INVESTIGATING THE IMPACT OF THE AFFORDABLE CARE ACT ON CANCER OUTCOMES FOR LOW-INCOME PATIENTS

A Research Paper submitted to the Department of Engineering and Society

Presented to the Faculty of the School of Engineering and Applied Science
University of Virginia • Charlottesville, Virginia

In Partial Fulfillment of the Requirements for the Degree
Bachelor of Science, School of Engineering

Hayden C. Ratliff
Spring 2023

On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

Advisor
Rider W. Foley, Department of Engineering and Society

Introduction

Cancer is the second-leading cause of death in the US, killing more than 600,000 people in 2021 alone (Seigel et al., 2021). Even though cancer survival rates have been increasing since 1975, the high cost of cancer treatment presents a significant barrier to patients (National Cancer Institute, 2022). According to a study by Iragorri et. al. (2021), the monthly out-of-pocket cost of cancer treatment in the US is nearly $2,600 on average, in 2018 dollars. For uninsured patients, the annual cost of cancer care can exceed $100,000 (Rimer, 2018). Overall, the cost of cancer treatment greatly exceeds most household incomes in the US (Prasad et al., 2017; Statistical Atlas, 2023). Underlining the financial burden of cancer treatment for both insured and uninsured patients is the following statistic: patients with cancer are 71% more likely than patients without cancer to experience a "severe adverse financial event" like bankruptcy or foreclosure (Shankaran et al., 2022).

In 2010, Congress passed the Patient Protection and Affordable Care Act (ACA), a law intended to fundamentally change healthcare in the US through a landmark suite of policies. By expanding the availability of cheaper health insurance plans and increasing both patient protections and patient rights, the ACA aimed to both improve health and decrease healthcare costs nationwide (Zhao et al., 2020). Four of the most prominent aspects of the law were the following: the *individual mandate*, which mandated that most citizens maintain a minimum level of healthcare insurance; the *expansion of Medicare*, a federal insurance program for seniors; the *dependent coverage expansion*, which allowed dependents to remain on their parents' health insurance plan until the age of 27; and the *expansion of Medicaid*, a federal program to assist low-income patients with medical expenses (Angelo, 2021; Davalon, 2022; Fiedler, 2020; Rudowitz et al., 2019). Together, these policies and the many others included in the law were the

government's response to rising healthcare costs. However, the ACA proved to be incredibly controversial, and was successfully challenged several times both in court and in the political arena. The law's Medicaid expansion program was modified in 2012 by the US Supreme Court in National Federation of Independent Business v. Sebelius—this decision nullified the federal mandate for states to expand Medicaid and instead allowed states to opt into the government's Medicaid expansion program (Rosenbaum & Westmoreland, 2012). To date, 40 states and the District of Columbia have opted into Medicaid expansion, while 10 states with Republican-dominated state legislatures remain as holdouts (Kaiser Family Foundation, 2022). Similarly, the individual mandate was effectively repealed by Congress in 2017, with this change going into effect in 2019 (Fiedler, 2020). But, despite these challenges, most of the law's major provisions remain intact today.

Understanding the impact of the ACA on cancer care is critical to our evaluation of the ACA's effectiveness. In this study, I will investigate the impact of the ACA on the US cancer care system. Specifically, I will focus on the ACA's impact on outcomes (e.g., remission or death) for low-income cancer patients, since these patients are most impacted by the high cost of cancer treatment and were the patients the law was designed particularly to protect.

Case Context

Over the last 13 years, the ACA has been a prominent focus of study. Research indicates that the law successfully increased health insurance coverage rates overall, with the uninsured rate of US residents reaching an all-time low of 8.0% in early 2022 (Lee et al., 2022). In the realm of cancer care, research has indicated that the law had a significant positive impact on health insurance coverage rates for cancer patients and survivors.

Nogueira et. al. (2019) examined temporal patterns of health insurance coverage rates for young adults in response to the dependent coverage expansion (DCE) in September 2010 and the expansion of Medicaid (ME) in December 2013. The study split insurance coverage data from the National Cancer Database 2003-2015 into three groups: pre-DCE, between DCE and ME, and post-ME. Using regression analysis, Nogueira et. al. found that DCE and ME had statistically significant impacts on coverage rates for young adult cancer patients, with ME having an especially dramatic and immediate impact on improving coverage rates.

H. A. Moss et. al. (2020) built on this study by conducting a systematic review of the impact of ME on cancer care. The study found that the ME "resulted in the expansion of insurance coverage among cancer patients and survivors" and improved several other aspects of cancer care like access to screening and earlier diagnosis. Patients living in states that expanded Medicaid saw large reductions in uninsurance rates, while patients living in non-expansion states still had better access to insurance through other provisions of the ACA.

Importantly, research also indicates that cancer outcomes are tied to poverty, with lower-income people experiencing higher cancer mortality rates. Through analysis of data from the National Cancer Institute's Surveillance, Epidemiology, and End Results Program (SEER), J. L. Moss et al. (2020) found a statistically significant disparity in cancer mortality rates between high-poverty and low-poverty counties across the US, with more than 20 more deaths per 100,000 residents in higher-poverty counties. Notably, these results used data from 2007-2011, which includes the three years before the ACA was enacted and a transition year following the law's passage when provisions were still being new.

Although the research of Nogueira et. al. (2019), H. A. Moss et. al. (2020), and J. L. Moss et al. (2020) tells us that cancer outcomes are negatively correlated with poverty and that

the ACA increased health insurance coverage rates for cancer patients, the specific impact of the ACA on cancer outcomes for low-income patients remains an important open question. Evaluating the impact of the ACA on cancer outcomes for low-income patients will help us understand whether the law had the positive impact it was intended to have. Moreover, broadening our understanding of the impact of the ACA can help inform future cancer-specific or general healthcare-related legislative action, which is frequently debated both in Congress and across the country (Kaplan & Thomas, 2017; Kirziner et al., 2022).

The Affordable Care Act Through an Infrastructure Lens

Cancer treatment is technical, involving drugs and complex treatment plans, but it is also a fundamentally human problem. Susan Leigh Star's (1999) paper, "The Ethnography of Infrastructure," can help us understand cancer care in the US as a form of human infrastructure. Star writes that infrastructure is commonly envisioned as a "system of substrates" like pipes and roads, but that this definition is too narrow when considering larger systems like the cancer care system in the US. Star defines nine dimensions of infrastructure, three of which are particularly applicable to cancer care. First, infrastructure is *embedded* because it is sunk within and coordinated with other structures. Second, infrastructure is *learned as a part of membership*, because it is something to be learned about and that participants can develop a familiarity with. Finally, infrastructure is *built on an installed base*, on top of infrastructure already in use.

