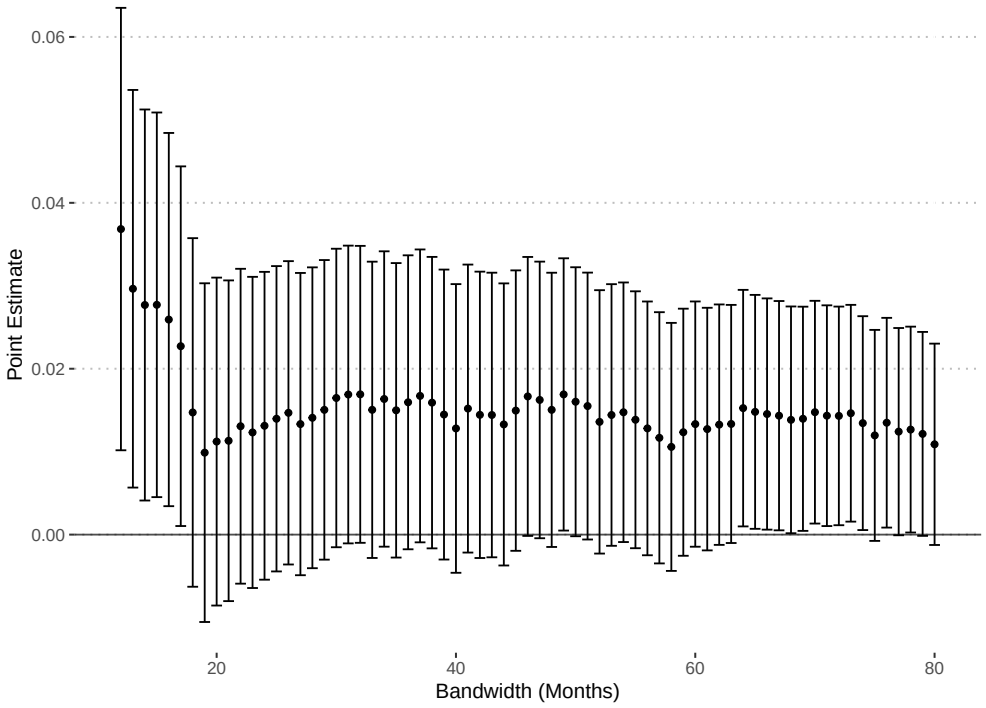
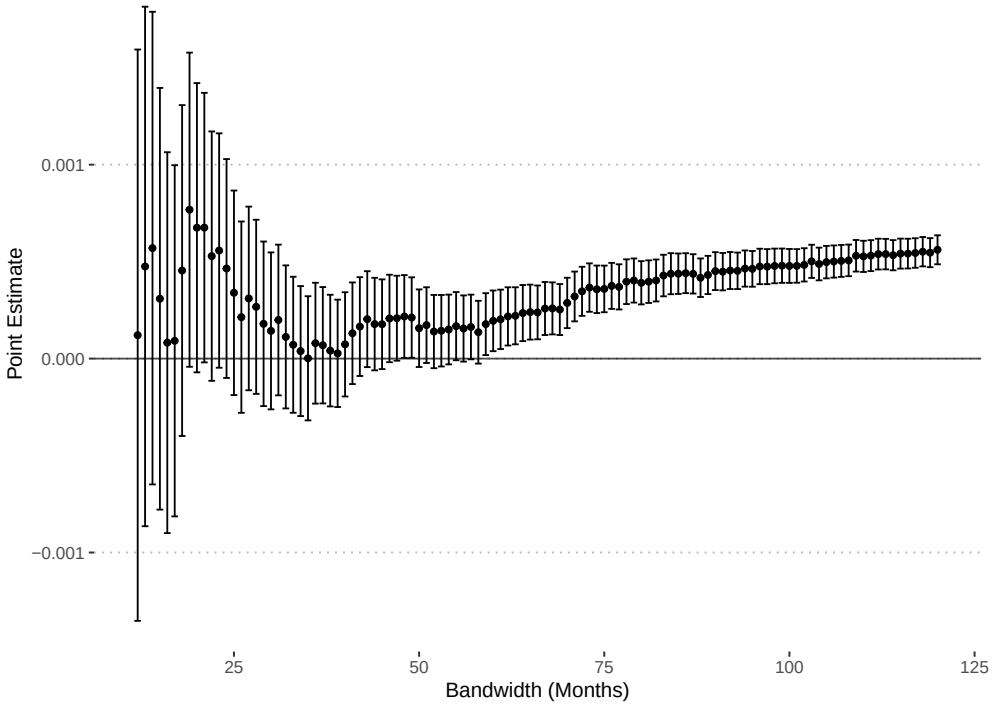
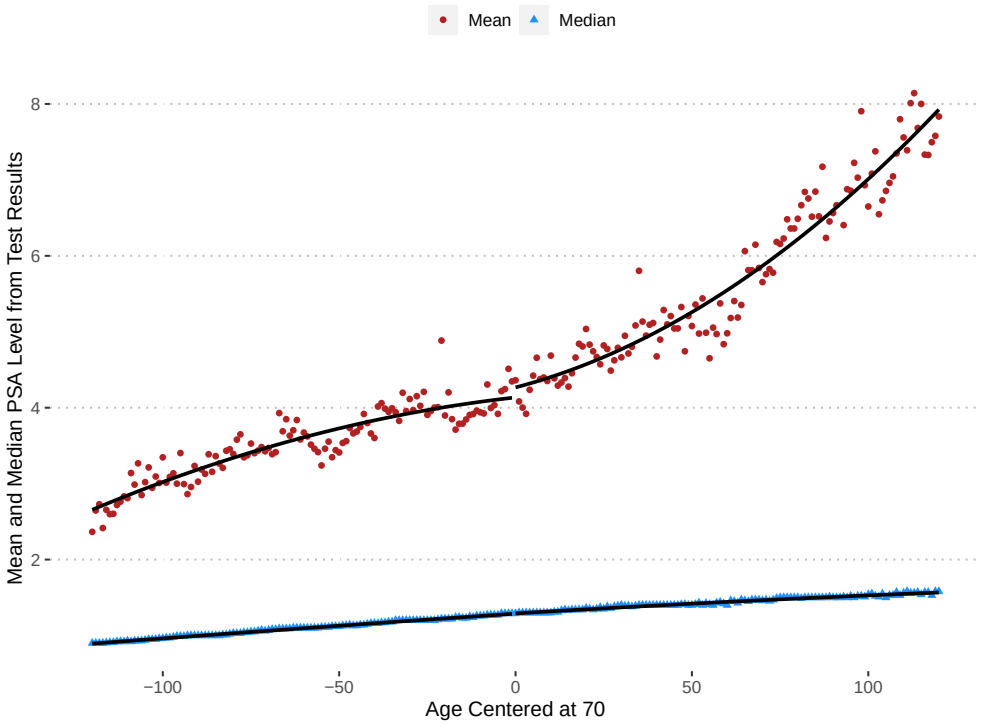