Applying Star's framework to cancer care in the US, it is clear that the US cancer care system is a form of infrastructure. Indeed, it is sunk within the healthcare and legislative systems, which are pieces of infrastructure themselves. Newly diagnosed cancer patients need to learn about their treatment plans, and become more familiar with their healthcare providers as their

treatment progresses. In addition, any new chemotherapy drug is designed to be mixed using industry-standard pharmacy methods and delivered by infusion pumps already deployed in hospitals around the US. Interpreting cancer care as a living form of human infrastructure can help us understand how it interacts as a system with other pieces of infrastructure.

The ACA is also a form of infrastructure. The law is embedded within the healthcare system as a whole, and is also learned as a part of membership, since it requires citizens and healthcare providers alike to become familiar with its programs and rules. Finally, it was built on an installed base, which included pre-existing government programs like Medicaid and Medicare as well as the private health insurance market. With the understanding that the cancer care system and the ACA are both forms of infrastructure, we can use Star's framework to investigate how the cancer care system responded to the ACA. To that end, the impact of the ACA on cancer outcomes is also a reflection on the extent to which the ACA has successfully operated as the ideal form of human infrastructure Star describes.

Therefore, the effectiveness of the ACA is also a measure of the extent to which the ACA became *embedded* within pre-existing healthcare systems, was successfully *learned as a part of membership* by patients, and was effectively *built on an installed base*. When it comes to cancer care, the same dynamics apply. The specific effectiveness of the ACA in improving cancer care outcomes is also a measure of how well the provisions included in the law became *embedded* within the cancer care system, how well it was *learned as a part of membership* by cancer patients, and was effectively *built on an installed base*. In the end, I used these twin viewpoints to structure my analysis and to propose explanations for why the ACA has behaved as it has.

Methods

My research investigated the following research question: *how did the passage of the Patient Protection and Affordable Care Act (ACA) impact cancer outcomes for low-income cancer patients?* As the largest healthcare law passed in the 21st century, it is imperative that we analyze the ACA's impact on the cancer care system and on outcomes for low-income patients in particular so that we can evaluate its success and inform future policy proposals.

I used the latest currently-available data from the National Cancer Institute's Surveillance, Epidemiology, and End Results Program (SEER) and the American Community Survey's five-year estimates (ACS), to conduct an analysis similar to J. L. Moss et al. (2020). I gathered cancer mortality rates from each US county using SEER's SEER*Stat software, and then combined this data with 5-year county-level poverty estimates from the ACS. Like J. L. Moss et al., I used the US Department of Agriculture's definition of persistent poverty, which defines counties experiencing persistent poverty as those counties with more than 20% of residents below the federal poverty line in the 1980, 1990, and 2000 decennial censuses and in the 2011-2015 ACS five-year estimates (Economic Research Service, 2019). I also collected Medicare expansion data for each state and the census region and metropolitan status for every county (Economic Research Service, 2020; Geography Division, 2023; Kaiser Family Foundation, 2022). For additional context, I pulled eight demographic variables from the ACS for each county: age composition (% of residents 65 years of age and older), sex composition (% female), racial composition (% non-Latino white, % non-Latino Black, and % Latino), educational attainment (% with a high school degree or higher and % with a bachelor's degree or higher), unemployment rate, median household income, total population, and health insurance coverage rate.

I combined all of these data fields into three datasets that corresponded to SEER's cancer mortality year bins. My 2008-2010 dataset contained only cancer mortality data due to the limited availability of ACS estimates from before 2011, while my 2011-2015 and 2016-2020 datasets contained all of the aforementioned data fields. I also created a fourth dataset that calculated the change in cancer mortality and insurance coverage between each five-year bin and across all 10 years.

I began my quantitative analysis by calculating descriptive statistics for persistent and nonpersistent poverty counties to discover demographic differences between the two county groups. I then utilized t-tests and analysis of variance (ANOVA) modeling to evaluate the differences in cancer mortality rates across counties with different poverty statuses, using several definitions of poverty to increase the robustness of my results. I then used my fourth dataset to repeat these t-test and ANOVA analyses, focusing on evaluating the differences in the change in cancer mortality rates over the study timeframe for persistent and nonpersistent poverty counties. Finally, with these preliminary results in mind, I used t-tests and linear regression to evaluate the specific impacts of Medicare expansion and insurance coverage changes on cancer mortality in persistent poverty counties.

On the qualitative side, I utilized Star's framework to explain the extent to which US citizens have learned how to navigate the new ACA markets by participating in them, and to evaluate how well the ACA interfaces with pre-installed public and private healthcare systems. Together, my quantitative and qualitative analysis help us understand holistically how the ACA has impacted the cancer care environment.

Results

In the decade following the enactment of the ACA, cancer outcomes improved significantly. However, while much progress was made in both persistent and nonpersistent poverty counties between 2010 and 2020, I did not observe a relationship between either Medicaid expansion or improved health insurance coverage, two key results of the ACA, and improved cancer outcomes for low-income patients. Moreover, I observed a concerning dynamic: over the decade following the enactment of the ACA, the cancer mortality rate in persistent poverty counties was at least 11.3% higher than in nonpersistent poverty counties, with 18.3 additional deaths per 100,000 residents. My results are structured in the following order: descriptive county-level statistics, comparisons of cancer mortality rates split by poverty status, comparisons of cancer mortality rate changes split by poverty status, analysis of the impact of specific ACA factors on cancer outcomes in persistent poverty counties, and finally evaluation of the ACA's performance as human infrastructure.

Descriptive Statistics

393 counties were defined as experiencing persistent poverty in the US Department of Agriculture's latest persistent poverty report (Economic Research Service, 2019). Geographically, these counties were primarily rural (83.0%), and concentrated in the Southern Census region (79.6%) (American Community Survey, 2023). Only 44.3% of persistent poverty counties resided in states that expanded Medicaid under the ACA, 17.6% less than nonpersistent poverty counties.

There were also several demographic factors distinguishing persistent poverty counties from nonpersistent poverty counties. Persistent poverty counties had lower concentrations of non-Latino white people (56.2% vs. 80.3%) and higher concentrations of both non-Latino Black

people (24.6% vs 6.6%) and Latino people (11.5% vs. 8.5%) on average than nonpersistent poverty counties. Persistent poverty counties also had lower average rates of high school graduation (77.3% vs. 87.8%) and bachelor's degree attainment (15.2% vs. 21.2%) than nonpersistent poverty counties. Finally, persistent poverty counties experienced an unemployment rate 4.5% higher (11.7% vs. 7.2%) than nonpersistent counties, and households in persistent poverty counties earned only two thirds as much as households in nonpersistent counties ($33,100 vs. $44,800).

We can see based on these descriptive statistics of persistent poverty counties that the burden of poverty fell disproportionately on people living in rural areas and on Black and Latino residents. Due to higher unemployment and lower educational attainment levels, it is likely difficult for people living in persistent poverty counties to claw their way out of poverty. A map of persistent poverty counties can be found in Figure 1, and a detailed tabular overview of the counties involved in this study can be found in Appendix A.

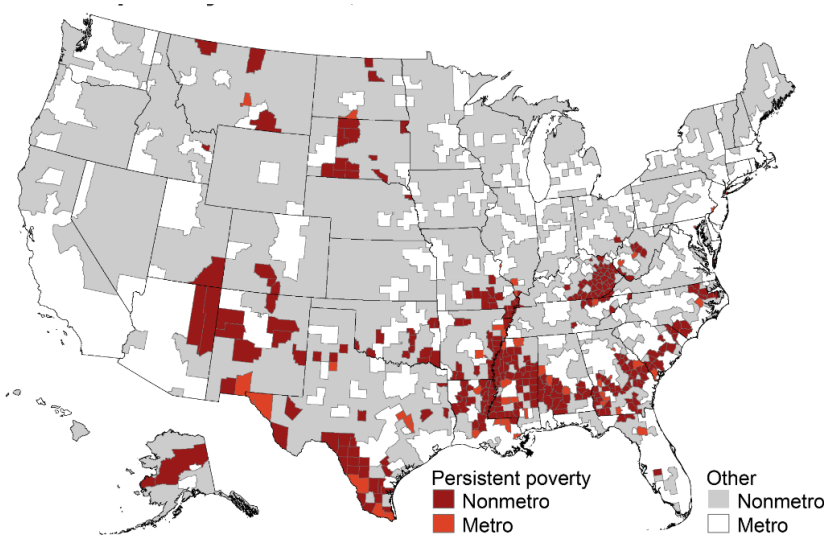

Figure 1. Persistent Poverty Counties (Economic Research Service, 2019).

In 2011-2015, the latest period covered in the US Department of Agriculture's persistent poverty report, 834 counties were identified as experiencing current poverty, with >20% or more

of residents experiencing poverty in the 2011-2015 ACS (Economic Research Service, 2019). Of these 834 counties, 414 were experiencing current but not persistent poverty while 393 were experiencing both current and persistent poverty. These 393 counties were the focus of this study.

The Impact of Poverty on Cancer Mortality Rates

Between 2008 and 2010, the years just before the ACA was enacted, the cancer mortality rate was 180.3 deaths per 100,000 residents in nonpersistent poverty counties and 202.7 in persistent poverty counties (Surveillance, Epidemiology, and End Results (SEER) Program, 2022). Cancer mortality was 12.4% higher in persistent poverty counties than nonpersistent poverty counties, translating to 22.7 additional deaths per year per 100,000 residents in persistent poverty counties. I used a t-test to determine that this discrepancy in cancer mortality rates based on persistent poverty status was statistically significant at the $p<0.0001$ level.

In the five years after the ACA was enacted, 2011 to 2015, the cancer mortality rate decreased in both nonpersistent and persistent poverty counties to 172.2 and 193.0 deaths per 100,000 residents, respectively (Surveillance, Epidemiology, and End Results (SEER) Program, 2022). However, a difference in mortality rates between counties based on persistent poverty status still existed between 2011 and 2015, with a 12.1% higher cancer mortality rate in persistent poverty counties than nonpersistent poverty counties. Although the difference in mortality rates between the two county subgroups decreased to 20.8 deaths per 100,000 residents per year, this difference remained statistically significant at the $p<0.0001$ level.

In the final five years covered in this study, 2016 to 2020, I observed a continuation of the aforementioned trends. Cancer mortality rates fell to 161.4 deaths per 100,000 residents in nonpersistent poverty counties and 179.7 in persistent poverty counties (Surveillance, Epidemiology, and End Results (SEER) Program, 2022). The percentage difference between the

mortality rates of the two county subgroups decreased to 11.3%, while the rate difference decreased to 18.3 deaths per 100,000 residents. Once again, this difference was statistically significant at the $p<0.0001$ level. These trends of cancer mortality over time based on persistent poverty status are displayed in Figure 2 and can be found in tabular form in Appendix B.