Figure A6: Robustness to Bandwidth of Regression Kink Estimates of the Change in Mortality Due to Prostate Cancer at Age 70



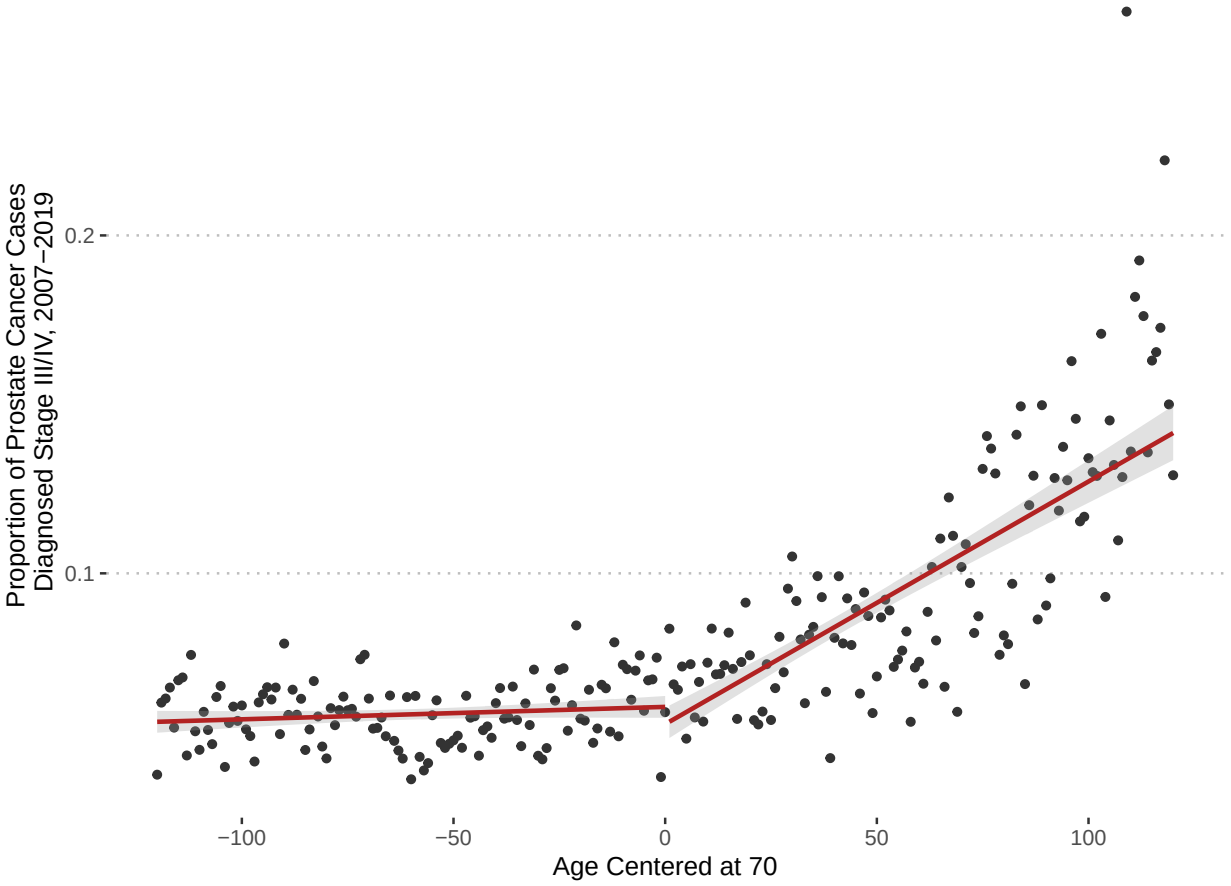
Appendix A.2. Test Values

Figure A7: Age Profile of Mean and Median PSA Test Values



Appendix A.3. Late-Stage Diagnosis

Figure A8: Age Profile of Proportion of Prostate Cancer Cases Diagnosed Stage III/IV, Regression Discontinuity



Appendix A.4. Mortality

Figure A9: Age Profile of Mortality with Two Years of Diagnosis, Regression Discontinuity