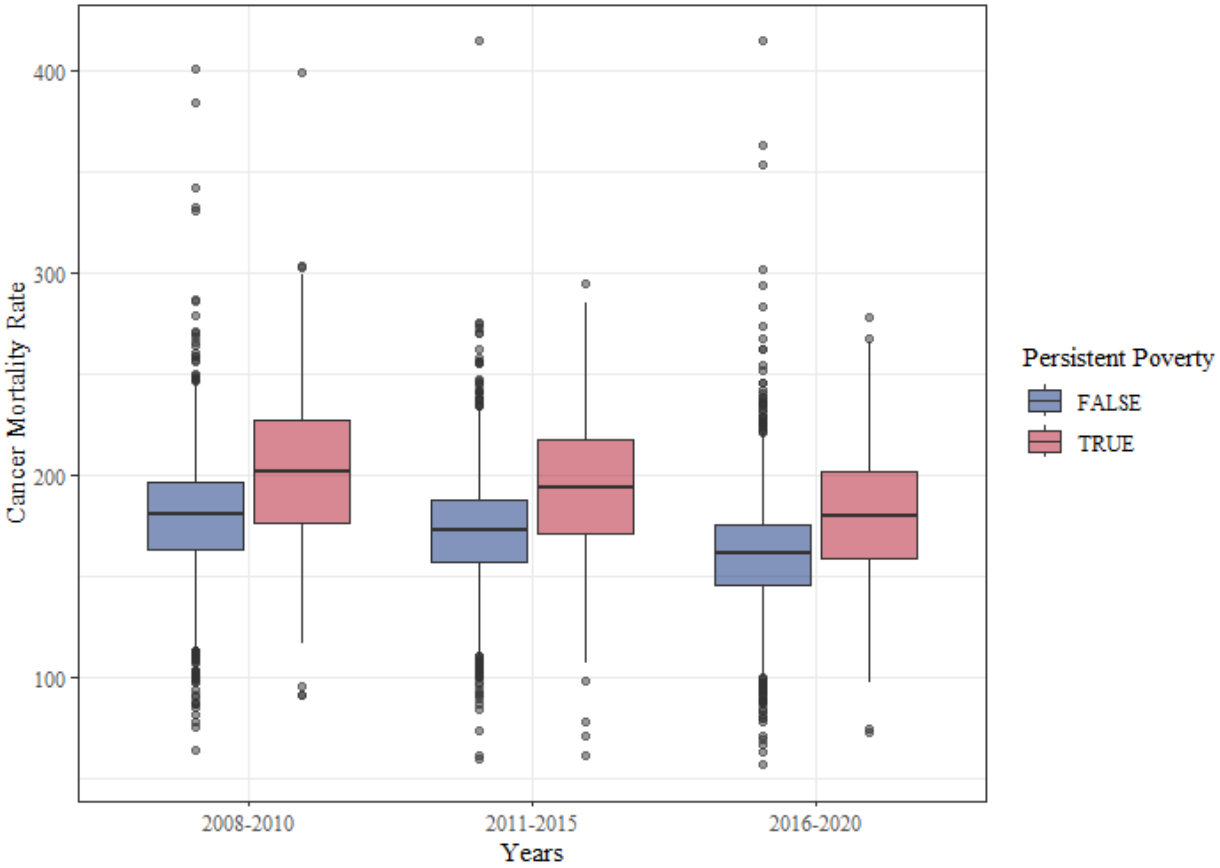

Figure 2. Cancer Mortality Rates by Year Range Split by Nonpersistent and Persistent Poverty Counties (Ratliff, 2023).

This result held when grouping counties based on both current poverty status and on persistent poverty status. In each of the three-year ranges, 2008-2010, 2011-2015, and 2016-2020, analysis of variance (ANOVA) modeling found that the subgroups had statistically distinct cancer mortality rates at the $p<0.0001$ significance level. Tukey testing of pairs of subgroups (e.g., no current poverty and current only) found a significant difference in cancer mortality levels for every pair at the $p<0.001$ level, with the exception of the current only and

persistent poverty pair in 2016-2020. This means that the only mortality rates that were not statistically dissimilar were the current only and persistent poverty rates in 2016-2020, which were 174.4 and 179.7 deaths per 100,000 residents respectively. The mortality rates from this subgroup analysis are displayed in Figure 3, and can be found in tabular form in Appendix B.

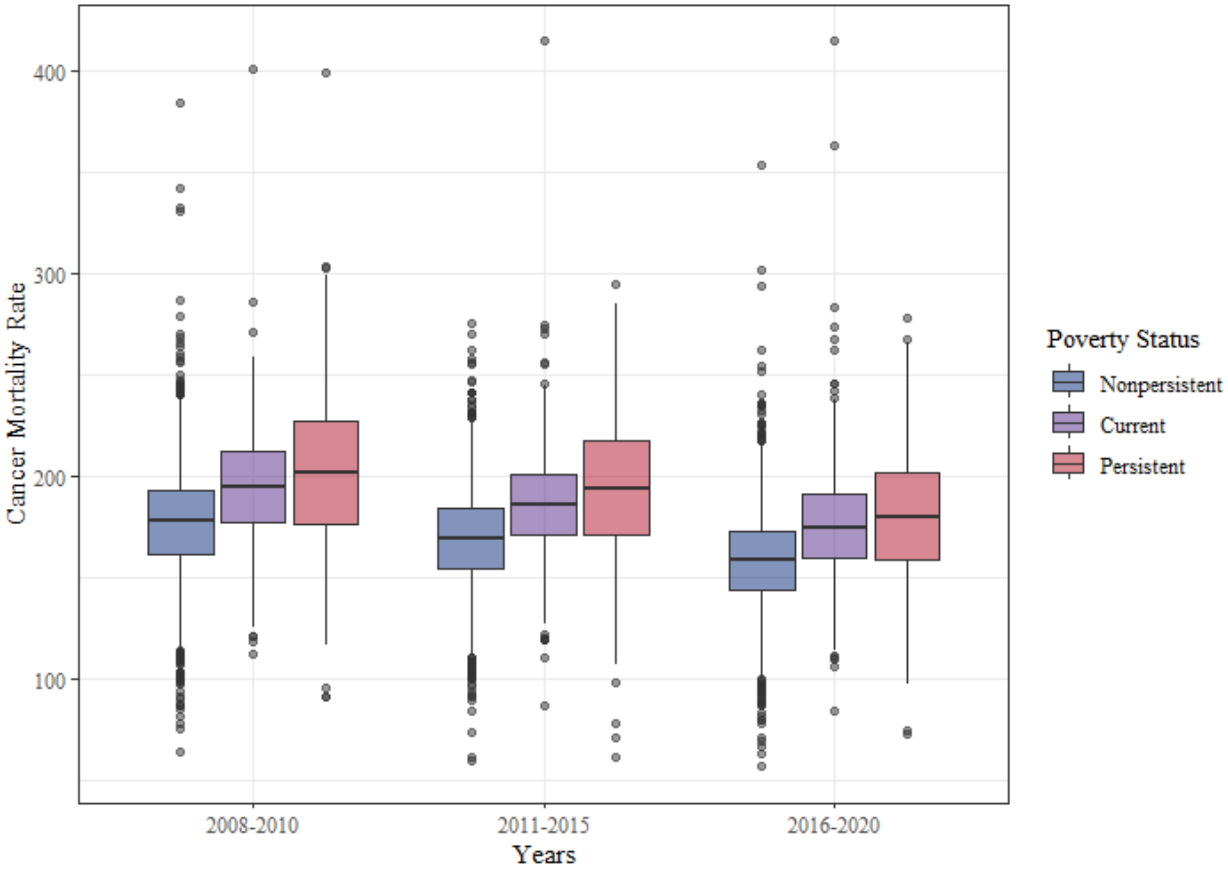

Figure 3. Cancer Mortality Rates by Year Range Split by Current Poverty Status and Persistent Poverty Status (Ratliff, 2023).

Taking a step back, over the 10 years after the ACA was enacted, cancer mortality rates fell overall and in every poverty status subgroup. However, there was little statistical difference in the changes in cancer mortality rates by persistent poverty status. There was no statistical difference between cancer mortality changes during the 2010-2015 and 2015-2020 periods, but there was a slight statistical difference ($p<0.05$) in mortality rates based on persistent poverty status when considering the entire 10-year time frame, 2010-2020, at once. This statistical

difference is a positive outcome, indicating that cancer mortality rates fell faster than in persistent poverty counties over the decade following the passage of the ACA. The changes in cancer mortality rates based on persistent poverty status can be found in Table 1.