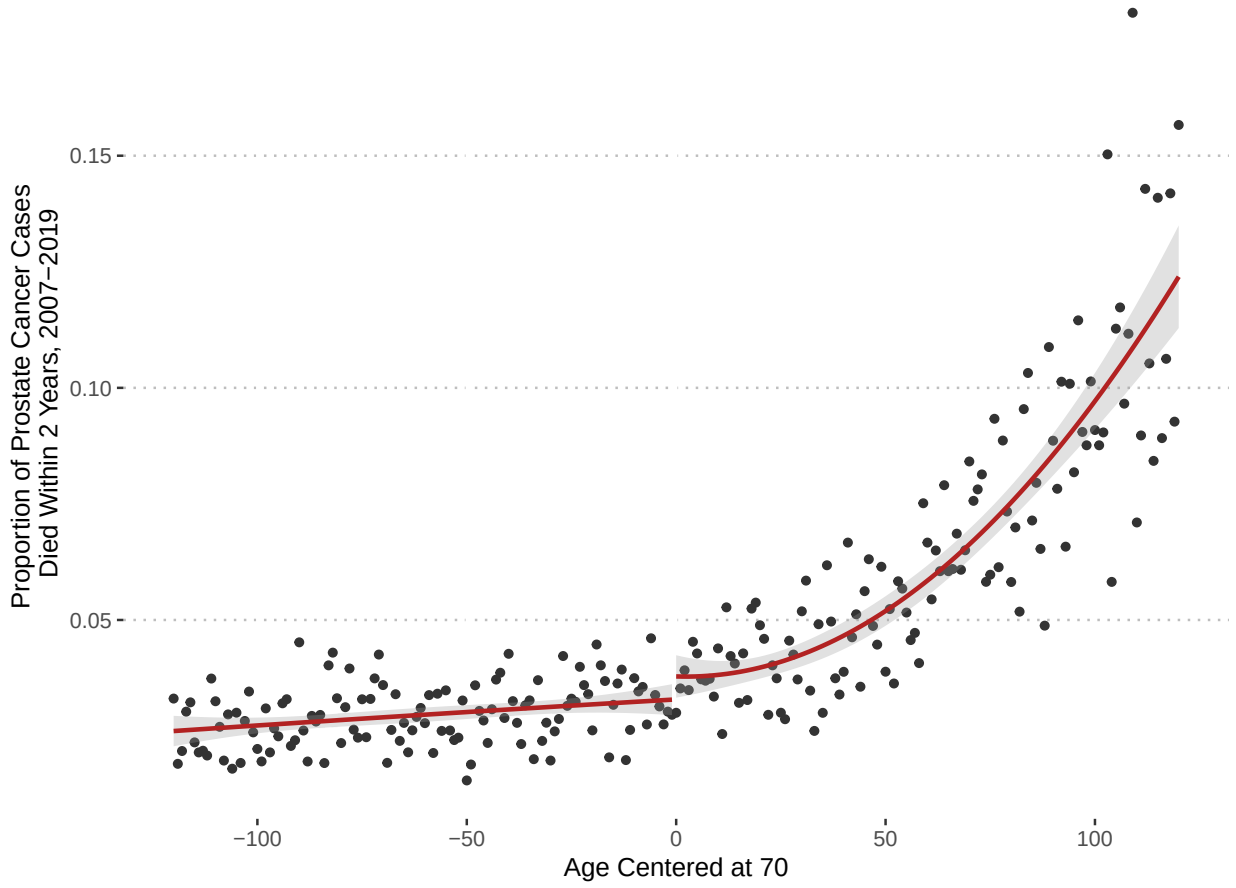
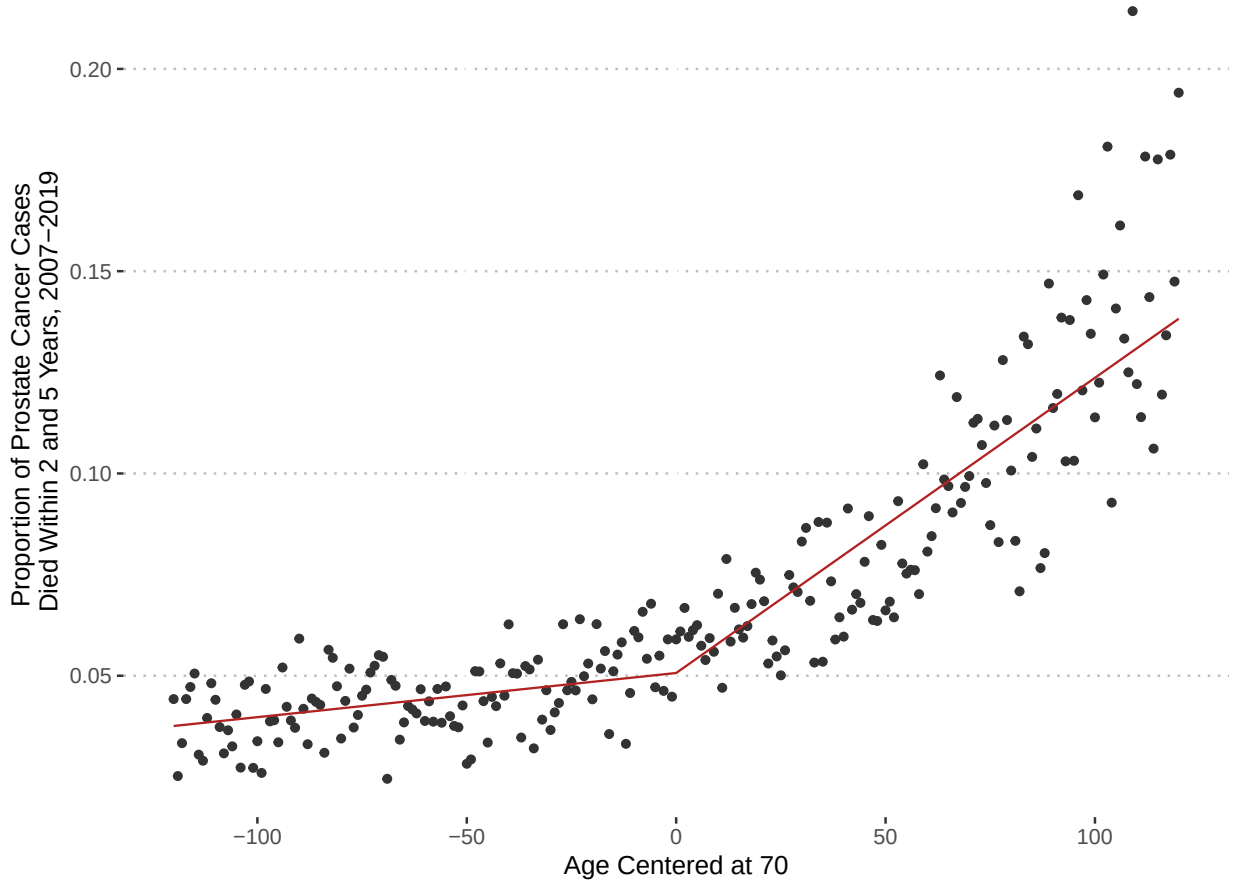


Figure A10: Age Profile of Mortality within Two Years of Diagnosis of Prostate Cancer, All Cause



Appendix A.5. PSA Testing and Downstream Services CPT Codes

Table A1: CPT codes used to capture utilization and cost of services related to PSA testing

Service	CPT Codes
Related Outpatient Visit	99201, 99202, 99203, 99204, 99205, 99211, 99212, 99213, 99214, 99215, 99241, 99242, 99243, 99244, 99245 *With ICD9 790.93 or ICD10 R97.20 or ICD10 R97.21*
Urology Visit	*VA Urology Visit*
Prostate Imaging	76872, 76873, 72192, 72193, 72194, 72195, 72196, 72197, 78300, 78305, 78306, 78315, 78350, 78251, 78399
Prostate Biopsy	55700, 55705, 55706, G0416

Service	CPT Codes
Androgen Deprivation Therapy	54520, 54522, 54530, 54535, J1050, J9217, J9218, J9219, J3315, J9202
Surgical Procedures	55801, 55810, 55812, 55815, 55821, 55831, 55840, 55842, 55845, 55866
Radiation Therapy	77401, 77402, 77407, 77412, 77417, 77423, 77424, 77425, 77427, 77431, 77432, 77435, 77469, 77470, 77499, 77750, 77761, 77762, 77763, 77767, 77768, 77770, 77771, 77771, 77772, 77778, 77789, 77790, 77799

References

Andersen, M.S., 2018. Effects of medicare coverage for the chronically ill on health insurance, utilization, and mortality: Evidence from coverage expansions affecting people with end-stage renal disease. Journal of Health Economics 60, 75–89. URL: https://www.sciencedirect.com/science/article/pii/S016762961730591X, doi:10.1016/j.jhealeco.2018.06.002.

Anderson, M.L., Dobkin, C., Gorry, D., 2020. The effect of influenza vaccination for the elderly on hospitalization and mortality: An observational study with a regression discontinuity design. Annals of Internal Medicine 172, 445–452. doi:10.7326/M19-3075. pMID: 32120383.

Andriole, G.L., Crawford, E.D., Grubb, R.L., Buys, S.S., Chia, D., Church, T.R., Fouad, M.N., Gelmann, E.P., Kvale, P.A., Reding, D.J., Weissfeld, J.L., Yokochi, L.A., O'Brien, B., Clapp, J.D., Rathmell, J.M., Riley, T.L., Hayes, R.B., Kramer, B.S., Izmirlian, G., Miller, A.B., Pinsky, P.F., Prorok, P.C., Gohagan, J.K., Berg, C.D., 2009. Mortality results from a randomized prostate-cancer screening trial. New England Journal of Medicine 360, 1310–1319. URL: https://doi.org/10.1056/NEJMoa0810696, doi:10.1056/NEJMoa0810696. publisher: Massachusetts Medical Society _eprint: https://doi.org/10.1056/NEJMoa0810696 PMID: 19297565.

Aouad, M., Brown, T.T., Whaley, C.M., 2019. Reference pricing: The case of screening colonoscopies. Journal of health economics 65, 246–259. URL: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7592414/, doi:10.1016/j.jhealeco.2019.03.002. pMID: 31082768 PMCID: PMC7592414.

Berwick, D.M., Hackbarth, A.D., 2012. Eliminating waste in us health care. JAMA 307, 1513–1516. URL: https://doi.org/10.1001/jama.2012.362, doi:10.1001/jama.2012.362.

Buchbinder, R., Underwood, M., Hartvigsen, J., Maher, C.G., 2020. The lancet series call to action to reduce low value care for low back pain: an update. PAIN 161, S57. URL: https://journals.lww.com/pain/fulltext/2020/09001/The_Lancet_Series_call_to_action_to_reduce_low.7.aspx, doi:10.1097/j.pain.0000000000001869.

Calonico, S., Cattaneo, M., Titiunik, R., 2015. rdrobust: An r package for robust nonparametric inference in regression-discontinuity designs. The R Journal 7, 38. URL: https://journal.r-project.org/archive/2015/RJ-2015-004/index.html, doi:10.32614/RJ-2015-004.

Cassel, C.K., Guest, J.A., 2012. Choosing wisely: Helping physicians and patients make smart decisions about their care. JAMA 307, 1801–1802. URL: https://doi.org/10.1001/jama.2012.476, doi:10.1001/jama.2012.476.

Chandra, A., Finkelstein, A., Sacarny, A., Syverson, C., 2016. Health care exceptionalism? performance and allocation in the us health care sector. American Economic Review 106, 2110–2144. URL: https://www.aeaweb.org/articles?id=10.1257/aer.20151080, doi:10.1257/aer.20151080.

Chandra, A., Skinner, J., 2012. Technology growth and expenditure growth in health care. Journal of Economic Literature 50, 645–680. URL: https://www.aeaweb.org/articles?id=10.1257/jel.50.3.645, doi:10.1257/jel.50.3.645.

Claxton, K., Lomas, J., Martin, S., 2018. The impact of nhs expenditure on health outcomes in england: Alternative approaches to identification in all-cause and disease specific models of mortality. Health Economics 27, 1017–1023. URL: https://onlinelibrary.wiley.com/doi/abs/10.1002/hec.3650, doi:10.1002/hec.3650. _eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1002/hec.3650.

CLIFF, B.Q., AVANCEÑA, A.L., HIRTH, R.A., LEE, S., 2021. The impact of choosing wisely interventions on low-value medical services: A systematic review. The Milbank Quarterly 99, 1024–1058. URL: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8718584/, doi:10.1111/1468-0009.12531. pMID: 34402553 PMCID: PMC8718584.

Clift, A.K., Coupland, C.A., Hippisley-Cox, J., 2021. Prostate-specific antigen testing and opportunistic prostate cancer screening: a cohort study in england, 1998–2017. The British Journal of General Practice 71, e157–e165. URL: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7805413/, doi:10.3399/bjgp20X713957. pMID: 33431381 PMCID: PMC7805413.