Table 1. Changes in Cancer Mortality Rates by Year Range and Persistent Poverty Status (Ratliff, 2023).

Year range	Nonpersistent	Persistent
2010-2015	-7.9	-9.2
2015-2020	-10.9	-13.3
2010-2020	-18.8	-22.6

A similar dynamic was observed when splitting the data into three subgroups based on current and persistent poverty status. ANOVA modeling found no statistical difference between cancer mortality rates across either of the five-year time frames, but found that the differences in mortality rate between counties without current poverty and both other subgroups of counties were significant at the $p<0.05$ level. Surprisingly, the mortality rates for each subgroup, displayed in Table 2, showcase a phenomenon that diverges from the previously observed trend. Cancer mortality rates in countries with current but nonpersistent poverty decreased the least of the three subgroups, in both of the five-year time frames and across all 10 years.

Table 2. Changes in Cancer Mortality Rates by Year Range, Current Poverty Status, and Persistent Poverty Status (Ratliff, 2023).

	Cancer Mortality Rate		
Year range	No Current	Current Only	Current and Persistent
2010-2015	-8.0	-7.6	-9.2
2015-2020	-11.1	-9.9	-13.3
2010-2020	-19.1	-17.6	-22.6

While cancer mortality rates decreased overall from 2010 to 2020, the gap between persistent and nonpersistent poverty counties only barely narrowed in this 10-year span, to a difference of 18.3 more cancer deaths per 100,000 residents per year in persistent poverty counties between 2016 and 2020. Putting this result in context, this means that the burden of cancer mortality not only fell disproportionately on poorer people, but also on people living in rural areas and on Black and Latino residents.

Therefore, although incremental progress was made between 2010 and 2020, there is clearly more work to be done to decrease the cancer mortality gap between persistent and nonpersistent counties. Indeed, a 10-year lag between cancer mortality rates in persistent and nonpersistent counties exists: the mortality rate in persistent poverty counties between 2016 and 2020 is roughly equivalent to the observed rate in nonpersistent poverty counties between 2008 and 2010. While it is heartening that cancer mortality rates have significantly improved overall since the ACA was enacted, it is unacceptable that the counties experiencing the highest burdens from poverty still experience 11.3% higher cancer mortality rates than those not experiencing a persistent burden.

The Impact of the ACA on Cancer Mortality Rates

Connecting to the ACA, I analyzed the impact of insurance coverage gains and Medicaid expansion (ME) in persistent poverty counties during the decade following the passage of the ACA. I observed no statistically significant linear relationship between changes in health insurance coverage rates between 2015-2020 and 10-year changes in cancer mortality rates in persistent poverty counties. This result held true for several other regression models, including the comparison between health insurance coverage gains between 2015 and 2020 and cancer mortality rate changes between 2015 and 2020, as well as between raw insurance coverage rates

and cancer mortality rate changes. This is a concerning result: I was not able to find any statistical connection between health insurance coverage gains in the 2010s, which can be reasonably attributed to the ACA, and better cancer outcomes for low-income cancer patients. The absence of a connection between insurance coverage and cancer mortality can be viewed in Figure 4.

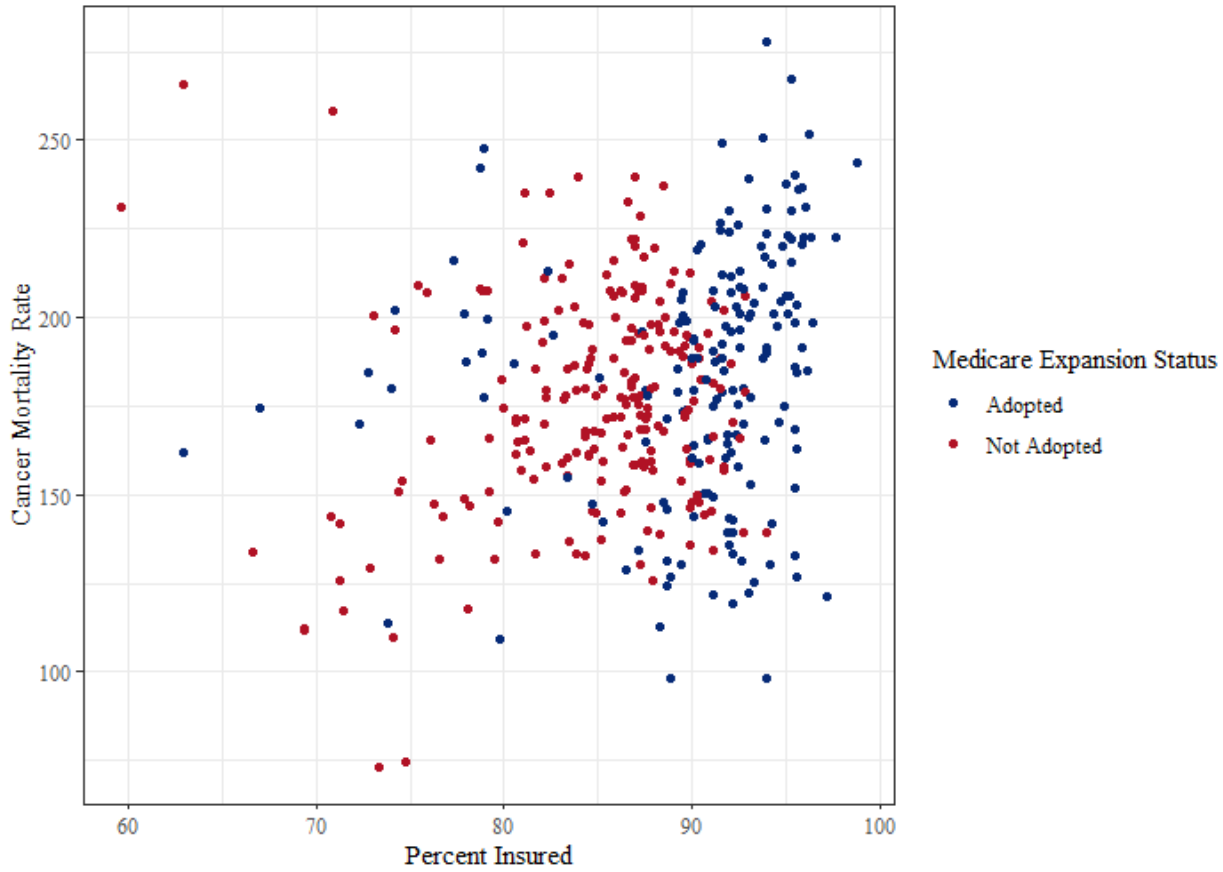

Figure 4. Trend in Insurance Coverage Versus Cancer Mortality Rate, Colored by Medicare Expansion Status (Ratliff, 2023).

I observed a similar result for ME. Unsurprisingly, Figure 4 shows that insurance rates were higher in counties that expanded Medicaid. However, although persistent poverty counties in states that expanded Medicaid saw a decrease of 2.97 more deaths per 100,000 residents per year from 2010 to 2020 than persistent poverty counties in states that did not expand Medicaid (-24.2 versus -21.2), I did not observe a statistically significant impact of ME at any significance

level. As can be seen in Figure 4, there was not a clear relationship between ME and better raw cancer mortality rates either. Because I did not observe a relationship between either changes in health insurance coverage rates or ME and cancer mortality rates in persistent poverty counties, I could not conclude that the ACA had a positive impact on cancer outcomes for low-income patients.

The ACA as Human Infrastructure

We can use Star's (1999) framework from her "The Ethnography of Infrastructure" paper to evaluate the implications of these results for the ACA. Specifically, the fact that I did not observe beneficial relationships between insurance rates and Medicare expansion and decreased cancer mortality rates in persistent poverty counties reflects poorly on the ACA's ability to become *embedded* within pre-existing systems, *learned as a part of membership*, and the successfulness of its construction *on an installed base* in the realm of cancer care and for people experiencing poverty over the 10 years following its enactment. While the law itself did not fail, it failed to completely operate as intended for low-income cancer patients.

There are many potential explanations for this observation, including hiccups during the initial release of the law's health insurance marketplace and sustained political resistance to the law at the state and federal level (Mortiere, 2013; Oberlander, 2020). Indeed, as I previously noted, the law's Medicare Expansion provision, a key component of my analysis, was never implemented as intended due to a 2012 Supreme Court ruling (Rosenbaum & Westmoreland, 2012). Moreover, the law's individual mandate was never fully embraced by opposition politicians and was only active for a handful of years before it was effectively repealed by Congress in 2017 (Fiedler, 2020).

However, although the law does not currently operate as the ideal form of human infrastructure Star describes in her paper, the ACA is still relatively young. It is likely that we will need more time to observe that the ACA has become sufficiently *embedded* within the cancer care system enough to produce significant results for low-income patients. As the system ages, users will likely continue to *learn* how to take advantage of the ACA's many benefits *as a part of membership*. Although the ACA has by no means become fully accepted in the US, we have reason to hope that the law will continue to become integrated within our healthcare system overall and the cancer care system specifically due to renewed political support for the law from President Biden's administration (Kirzinger et al., 2022; The White House, 2023). Hopefully, if the ACA continues on its pathway towards Star's ideal form of infrastructure, the ACA will have a greater impact on mitigating cancer mortality, both overall and in persistent poverty counties in particular.

Discussion

Through a thorough analysis of cancer mortality data from 2008-2010, 2011-2015, and 2016-2020, I found that cancer mortality rates decreased in persistent and nonpersistent poverty counties over the 10 years since the ACA was enacted. However, while rates decreased overall, the gap between persistent and nonpersistent poverty counties only barely narrowed over this 10-year span, with 18.3 more cancer deaths per year in persistent poverty counties between 2016 and 2020. In fact, the cancer mortality rate in persistent poverty counties lagged nonpersistent poverty counties by a *decade*. With these twin trends in hand, I examined whether Medicare Expansion (ME) and insurance coverage rates, two factors heavily connected to the passage of the ACA, had an effect on the 10-year changes in cancer mortality in persistent poverty counties.

My analysis found that neither of these factors significantly affected cancer mortality rates, indicating that these two aspects of the ACA did not significantly improve cancer outcomes for low-income cancer patients. Despite these results, Star's framework tells us that there is still potential for the ACA to have a more visible impact on improving cancer outcomes for low-income patients, if the law can continue to become embedded within the healthcare system and learned by users.

My findings are in agreement with J. L. Moss et al. (2020), whose paper was a jumping-off point for my study. In their analysis of cancer mortality rates from 2007 to 2011, J. L. Moss et al. found that the mortality rate was 22.0 deaths per year per 100,000 residents, or 12.3%, higher in persistent poverty counties than nonpersistent poverty counties. My analysis is a useful complement to J. L. Moss et al.'s original work because I observed this phenomenon during two later time-periods (2011-2015 and 2016-2020) and because I observed the gap between the cancer mortality rate in persistent and nonpersistent poverty counties decrease to 18.3.

My results also provide necessary context to previous work that found the ACA helped improve health insurance coverage rates in the US, particularly the work of Nogueira et al. (2019) and Lee et al. (2022). As expected, I observed a positive relationship between insurance coverage rates and Medicaid expansion in persistent poverty counties. But, although insurance coverage rates increased in both persistent and nonpersistent poverty counties in the period after the initial round of states expanded Medicaid and the ACA health insurance market opened (in this study, my best proxy for this period is 2015-2020), these improvements in health insurance coverage were not correlated with the 10-year of five-year (2015-2020) change in cancer mortality rates in persistent poverty counties. This result is surprising: according to a report by

the American Hospital Association (2019), health care coverage expansion is correlated with decreases in overall mortality. Based on this research, prior to this study we could have reasonably expected that counties that experienced the highest gains in health insurance coverage would have also experienced the greatest decreases in cancer mortality. We could have also assumed that counties with higher overall health care coverage rates during the period between 2016 and 2020 would have seen the greatest decreases in cancer mortality and would have seen the lowest raw cancer mortality rates. Finally, we could have expected that counties within states that expanded Medicaid would have seen greater decreases in cancer mortality than counties in states that did not expand Medicaid. That the results of this study did not align with these expectations suggests that the correlation between increased health insurance coverage and decreased mortality rates does not strongly apply in the field of cancer.