Colla, C.H., Mainor, A.J., Hargreaves, C., Sequist, T., Morden, N., 2017. Interventions aimed at reducing use of low-value health services: A systematic review. Medical Care Research and Review 74, 507–550. URL: https://doi.org/10.1177/1077558716656970, doi:10.1177/1077558716656970. publisher: SAGE Publications Inc.

Colla, C.H., Morden, N.E., Sequist, T.D., Schpero, W.L., Rosenthal, M.B., 2015a. Choosing wisely: prevalence and correlates of low-value health care services in the united states. Journal of General Internal Medicine 30, 221–228. doi:10.1007/s11606-014-3070-z. pMID: 25373832 PMCID: PMC4314495.

Colla, C.H., Morden, N.E., Sequist, T.D., Schpero, W.L., Rosenthal, M.B., 2015b. Choosing wisely: prevalence and correlates of low-value health care services in the united states. Journal of General Internal Medicine 30, 221–228. doi:10.1007/s11606-014-3070-z. pMID: 25373832 PMCID: PMC4314495.

Cutler, D., Skinner, J.S., Stern, A.D., Wennberg, D., 2019. Physician beliefs and patient preferences: A new look at regional variation in health care spendingf. American Economic Journal. Economic Policy 11, 192–221. doi:10.1257/pol.20150421. pMID: 32843911 PMCID: PMC7444804.

Dong, Y., 2018. Jump or kink? regression probability jump and kink design for treatment effect evaluation. Working Paper .

E., S.J., Sameer, M., C., H.J., 2016. Reevaluating psa testing rates in the plco trial. New England Journal of Medicine 374, 1795–1796. URL: https://www.nejm.org/doi/full/10.1056/NEJMc1515131, doi:10.1056/NEJMc1515131. publisher: Massachusetts Medical Society _eprint: https://www.nejm.org/doi/pdf/10.1056/NEJMc1515131.

Finkelstein, A., Taubman, S., Wright, B., Bernstein, M., Gruber, J., Newhouse, J.P., Allen, H., Baicker, K., Group, O.H.S., 2012. The oregon health insurance experiment: Evidence from the first year. The Quarterly Journal of Economics 127, 1057–1106. doi:10.1093/qje/qjs020. pMID: 23293397 PMCID: PMC3535298.

Gallet, C.A., Doucouliagos, H., 2017. The impact of healthcare spending on health outcomes: A meta-regression analysis. Social Science & Medicine 179, 9–17. URL: https://www.sciencedirect.com/science/article/pii/S0277953617301132, doi:10.1016/j.socscimed.2017.02.024.

Ganguli, I., Crawford, M.L., Usadi, B., Mulligan, K.L., O'Malley, A.J., Yang, C.W.W., Fisher, E.S., Morden, N.E., 2023. Who's accountable? low-value care received by medicare beneficiaries outside of their attributed health systems. Health Affairs 42, 1128–1139. URL: https://www.healthaffairs.org/doi/abs/10.1377/hlthaff.2022.01319, doi:10.1377/hlthaff.2022.01319. publisher: Health Affairs.

Hibbard, J.H., Greene, J., Sofaer, S., Firminger, K., Hirsh, J., 2012. An experiment shows that a well-designed report on costs and quality can help consumers choose high-value health care. Health Affairs 31, 560–568. URL: https://www-healthaffairs-org.laneproxy.stanford.edu/doi/10.1377/hlthaff.2011.1168, doi:10.1377/hlthaff.2011.1168. publisher: Health Affairs.

Hollingsworth, B., 2008. The measurement of efficiency and productivity of health care delivery. Health Economics 17, 1107–1128. URL: https://onlinelibrary.wiley.com/doi/abs/10.1002/hec.1391, doi:10.1002/hec.1391. _eprint:

https://onlinelibrary.wiley.com/doi/pdf/10.1002/hec.1391.

Hynes, D.M., Edwards, S., Hickok, A., Niederhausen, M., Weaver, F.M., Tarlov, E., Gordon, H., Jacob, R.L., Bartle, B., O'Neill, A., Young, R., Laliberte, A., 2021. Veterans' use of veterans health administration primary care in an era of expanding choice. Medical Care 59, S292–S300. URL: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8132904/, doi:10.1097/MLR.0000000000001554. pMID: 33976079 PMCID: PMC8132904.

Ilic, D., Djulbegovic, M., Jung, J.H., Hwang, E.C., Zhou, Q., Cleves, A., Agoritsas, T., Dahm, P., 2018. Prostate cancer screening with prostate-specific antigen (psa) test: a systematic review and meta-analysis. BMJ 362, k3519. URL: https://www.bmj.com/content/362/bmj.k3519, doi:10.1136/bmj.k3519. publisher: British Medical Journal Publishing Group Section: Research PMID: 30185521.