Although I attempted to be as thorough as possible in this study, my results are not without limitations. Unlike Nogueira et al.'s (2019) study, I was unable to bin the cancer mortality rate according to ACA milestones due to the pre-set bins with the SEER database. SEER's 2011-2015 and 2016-2020 bins prevented me from conducting a time-series analysis similar to Nogueira et al. to specifically analyze the impacts of the law's passage in 2010 and Medicare expansion in 2014. My ACA-specific analysis was also limited by data availability: because health insurance coverage data was not available through the ACS until 2012, I was unable to analyze the impact of coverage expansion over the entire 10-year span of my study. Due to the enormity of the US Census database, a practically infinite amount of analysis could be conducted to analyze demographics and cancer mortality rates. Thus, there are probably several other data fields that I could have included that might have provided additional context to my results.

If I conducted this analysis again, I would attempt to implement an analysis of covariance (ANCOVA) model to examine adjusted differences in cancer mortality based on persistent poverty. I would also attempt to utilize data fields from outside the US census to measure the impact of health care coverage gains between 2010 and 2020 on cancer mortality rates, something I was not able to include in this iteration of the analysis due to this data not existing within the ACS five-year estimates. While I believe my analysis in this paper was robust, I think it could be interesting to explore whether the results I observed held true for different cancer types, similar to the analysis J. L. Moss et al. (2020) conducted. Finally, I think that including an analysis of political factors that impacted the ACA's success would provide important political context in a future iteration of this study.

This research can be used to advance my engineering practice by functioning as a jumping-off point for future work and as a lesson. I would appreciate the opportunity to continue to delve into the dynamic arena of cancer care in the US, especially if I were to research the politics of cancer care. My research has reminded me of the inequality that exists in the US, and I will certainly carry this reminder with me onto future engineering and political projects. If anything, my research provides a clear indication that lives are lost as a result of inequality in our country. I hope that in my lifetime and throughout my career, I can observe and contribute to efforts to reduce the inequality in our cancer system, healthcare systems, and our country.

Conclusion

The findings of this study help us understand how cancer mortality rates have changed over the decade since the ACA was enacted: overall, mortality rates decreased, but mortality rates in persistent poverty counties lagged nonpersistent counties by 10 years. Although I did not

find that Medicaid expansion or health insurance coverage gains improved outcomes for low-income patients, future researchers may have greater success dissecting the relationship between ACA and the changes in cancer mortality between 2010 and 2020. Future researchers could connect their analysis more closely to ACA milestones like the law's passage and Medicaid expansion if they discover a way to bin SEER data into pre-2011, 2011-2013, and 2014-present subgroups. Moreover, future researchers could use health insurance coverage data from other sources to conduct a more complete analysis of the relationship between insurance coverage and cancer mortality in persistent and nonpersistent poverty counties during the 2010-2020 period. In the broader scope, my research can be used to inform future cancer treatment-related policy. My results show that there is a clear need for better cancer treatment in persistent poverty counties, which tend to be more rural and contain higher concentrations of Black and Latino people than nonpersistent poverty counties. Policymakers must prioritize ensuring that the ACA and other cancer care policies become *embedded*, *learned as a part of membership*, and integrated with the *installed base* of the healthcare system in persistent poverty counties. As a final note, while my study failed to find concrete evidence that the ACA improved cancer outcomes for low-income patients, this does not mean that the ACA was a conclusive failure in the realm of cancer care. Progress was made to improve cancer care outcomes in the decade following the passage of the ACA, but there is much progress left to be made to equalize cancer outcomes.

References

American Community Survey. (2023). 5-year estimates. *American Community Survey*. data.census.gov

American Hospital Association. (2019). *Report: The Importance of Health Coverage*. https://www.aha.org/system/files/media/file/2019/10/report-importance-of-health-coverage_1.pdf

Angelo, E. (2021). The impact of the Affordable Care Act on patient coverage and access to care: Perspectives from FQHC administrators in Arizona, California and Texas. *BMC Health Services Research*, *21*, 920.

Boussios, S., Pentheroudakis, G., Katsanos, K., & Pavlidis, N. (2012). Systemic treatment-induced gastrointestinal toxicity: Incidence, clinical presentation and management. *Annals of Gastroenterology*, *25*(2), 106–118.

Davalon, B. (2022, October 13). History and Timeline of the Affordable Care Act (ACA). *EHealth*. https://www.ehealthinsurance.com/resources/affordable-care-act/history-timeline-affordable-care-act-aca

Economic Research Service. (2019). Description and Maps: County Economic Types, 2015 Edition. *U.S. Department of Agriculture*. https://www.ers.usda.gov/data-products/county-typology-codes/descriptions-and-maps/

Economic Research Service. (2020, December 10). Rural-Urban Continuum Codes. *U.S. Department of Agriculture*. https://www.ers.usda.gov/data-products/rural-urban-continuum-codes.aspx

Fiedler, M. (2020). The ACA's Individual Mandate In Retrospect: What Did It Do, And Where Do We Go From Here? *Health Affairs*, *39*(3). https://doi.org/10.1377/hlthaff.2019.01433

Geography Division. (2023). Census Regions and Divisions of the United States. *U.S. Census*. https://www2.census.gov/geo/pdfs/maps-data/maps/reference/us_regdiv.pdf

Iragorri, N., de Oliveira, C., & Fitzgerald, N. (2021). The Out-of-Pocket Cost Burden of Cancer Care—A Systematic Literature Review. *Current Oncology*, *28*(2), 1216–1248.

Kaiser Family Foundation. (2022, September 20). Status of State Medicaid Expansion Decisions: Interactive Map. *Kaiser Family Foundation*. https://www.kff.org/medicaid/issue-brief/status-of-state-medicaid-expansion-decisions-interactive-map/

Kaplan, T., & Pear, R. (2017, May 4). House Passes Measure to Repeal and Replace the Affordable Care Act. *The New York Times*. https://www.nytimes.com/2017/05/04/us/politics/health-care-bill-vote.html

Kirzinger, A., Montero, A., Hamel, L., & Brodie, M. (2022, April 14). 5 Charts About Public Opinion on the Affordable Care Act. *Kaiser Family Foundation*. https://www.kff.org/health-reform/poll-finding/5-charts-about-public-opinion-on-the-affordable-care-act-and-the-supreme-court/

Lee, A., Ruhter, J., Peters, C., De Lew, N., & Sommers, B. D. (2022). National Uninsured Rate Reaches All-Time Low in Early 2022. *Assistant Secretary for Planning and Evaluation Office of Health Policy*. https://aspe.hhs.gov/sites/default/files/documents/15c1f9899b3f203887deba90e3005f5a/Uninsured-Q1-2022-Data-Point-HP-2022-23-08.pdf

Mayo Clinic. (2022, March 22). Chemotherapy. *Mayo Clinic*. https://www.mayoclinic.org/tests-procedures/chemotherapy/about/pac-20385033

Mortiere, P. (2013, November 15). Timeline of botched ObamaCare rollout. *The Hill*. https://thehill.com/blogs/blog-briefing-room/news/190485-timeline-of-botched-implementation-of-obamacare/

Moss, H. A., Wu, J., Kaplan, S. J., & Zafar, S. Y. (2020). The Affordable Care Act's Medicaid Expansion and Impact Along the Cancer-Care Continuum: A Systematic Review. *Journal of the National Cancer Institute*, *112*(8), 779–791. https://doi.org/10.1093/jnci/djaa043

Moss, J. L., Pinto, C. N., Srinivasan, S., Cronin, K. A., & Croyle, R. T. (2020). Persistent Poverty and Cancer Mortality Rates: An Analysis of County-Level Poverty Designations. *Cancer Epidemiology, Biomarkers & Prevention*, *29*(10), 1949–1954.

National Cancer Institute. (2022, October). Survival. *National Cancer Institute Cancer Trends Progress Report*. https://progressreport.cancer.gov/after/survival

Nogueira, L., Chawla, N., Han, X., Jemal, A., & Yabroff, K. R. (2019). Patterns of Coverage Gains Among Young Adult Cancer Patients Following the Affordable Care Act. *JNCI Cancer Spectrum*, *3*(1). https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6649747/

Oberlander, J. (2020). The Ten Years' War: Politics, Partisanship, And The ACA. *Health Affairs*, *39*(3). https://doi.org/10.1377/hlthaff.2019.01444

Prasad, V., De Jesus, K., & Mailankody, S. (2017). The high price of anticancer drugs: Origins, implications, barriers, solutions. *Nature Reviews Clinical Oncology*, *14*, 381–390.

Rimer, B. K. (2018, March 15). The Imperative of Addressing Cancer Drug Costs and Value. *National Cancer Institute*.

https://www.cancer.gov/news-events/cancer-currents-blog/2018/presidents-cancer-panel-drug-prices

Rosenbaum, S., & Westmoreland, T. M. (2012). The Supreme Court's surprising decision on the Medicaid expansion: How will the federal government and states proceed? *Health Affairs (Millwood)*, *31*(8). https://doi.org/10.1377/hlthaff.2012.0766

Rudowitz, R., Garfield, R., & Hinton, E. (2019, March 6). 10 Things to Know about Medicaid: Setting the Facts Straight. *Kaiser Family Foundation*. https://www.kff.org/medicaid/issue-brief/10-things-to-know-about-medicaid-setting-the-facts-straight/

Shankaran, V., Li, L., Fedorenko, C., Sanchez, H., Du, Y., Khor, S., Kreizenbeck, K., & Ramsey, S. (2022). Risk of Adverse Financial Events in Patients With Cancer: Evidence From a Novel Linkage Between Cancer Registry and Credit Records. *Journal of Clinical Oncology*, *40*(8), 884–891. https://doi.org/10.1200/JCO.21.01636

Star, S. L. (1999). The Ethnography of Infrastructure. *American Behavioral Scientist*, *43*(3), 377–391. https://doi.org/10.1177/00027649921955326

Statistical Atlas. (2023). Household Income in the United States. *Statistical Atlas*. https://statisticalatlas.com/United-States/Household-Income

Surveillance, Epidemiology, and End Results (SEER) Program. (2022). Mortality—All COD, Aggregated With County, Total U.S. (1969-2020) <Katrina/Rita Population Adjustment>. *National Cancer Institute, DCCPS, Surveillance Research Program*. www.seer.cancer.gov

The White House. (2023, January 25). *Statement from President Joe Biden on Record ACA Enrollment Numbers*.

https://www.whitehouse.gov/briefing-room/statements-releases/2023/01/25/statement-from-president-joe-biden-on-record-aca-enrollment-numbers/

Zhao, J., Mao, Z., Fedewa, S. A., Nogueira, L., Yabroff, K. R., Jemal, A., & Han, X. (2020). The Affordable Care Act and access to care across the cancer control continuum: A review at 10 years. *CA: A Cancer Journal for Clinicians*, *70*(3), 165–181. https://doi.org/10.3322/caac.21604

Appendix A

Table A1. Descriptive Statistics for Counties in the United States, Split by Poverty Characteristics from 2011-2015 (Ratliff, 2023).

	United States (n=3138)		Nonpersistent poverty (n=2745)		Persistent poverty (n=393)	
	N	%	N	%	N	%
Non-metro	1973	62.9	1647	60.0	326	83.0
Metropolitan	1165	37.1	1098	40.0	67	17.0
Northeast	217	6.9	214	7.80	3	0.8
Midwest	1054	33.6	1012	36.8	42	10.7
South	1421	45.3	1108	40.4	313	79.6
West	446	14.2	411	15.0	35	8.9
No Medicare Expansion	1264	40.3	1045	38.1	219	55.7
Medicare Expansion	1874	59.7	1700	61.9	174	44.3
	Mean	Median	Mean	Median	Mean	Median
% female	50.0	50.4	49.9	50.4	50.2	50.9
% >65	17.1	16.8	17.3	17.0	15.6	15.5
% white	77.3	84.7	80.3	86.2	56.2	55.5
% Black	8.9	2.1	6.6	1.8	24.6	22.9
% Latino	8.8	3.7	8.5	3.9	11.5	2.4
% high school or higher	85.4	86.9	86.6	87.8	77.3	77.4
% bachelors or higher	20.4	18.2	21.2	18.9	15.2	12.9
% unemployed	7.8	7.5	7.2	7.1	11.7	11.1
Household income ($1,000s)	46.8	45.1	48.8	46.8	33.1	32.4
% insured	86.6	87.1	87.3	87.8	81.9	83.1

Appendix B

Table B1. Cancer Mortality Rates by Year Range Split by Nonpersistent and Persistent Poverty Counties (Ratliff, 2023).

	Cancer Mortality Rate	
Year range	Nonpersistent Poverty	Persistent Poverty
2008-2010	180.3	202.7
2011-2015	172.2	193.0
2016-2020	161.4	179.7

Table B2. Cancer Mortality Rates by Year Range Split by Current Poverty Status and Persistent Poverty Status (Ratliff, 2023).

	Cancer Mortality Rate		
Year range	No Current Poverty	Current Poverty Only	Current and Persistent Poverty
2008-2010	177.6	194.2	202.7
2011-2015	169.5	186.4	193.0
2016-2020	160.4	174.4	179.7