Kim, D.D., Do, L.A., Daly, A.T., Wong, J.B., Chambers, J.D., Ollendorf, D.A., Neumann, P.J., 2021. An evidence review of low-value care recommendations: Inconsistency and lack of economic evidence considered. Journal of General Internal Medicine 36, 3448–3455. URL: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8606489/, doi:10.1007/s11606-021-06639-2. pMID: 33620623 PMCID: PMC8606489.

Kjelle, E., Andersen, E.R., Soril, L.J.J., van Bodegom-Vos, L., Hofmann, B., 2021. Interventions to reduce low-value imaging – a systematic review of interventions and outcomes. BMC Health Services Research 21, 983. URL: https://doi.org/10.1186/s12913-021-07004-z, doi:10.1186/s12913-021-07004-z.

Kullgren, J.T., Krupka, E., Schachter, A., Linden, A., Miller, J., Acharya, Y., Alford, J., Duffy, R., Adler-Milstein, J., 2018. Precommitting to choose wisely about low-value services: a stepped wedge cluster randomised trial. BMJ Quality and Safety 27, 355–364. doi:10.1136/bmjqs-2017-006699. pMID: 29066616.

Levick, D.L., Stern, G., Meyerhoefer, C.D., Levick, A., Pucklavage, D., 2013. "reducing unnecessary testing in a cpoe system through implementation of a targeted cds intervention". BMC medical informatics and decision making 13, 43. doi:10.1186/1472-6947-13-43. pMID: 23566021 PMCID: PMC3629995.

Lundgren, P.O., Kjellman, A., Norming, U., Gustafsson, O., 2018. Long-term outcome of a single intervention population based prostate cancer screening study. The Journal of Urology 200, 82–88. URL: https://www.sciencedirect.com/science/article/pii/S0022534718301733, doi:10.1016/j.juro.2018.01.080.

Maratt, J.K., Kerr, E.A., Klamerus, M.L., Lohman, S.E., Froehlich, W., Bhatia, R.S., Saini, S.D., 2019. Measures used to assess the impact of interventions to reduce low-value care: a systematic review. Journal of General Internal Medicine 34, 1857–1864. URL: https://doi.org/10.1007/s11606-019-05069-5, doi:10.1007/s11606-019-05069-5.

Martin, R.M., Donovan, J.L., Turner, E.L., Metcalfe, C., Young, G.J., Walsh, E.I., Lane, J.A., Noble, S., Oliver, S.E., Evans, S., Sterne, J.A.C., Holding, P., Ben-Shlomo, Y., Brindle, P., Williams, N.J., Hill, E.M., Ng, S.Y., Toole, J., Tazewell, M.K., Hughes, L.J., Davies, C.F., Thorn, J.C., Down, E., Davey Smith, G., Neal, D.E., Hamdy, F.C., Group, C.T., 2018. Effect of a low-intensity psa-based screening intervention on prostate cancer mortality: The cap randomized clinical trial. JAMA 319, 883–895. URL: https://doi.org/10.1001/jama.2018.0154, doi:10.1001/jama.2018.0154.

Martin, R.M., Turner, E.L., Young, G.J., Metcalfe, C., Walsh, E.I., Lane, J.A., Sterne, J.A.C., Noble, S., Holding, P., Ben-Shlomo, Y., Williams, N.J., Pashayan, N., Bui, M.N., Albertsen, P.C., Seibert, T.M., Zietman, A.L., Oxley, J., Adolfsson, J., Mason, M.D., Davey Smith, G., Neal, D.E., Hamdy, F.C., Donovan, J.L., Group, C.T., 2024. Prostate-specific antigen screening and 15-year prostate cancer mortality: A secondary analysis of the cap randomized clinical trial. JAMA 331, 1460–1470. URL: https://doi.org/10.1001/jama.2024.4011, doi:10.1001/jama.2024.4011.

Martin, S., Claxton, K., Lomas, J., Longo, F., 2023. The impact of different types of nhs expenditure on health: Marginal cost per qaly estimates for england for 2016/17. Health Policy 132, 104800. URL: https://www.sciencedirect.com/science/article/pii/S0168851023000854, doi:10.1016/j.healthpol.2023.104800.

McCrary, J., 2008. Manipulation of the running variable in the regression discontinuity design: A density test. Journal of Econometrics 142, 698–714. URL: https://www.sciencedirect.com/science/article/pii/S0304407607001133, doi:10.1016/j.

jeconom.2007.05.005.

McCulloch, P., Taylor, I., Sasako, M., Lovett, B., Griffin, D., 2002. Randomised trials in surgery: problems and possible solutions. BMJ 324, 1448–1451. URL: https://www.bmj.com/content/324/7351/1448.1, doi:10.1136/bmj.324.7351.1448. publisher: British Medical Journal Publishing Group Section: Education and debate PMID: 12065273.

McMillan, J.A., Ziegelstein, R.C., 2014. Implementing a graduate medical education campaign to reduce or eliminate potentially wasteful tests or procedures. JAMA Internal Medicine 174, 1693. URL: https://doi.org/10.1001/jamainternmed.2014.3472, doi:10.1001/jamainternmed.2014.3472.

Morden, N.E., Colla, C.H., Sequist, T.D., Rosenthal, M.B., 2014. Choosing wisely — the politics and economics of labeling low-value services. The New England journal of medicine 370, 589–592. URL: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4104300/, doi:10.1056/NEJMp1314965. pMID: 24450859 PMCID: PMC4104300.

Moriates, C., 2023. We need to talk about low-value care. JAMA Network Open 6, e2342445. URL: https://doi.org/10.1001/jamanetworkopen.2023.42445, doi:10.1001/jamanetworkopen.2023.42445.

Papanicolas, I., Woskie, L.R., Jha, A.K., 2018. Health care spending in the united states and other high-income countries. JAMA 319, 1024–1039. URL: https://doi.org/10.1001/jama.2018.1150, doi:10.1001/jama.2018.1150.

Pickering, A.N., Zhao, X., Sileanu, F.E., Lovelace, E.Z., Rose, L., Schwartz, A.L., Oakes, A.H., Hale, J.A., Schleiden, L.J., Gellad, W.F., Fine, M.J., Thorpe, C.T., Radomski, T.R., 2022. Assessment of care cascades following low-value prostate-specific antigen testing among veterans dually enrolled in the us veterans health administration and medicare systems. JAMA Network Open 5, e2247180. URL: https://doi.org/10.1001/jamanetworkopen.2022.47180, doi:10.1001/jamanetworkopen.2022.47180.

Reid, R.O., Rabideau, B., Sood, N., 2017. Impact of consumer-directed health plans on low-value healthcare. The American Journal of Managed Care 23, 741–748. PMID: 29261240 PMCID: PMC6132267.

Schröder, F.H., Hugosson, J., Roobol, M.J., Tammela, T.L.J., Zappa, M., Nelen, V., Kwiatkowski, M., Lujan, M., Määttänen, L., Lilja, H., Denis, L.J., Recker, F., Paez, A., Bangma, C.H., Carlsson, S., Puliti, D., Villers, A., Rebillard, X., Hakama, M., Stenman, U.H., Kujala, P., Taari, K., Aus, G., Huber, A., Kwast, T.H.v.d., Schaik, R.H.N.v., Koning, H.J.d., Moss, S.M., Auvinen, A., 2014. Screening and prostate cancer mortality: results of the european randomised study of screening for prostate cancer (erspc) at 13 years of follow-up. The Lancet 384, 2027–2035. URL: https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(14)60525-0/fulltext?referrer=&priority=true&module=meter-Links&pgtype=Blogs&contentId=&action=click&contentCollection=meter-links-click&version=meter+at+null&mediaId=%25%25ADID%25%25, doi:10.1016/S0140-6736(14)60525-0. publisher: Elsevier PMID: 25108889.

Schwartz, A.L., Landon, B.E., Elshaug, A.G., Chernew, M.E., McWilliams, J.M., 2014. Measuring low-value care in medicare. JAMA Internal Medicine 174, 1067–1076. URL: https://doi.org/10.1001/jamainternmed.2014.1541, doi:10.1001/jamainternmed.2014.1541.

Sharma, S., Guttmann, D., Small, D.S., Rareshide, C.A.L., Jones, J., Patel, M.S., Bekelman, J.E., 2019. Effect of introducing a default order in the electronic medical record on unnecessary daily imaging during palliative radiotherapy for adults with cancer: A stepped-wedge cluster randomized clinical trial. JAMA Oncology 5, 1220–1222. URL: https://doi.org/10.1001/jamaoncol.2019.1432, doi:10.1001/jamaoncol.2019.1432.

Siddiqui, M., Roberts, E.T., Pollack, C.E., 2015. The effect of emergency department copayments for medicaid beneficiaries following the deficit reduction act of 2005. JAMA Internal Medicine 175, 393–398. URL: https://doi.org/10.1001/jamainternmed.2014.7582, doi:10.1001/jamainternmed.2014.7582.

Vartanians, V.M., Sistrom, C.L., Weilburg, J.B., Rosenthal, D.I., Thrall, J.H., 2010. Increasing the appropriateness of outpatient imaging: effects of a barrier to ordering low-yield examinations. Radiology 255, 842–849. doi:10.1148/radiol.10091228. pMID: 20501721.

of Veterans Affairs, D., of Inspector General, O., 2015. Alleged Substandard Prostate Cancer Screening VA Eastern Colorado Health Care System Denver, Colorado. Technical Report. URL: https://www.va.gov/oig/pubs/VAOIG-14-03833-385.pdf.

Wennberg, J.E., 2002. Unwarranted variations in healthcare delivery: implications for academic medical centres. BMJ : British Medical Journal 325, 961–964. URL: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1124450/. pMID: 12399352 PMCID: PMC1124450.